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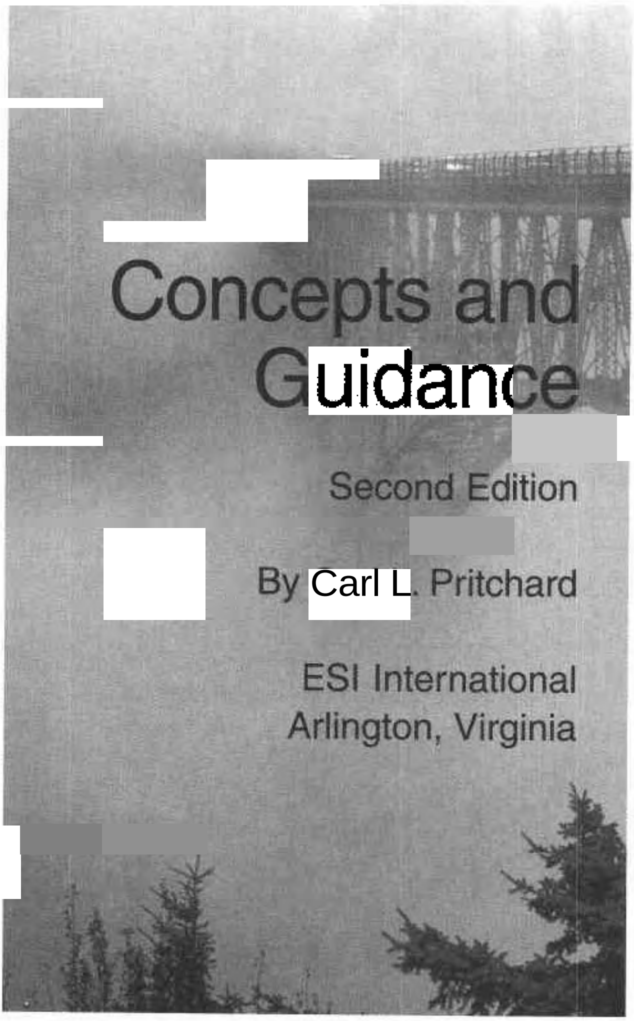
RISK MANAGEMENT



Concepts and Guidance

Second Edition

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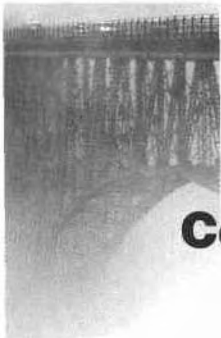

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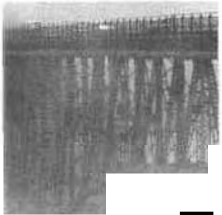

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Preface

Change generates risk. Change is a constant. Therefore, risk is a constant. Yet while risk is forever with us, particularly in the project environment, the interpretations of risk management shift with the times. The most recent shift came in late 2000 with the latest version of the Project Management Institute, Inc.'s *A Guide to the Project Management Body of Knowledge* (*PMBOK*®[1] Guide–2000 Edition). For years, the Project Management Institute's philosophy on risk management mirrored that of the U.S. Department of Defense. In fact, the first edition of this book was in part edited from the publication of the same title by the Defense Systems Management College.

With the release of the revised *PMBOK*® Guide–2000 Edition, there are new perspectives on risk. Most notably, there has been a shift in recognizing that most organizations are not willing to invest the time and energy essential for building deep quantitative analyses of project risk. With the technological revolution, time is of the essence, and as such, organizations seek opportunities to qualify—rather than quantify—their risks and move on. This has caused a profusion of tools and techniques that address risks' "softer side." This book reflects that shift with significant changes to the ways in which some tools are applied and with 13 new chapters in Part II: Risk Management Techniques.

In keeping with the book's DOD roots, I have retained the format, the tables, and the matrices that allow for quick analysis and cross-reference of the contents herein. References to specific analyses still hark back to the 380 surveys initially done for this work, but the original caveat holds true. The risk techniques resulting from this effort have not been evaluated for all circumstances; therefore, you must determine the validity and appropriateness of a particular technique for your own applications.

[1] PMBOK® is a trademark of the Project Management Institute, Inc., and is registered in the United States and other nations.

The appendixes have been largely untouched, as most of their content is rooted in history and accepted practice.

My heartfelt thanks go to the teams that contributed so diligently to this text as it was developed. I thank my fellow project managers and instructors from ESI International (most notably LeRoy Ward) who offered their time and support in the review and development of this material. Thanks to my students for their recommendations throughout the past few years and especially to LT Dennis Evans, U.S. Coast Guard, for his valuable insights on estimating relationships. Thanks as well to the internal teams who made significant contributions as this publication was shepherded from editing through desktop publishing.

I wish to extend special thanks to Myron Taylor and Chester Zhivanos, the talented (and patient) editors who worked to ensure that the second edition was a major step forward from the first and who lent their skills toward making this a richer, clearer volume. My thanks to Ron Guappone for his creative cover design and to Rebecca Kingery and Trinh Le for their superb desktop publishing. And lastly, my sincere thanks to their Vice President, Julie Zinn, a close friend and a driving force in keeping ESI and IIR at the cutting edge.

About the Author

Carl L. Pritchard is the Principal of Pritchard Management Associates and is a widely recognized risk management authority and lecturer. Mr. Pritchard's publications include courses in risk management as well as *How to Build a Work Breakdown Structure* and *Precedence Diagramming: Successful Scheduling in the Team Environment*. He coauthored *Managing Projects in Organizations—the CD-ROM* with J. Davidson Frame. He has contributed chapters for numerous major project management texts, including Dr. David Cleland's *Field Guide to Project Management* and Joan Knutson's *Project Management for the Business Professional.* He is the U.S. correspondent for *Project Manager Today,* a project management journal published in the United Kingdom.

Mr. Pritchard also designs and develops project management programs and was the original architect of ESI International's landmark offerings in project management in a distance-learning format. He is a trainer both on-line and in the classroom.

In his role as lecturer, Mr. Pritchard speaks regularly at national symposia on project management and serves as the "speaker's coach" for several national conferences, providing guidance on how most effectively to share the project management gospel.

He is active in professional project management associations and is a certified Project Management Professional (PMP®[2]). He earned a B.A. degree in journalism from The Ohio State University.

Mr. Pritchard lives in Frederick, Maryland, with his wife, Nancy, and two sons, Adam and James.

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[2] PMP is a certification mark of the Project Management Institute, Inc., and is registered in the United States and other nations.

About ESI International

ESI International is the industry leader in project management and contract management training and professional services. Since 1981, ESI has served Fortune Global 500 companies worldwide and nearly every major agency of the U.S. government to improve business performance. More than 486,000 professionals have benefited from our innovative offerings in project management and contract management. Our Project Management Professional Development Program has achieved the distinction of being the world's most comprehensive continuing education program for building project management knowledge and skills.

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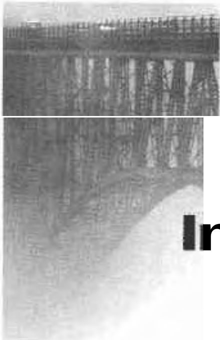


Introduction

Risk Management: Concepts and Guidance is designed to provide a look at risk in light of the latest information but still be grounded in the history of risk practice. As a reference volume, it provides a fundamental introduction on the basics associated with particular techniques. As an educational tool, it clarifies the concepts of risk and how they apply in projects. For those immersed in project management culture, it is now compliant with the Project Management Institute, Inc. publication, *A Guide to the Project Management Body of Knowledge* (*PMBOP Guide*–2000 Edition).

When originally published, this material was geared toward the government environment. In the first edition, the effort was to reorient the material toward a more general business audience. In this latest version, the content has been designed to align with day-to-day project management practice and the application of risk management in the field.

In the first edition, this book departed from the *PMBOP Guide*–1996 Edition by adding an additional phase called risk planning, which incorporated the broad-ranging issues associated with preparing project organizations with an infrastructure and strategies for risk. The *PMBOP Guide*–2000 Edition now identifies risk management planning as a critical step. The *PMBOP Guide*–2000 Edition has also added a new phase identified as risk qualification. Consequently, this book now reflects the processes of risk planning, risk identification, risk qualification, risk quantification, risk response development, and risk monitoring and control.

Scope

Risk management is a "method of managing that concentrates on identifying and controlling the areas or events that have a potential of causing unwanted change . . . it is no more and no less than informed management" (Caver 1985). In keeping with this definition, this book covers project risk management from the project manager's perspective. It does not cover insurance risk, safety risk, or accident risk outside the project context. Risk management is an integral part of project management and should be thought of as a component of any project management methodology rather than as an independent function distinct from other project management functions.

Approach

Risk Management uses a holistic approach to risk. That is, risk is examined as a blend of environmental, programmatic, and situational concerns. Although technical issues are a primary source of risk and figure prominently throughout the book, they must be balanced with managing other aspects of the project.

Throughout the text, risk is considered exclusively as a future phenomenon. Risks are events that *may* happen to a project. They are not events that have already occurred. It is vital to consider risk in that context because otherwise, every negative issue or change in plans may potentially be mislabeled as a risk event.

Using This Book

When using Risk Management, remember that risk is a complex concept subject to individual perception. Some people take risks, whereas others are more risk averse. Hence, it is difficult to develop universal rules for dealing with risk. Nevertheless, this book includes substantial guidance, structure, and sample handling techniques that follow sound management practice. Although the principles, practices, and theories presented hold true in nearly all situations, under certain circumstances, the rules by which risk is evaluated may change drastically. For example, when confronted by an extreme threat, people can do extraordinary things. They will take risks that under ordinary circumstances would be deemed unacceptable. As a result, high-risk projects are not always bad and should not necessarily be avoided. Rather, if risks are assumed, they should be rigorously monitored and controlled.

Risk Management is structured in a tutorial fashion and is presented in two parts. Part I begins in Chapter 1 by analyzing the systems that can be used to apply risk management. The next chapter defines risk in terms relevant to project management and establishes the basic concepts necessary to understand the nature of risk. Chapter 3 defines the risk management structure and processes that can be applied to all project phases, with an emphasis on risk management planning.

Part II presents specific techniques necessary to successfully implement the processes described in Part I. Using these techniques, the project manager can gain some of the insights essential to proceed with risk management. The techniques evaluated include—

- Expert interviews
- Planning meetings
- Risk practice methodology
- Documentation reviews
- Analogy comparisons
- Plan evaluation
- Delphi technique
- Brainstorming
- Crawford Slip Method (CSM)
- SWOT analysis
- Checklists
- Project templates
- Assumptions analysis
- Decision analysis–expected monetary value
- Estimating relationships
- Network analysis
- Program Evaluation and Review Technique (PERT)
- Other diagramming techniques
- Rating schemes
- Risk modeling
- Monte Carlo simulations
- Risk factors
- Risk response matrix
- Performance tracking and technical performance measurement
- Risk reviews and audits

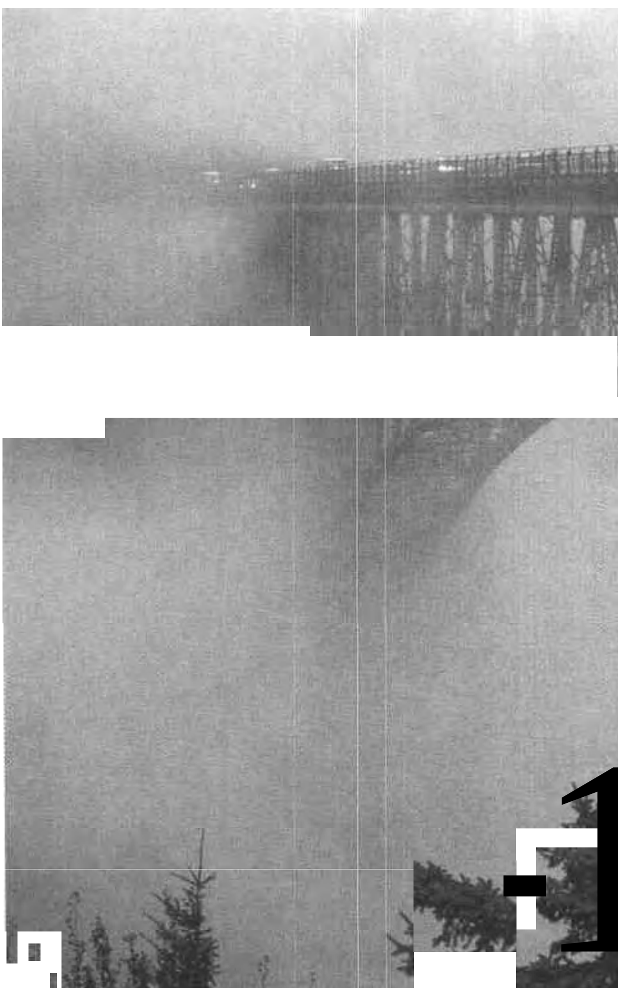
The appendixes serve as reference materials and provide supporting detail for some of the concepts presented in the text:

- Appendix A, *Contractor Risk Management*: A review of some standard clauses and language incorporated to address contractor risk issues.
- Appendix B, An Abbreviated List of Risk Sources: A compilation that serves as an initial risk checklist.
- Appendix C, Basic Probability Concepts: A refresher and basic primer for the material in the text.
- Appendix D, Quantifying Expert Judgment: A deeper exploration of how to transform qualitative information into quantitative information during expert interviews.
- Appendix E, Special Notes on Software Risk: A series of tables designed to support probability and impact analysis in software projects.

Risk Management also provides a glossary, bibliography, and index.

As you work through all this material, remember that risk is a highly personal and unique experience. No two projects will share exactly the same risks. As such, the ultimate authority on risk is not any tool or technique addressed between these covers. Rather, the ultimate authority on your project's risk is the project manager: you!

Risk Processes and Practices—Why Risk Management?



PART ONE

1

Part I

Risk Processes and Practices—Why Risk Management?

The first part of Risk Management: Concepts and Guidance reviews the basic processes and practices associated with risk management in the project environment. It does so in depth, assessing the "rules of the road" in planning for, identifying, assessing, developing responses to, and controlling risk. It is a conceptual overview of how risk should be addressed.

In institutionalizing risk management in an organization, there is inevitably a dread of "analysis paralysis," the fear that so much time will be spent examining concerns and potential problems that none of them are ever resolved. There is also a fear of administrative overburden. Project managers are frequently among the busiest people in an organization. They fear that they will have to do even more.

As a result, risk sometimes becomes a secondary issue. In organizations where success is the norm and failure is a rarity, risk management is relegated to obscurity in the hope that project managers will be able to handle project issues and problems as they occur. Nevertheless, these organizations should embrace risk management. Risk remains a secondary issue only as long as an organization's luck holds out. Sooner or later, bad things happen to good projects, and a project manager without a clear risk strategy will eventually pay a price. Regardless of whether calculated in terms of lost resources, a blown schedule, or a budget overrun, the repercussions of such failure fall directly on the project manager.

Needless to say, there is also a negative aspect to risk management. It is perceived as the "dark side" of a project, and the project manager becomes the prophet of doom and gloom. When applied inconsistently, risk management makes good risk managers appear to be pessimists and naysayers, while those who take no proactive posture on risk are regarded as team players. Therefore, the only time a project manager can really succeed as a risk manager, both individually and organizationally, is when that manager has the support of the organization and its practices. That is why a clear, well-developed set of risk practices and protocols is vital to the long-term survival of any project organization.

Chapter 1

Risk Management Practices

Even the simplest business decision involves some risk. Because every project involves some measure of risk, it is the project's success criteria that often serve as the determining factors for which risks are worth taking and which risks are not. Consider, for example, the decision to drive or fly on a business trip. If cost is the success criterion, risk determination is simple: compare the costs of flying and driving (compounded by potential inflationary factors). However, another success criterion might be safety, and thus statistics concerning accidents should be evaluated. If punctual arrival is added as a third criterion, airline on-time statistics, automobile dependability, and road conditions should be evaluated. As other success criteria are added, decision making becomes more complicated and involves more judgment. In the present example, increased cost is perhaps an acceptable risk, being late may be unacceptable, and not arriving safely is certainly unacceptable. If project managers do not know what success criteria are driving the project, they cannot hope to identify the risks that may impede their road to success.

Increasing technical complexity, in turn, increases risk. Every new generation of technology is layered on the old. Nevertheless, most organizations tend to weight decisions heavily toward cost and schedule goals because they are easy to understand. But the effect of cost and schedule decisions related to technical performance risk frequently is unclear. Thus, a formal methodology for evaluating the effects of decision making and foreseeable problems is indispensable and should also help to identify practical and effective workarounds for achieving project goals.

A Systematic Process

Not all projects require a formal risk management approach, but to obtain the maximum benefit, risk management must become a systematic process applied in a disciplined manner. Put more simply, not every project has to follow every step, but implementing the basic practices should be rote.

Many project managers use intuitive reasoning (guessing) as the starting point in the decision-making process. That's not a bad place to start. But truly effective managers will look beyond simple reasoning and experience in making decisions that involve significant risk. Even the most experienced project managers have not encountered every risk. There are some risks that they cannot imagine or that do not match their paradigm; and there are still others they just cannot predict. Some risks are so far outside any individual's expectations or experience that those risks could not possibly be considered without any external inputs.

Numerous inhibitions restrain implementing risk management as a standard project practice. It's unpopular. It points out the negative. It primarily focuses on potentially bad news.

In 2000, the Standards Committee of the Project Management Institute, Inc. (PMI®)[3] made a major shift in the context of how risk management will be applied. The original four-step content on risk management (1996) was discarded in its entirety and replaced with a new set of processes and practices. The PMI® approach to risk now comprises six basic steps:

- *Risk Management Planning.* In this new area, project risk infrastructure is established and a project-specific risk management plan is generated.
- *Risk Identification.* Events that will have potentially negative impacts on projects are clearly described.
- *Risk Qualification.* Risks are evaluated according to nonnumeric assessment protocols.
- *Risk Quantification.* The most significant risks are evaluated according to their numeric probability and impact.
- *Risk Response Planning.* Strategies to deal with or preclude risks are evaluated and communicated.
- *Risk Monitoring and Control.* Risk management and response plans are put into action.

The move from four to six steps raised concern among some project managers that a larger process would discourage individuals from adopting risk management practices. However, these process steps were designed to encourage more flexible, adaptable approaches within an organization's project methodology and facilitate risk management implementation.

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[3] PMI® is a service mark and trademark of the Project Management Institute, Inc., and is registered in the United States and other nations.

All project managers should perform some documented risk management activity, either qualitative or quantitative. All significant projects should include formal, intense risk management activities; smaller, less critical projects may require only a scaled-down risk effort. Thus, the ultimate authority on risk is the project manager, who must make determinations based on the project's cost, schedule, and performance challenges.

Summary

- Risk management is essential.
- Risk management should be systematic.
- All projects should have some documented risk management activity.

Chapter 2
Risk Concepts

Although the terms *risk* and *uncertainty* are often used interchangeably, they are not the same. Risk is defined as the *"cumulative effect of the probability of uncertain occurrences that* may *positively or negatively affect project objectives"* (Ward *2000).* This is unlike uncertainty, which considers only the event and where the probability is completely unknown. The traditional view says that risk is a situation where an event may happen, and the frequency of occurrence can be evaluated based on a probability distribution of past occurrences or environmental considerations. Although that observation has limited utility in project management, it does distinguish between risk and uncertainty. With risk, there is a sense of the relative level of event probability. With uncertainty, however, that probability is completely unknown.

To understand whether an event is truly "risky," the project manager must understand the potential effects resulting from its occurrence or nonoccurrence. Determining risk in this manner requires using some judgment. For example, although an event may have a low likelihood of occurring, the consequences, if it does occur, can be catastrophic. A commercial airline flight illustrates this type of situation: Although the probability of a crash is low, the consequences are generally grave. Although many people feel uncomfortable about flying because of the consequences of failure, most people do not consider flying a high risk. This example also emphasizes the principle that risk depends greatly on individual perception.

The nature of any given risk is composed of three fundamental elements: the event, the probability, and the severity (or impact) (see Figure 1). The event is the description of the risk as it may occur. Event descriptions are crucial. The probability and impact of a plane crash at the gate are far different from the probability and impact of a plane crash from an altitude of 30,000 feet. Thus, risk managers must explore the nature of the risk event itself before they can begin to examine risk probability and impact. Without a clear definition of the risk event, ascertaining probability and impact become far more difficult.

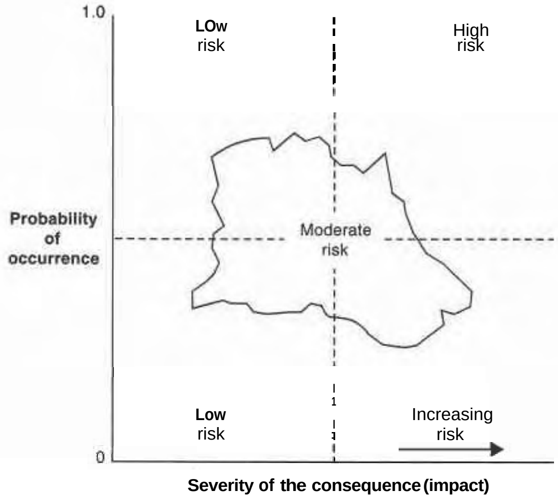


Figure 1. Concept of Risk

Once the risk event has been defined, probability must be considered. Statistical data and probability theory play important roles in determining this variable, yet the remaining issue is the severity of the consequence if the event occurs. Again, statistics and probability help determine the degree of impact after it is identified. (Note, however, that probability is of limited use here and not always appropriate.) These factors are then evaluated to establish the relative level of risk associated with any given risk event.

In most organizations and for most projects, there is little disagreement about the level of risk if the variables are classified as follows:

- Low probability and low impact equal low risk
- High probability and high impact equal high risk
- High probability and low impact equal low risk (to the project's overall success)

However, as you move toward the low probability/high impact quadrant of the figure, determining the risk level becomes more subjective and requires strict guidelines. A project with many moderate-risk items may be considered high risk, whereas a project with a few high-risk items may have a lower overall risk rating. These situations usually require some type of modeling to ascertain the project risk level. Consequently, many attempts have been made to model this subjective quantification of risk mathematically.

Some statisticians and project managers may apply probability distributions (see Appendix C), whereas others may not.

As stakeholders rate risks, disagreements can occur. Although project managers must sometimes rely on technical experts in the risk management process, they must also be prepared to make the final judgment themselves. Some guidelines on rating risks are included in Chapter 3 under "Risk Quantification." And whereas it is important to examine the quantifiable probabilities for loss, an additional item to consider is opportunity. If no real opportunity exists, there is no reason to pursue a risky activity. However, as the potential gain increases, so does the threshold for accepting risk.

Classifying Risk

To the project manager, risks are primarily rooted in the process to deliver a specified product or service at a specified time for a specified cost. A properly planned project will provide the project manager with some reserve funds and slack time to work around unanticipated problems and still meet original cost, schedule, and performance goals. But a wide variety of problems can keep the manager from meeting project objectives: the product may not attain the performance level specified, the actual costs may be too high, or delivery may be too late. (There is, of course, a risk that the original cost, schedule, and performance goals were unattainable, unrealistic, or conflicting.)

To make it manageable, risk must be classified. Historically, although a number of different classification schemes have been successful, we will examine three schemes here: risk facets (per the Defense Systems Management College) and two risk categorization approaches (per the Project Management Institute). What is important is not to select one particular scheme, but instead, to select approaches that mirror an organization's risk needs.

Risk Facets

The original Risk Management: Concepts and Guidance book that the Defense Systems Management College (DSMC) published in 1986 classified risk into five facets:

- Technical (performance related)
- Programmatic (performance related)
- Supportability (environment related)
- Cost
- Schedule

Because they are frequently indicators of project status, cost and schedule risks are treated somewhat differently from the others. However, cost and schedule can become a major source of project risk.

Classifying a risk into one or more of the five facets requires examining the source of the risk. It is not always easy to determine the appropriate category (nor is it that important just for the sake of classification). However, understanding the source of the risk and the affected areas, as well as providing a structure to examine risk, are critical elements if the risk is to be managed effectively. Table 1 lists sample risks from each facet.

Risk Facet	**Sources of Risk**	
Technical	Physical properties	Requirement changes
	Material properties	Fault detection
	Radiation properties	Operating environment
	Testing and modeling	Proven or unproven technology
	Integration and interface	System complexity
	Software design	Unique or special resources
	Safety	
Programmatic	Material availability	Labor strikes
	Personnel availability	Requirement changes
	Personnel skills	Political advocacy
	Safety	Contractor stability
	Security	Funding profile
	Environmental impact	Regulatory changes
	Communication problems	
Supportability	Reliability and maintainability	Facility considerations
	Training and training support	Interoperability considerations
	Equipment	Transportability
	Human resource considerations	Computer resources support
	System safety	Packaging, handling, storage
	Technical data	
Cost	Sensitivity to technical risk	Sensitivity to schedule risk
	Sensitivity to programmatic risk	Overhead and general and administrative rates
	Sensitivity to supportability risk	Estimating error
Schedule	Sensitivity to technical risk	Sensitivity to cost risk
	Sensitivity to programmatic risk	Degree of concurrency
	Sensitivity to supportability risk	Number of critical path items
		Estimating error

Table 1. Typical Sources of Risk by Facet

Technical Risk

Technical risk is the risk associated with developing a new design (or approach), either to provide a greater level of performance or to accommodate some new constraints. The nature and causes of technical risks are as varied as the approaches and system designs. Many, if not most, technical risks result from the omnipresent requirement to minimize or maximize physical properties of processes, systems, and equipment. What is technically risky at first may become routine later as risky areas on a project with high performance requirements may be routine on systems with lower performance requirements.

Many of the "-ilities," such as reliability, maintainability, and long-term viability, must be addressed in the project environment. All can be viewed as additional requirements placed on system or process designers attempting to develop an efficient design capable of the desired performance level. All can be sources of risk.

Nevertheless, describing all possible technical risks is not easy because, when examined at the lowest level of detail, there are so many. Usually, many items or steps need to be designed and integrated with other items and steps. There may be several design objectives for each site, and each combination of item and design objective is subject to many "-ility" requirements as well as cost and schedule constraints.

Appendix B contains an abbreviated list of technical risk areas. It does not list types of risks by processes, components, parts, subassemblies, assemblies, subsystems, and systems for all the many associated integration design tasks. Nor does it address all possible aspects of performance, which vary widely from project to project. As the design architecture, performance, other requirements, and project constraints become known on a given project, a more detailed list of risks should be prepared based on project-specific information.

Programmatic Risk

Programmatic risk is the risk associated with obtaining and using applicable resources and activities that can affect project direction, but that may be outside the project manager's control. Generally, programmatic risks are not directly related to improving the state of the art. Programmatic risks are grouped into categories based on the nature and source of factors that have the potential to disrupt the project's implementation plan. They include disruptions caused—

- By decisions made at higher levels of authority directly related to the project
- By events or actions that affect the project but are not directed specifically at it
- Primarily by a failure to foresee production-related problems
- By imperfect capabilities

- Primarily by a failure to foresee problems other than those included in the first four categories

These risks tend to be a function of the business environment. Appendix B has a more detailed listing of sample programmatic risks.

Supportability Risk

Supportability risk is the risk associated with fielding and maintaining systems or processes that are currently being developed or that have been developed and are being deployed. Supportability risk comprises both technical and programmatic aspects. Certainly, any design effort of substance should consider what the supportability issues are likely to be when the system is fielded. Another example is training, which is generally a programmatic risk but quickly becomes a supportability risk when maintenance and operations support become the main factors.

It is important to understand that any given risk may belong to more than one of the five facets cited. For example, a particular piece of support equipment may pose a technical challenge and have significant supportability implications.

Cost and Schedule Risk

In many organizations there is a long history of project cost and schedule growth. During times of limited budgets, cost and schedule growth in one project may dictate reductions in another. Therefore, the risk of cost and schedule growth is a major concern. This problem is further complicated because performance and design technical problems are sometimes solved by increasing the planned project scope, thereby increasing project cost and/or schedule.

The difference between the estimated project cost and schedule and the actual results provides the evidence of cost and schedule growth. Two major risk areas have an effect on cost and schedule growth:

- Unreasonably low cost or schedule estimates
- Poor project efficiency on cost and schedule objectives

Poor estimates are analysis related; poor efficiencies are not. Efficiency in a project environment is frequently a function of the project manager's skill in accommodating unanticipated problems related to technical, programmatic, and supportability risks. Those project managers without sound solutions to these problems often face increased costs and schedules.

Poor estimate risks are not simply borne out of low initial guesses on cost and schedule. They may result from—

- Inadequate system descriptions
- Inadequate historical cost or schedule data
- Lack of an effective estimating methodology
- Incomplete estimates

In both of these contexts there are few risks that can be labeled true cost or schedule risks. But more often than not, cost or schedule uncertainty reflects technical, programmatic, and supportability risk.

Facet Organization

There are risk drivers and risk indicators. Risk drivers are usually the technical, programmatic, and supportability facets, whereas cost and schedule facets are the indicators. The difference between drivers and indicators is that drivers are seen as the causes of risk, while indicators are the outcomes. Although both can be affected through risk management, their natures differ. As risk managers, project managers can consider ways to address the drivers and the indicators. The emphasis on each, however, is somewhat different.

As Figure 2 illustrates, addressing one driver may have an influence on both cost and schedule. But considering cost or schedule outcomes may also resolve multiple risks from multiple sources. For example, in developing a Web site, solving a technical problem with Web page programming may reduce cost and schedule exposure. However, negotiating an expanded schedule with the customer may allow time for more technical issue resolution, organizational resource conflicts, and management intervention.

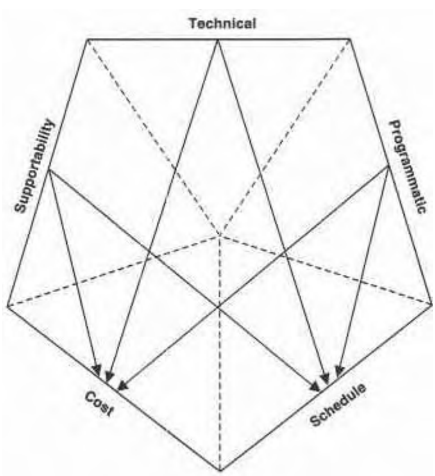


Figure 2. Relationships Among the Five Risk Facets

In situations where risks seem insurmountable, alternatives can sometimes be found in examining the outcomes rather than the sources of risk. Still, having an understanding of both can be crucial.

Risk Categories

There are other ways to examine the sources and categories of risk. In A Guide to the Project Management Body of Knowledge (*PMBOK®*[4] Guide–1987 Edition) (Project Management Institute Standards Committee 1987), risk categories included:

- External unpredictable
- External predictable
- Internal (nontechnical)
- Technical
- Legal

Sample risks or risk sources from each category are shown in Table 2.

Risk Category	Sample Risks/Risk Sources	
External unpredictable	Unplanned regulatory change	Site zoning or access denied
	Flood	Earthquake
	Sabotage	Vandalism
	Social upheaval	Environmental catastrophe
	Political unrest	Unpredictable financial collapse
External predictable	Financial market fluctuation	Raw materials demand
	Competitive shifts	Product/service value
	Inflation	Taxation
	Safety	Health regulation
Internal (nontechnical)	Procurement process delays	Team member inexperience
	Senior staff changes	Integration mistakes
	Poor human resources coordination	Access limitations
	Cash flow concerns	Late deliveries
Technical	Technology shifts	Design imprecision
	Quality demand changes	Requirements changes
	Productivity limitations	Improper implementation
	Operational demand changes	Reliability challenges
Legal	License challenges	Contract failures
	Patent litigation	Staff lawsuits
	Customer lawsuits	Government action

Table 2. Risk Categories and Sources (per PMBOK® Guide–1987 Edition)

[4] PMBOK® is a trademark of the Project Management Institute, Inc., and is registered in the United States and other nations.

However, in the latest edition (PMBOP Guide–2000 Edition) (Project Management Institute 2000), the risk categories shifted slightly, becoming—

- Technical, quality, and performance
- Project management
- Organizational
- External

Sample risks and sources of risk are shown in Table 3.

Risk Category	Sample Risks/Risk Sources	
Technical, quality, and performance	Higher performance goals	New industry standards
	Technology shifts	Complex technology
	Platform changes	Unproven technology
Project management	Poor time allocation	Poor resource allocation
	Poor budget planning	Poor project planning
Organizational	Weak infrastructure	Intra-organizational resource conflict
	Unclear organizational objectives	Shifting funding availability
External	Legal challenges	Natural disasters
	Shifting customer goals	Regulatory shifts

Table 3. Risk Categories and Sources (per PMBOK® Guide–2000 Edition)

Their differences notwithstanding, in both instances the emphasis is on the risk drivers rather than the risk indicators.

External Unpredictable

Issues that loom at the doorstep of any given project are the classic "act of God" risks. Natural disasters, capricious acts of government, sociological upheaval, or environmental change can happen without warning, thus changing the entire tenor of a project. Project rationale may be subverted, and approaches may be subsumed. Although there is generally little that can be done to preclude these events, awareness of their existence is crucial.

External Predictable

External predictable risks are those externally driven problems that can be foreseen. Although the total impact may be difficult or impossible to discern, it is possible to work through the issue in depth and examine potential outcomes and potential time frames. For example, changes in financial markets can be predicted, but the degrees of accuracy vary widely depending on who makes the predictions. External predictable risks are perceived as those environmental risks that project managers should be attuned to and prepared for, as they can be more readily detected than their unpredictable peers.

Internal (Nontechnical)

By virtue of their existence, organizations generate risk. Levels of bureaucracy, staffing policies, administrative procedures, and basic internal procedures drive certain risks. Although many of these risks are not under the project manager's direct purview, there is still an expectation that the project manager will take responsibility for ensuring project success in the context of this environment. These are not the risks associated with carrying out the actual tasks in a project but are rather the risks associated with the setting in which the project will take place.

Technical

As the name implies, technical performance drives technical risks. What does it take to get the job done? Whether the project objective is to deploy servers or to pave a road, there remains a certain level of technical risk. Given the current marketplace of ideas and approaches, technical risks increase dramatically as new technologies are brought to bear. Moreover, attempting to balance capability with technology makes this all the more demanding.

As discussed earlier, the increasing complexity of the technical environment makes risk identification within this category an escalating challenge. As a result, project managers should expect, at a minimum, to have a clear understanding of the breadth of the risks associated with a particular technical level.

Legal

When the earlier version of the *PMBOK® Guide* (1987) was published, legal risks were regarded as having sufficient weight to merit their own category—and with good reason. Within projects, legal risks are legion since many are contractually based, and all serve a body of widely varied stakeholders. With the societal propensity for lawsuits (particularly in the United States), the unique nature of projects makes them an open and ready target for the litigious.

Technical, Quality, and Performance

The new category of technical, quality, and performance mirrors the category designated "technical" in the earlier PMBOP *Guide* (1987) and the original DSMC text. However, with our increasing emphasis on quality and performance, there is recognition that the level of quality requested and the capabilities of the system can drive additional risks. Higher levels of complexity drive higher levels of risk, as do higher demands for quality. In both instances, there is a greater possibility that customer expectations may not be achieved.

Interestingly, high-quality projects are frequently those that are perceived as generating a *lower* level of risk for the buyer. Building in such risk protection, however, often bears its own set of risks for the seller. The seller must develop a product or service that has, to a degree, been risk-proofed. During the development process, the seller becomes responsible for examining the breadth of possibilities for risk associated with the deliverable and for ensuring that those risks either do not materialize or are transparent to the buyer if they do occur.

Project Management

Project managers are not solely responsible for project management, but they must take responsibility for its outcomes. Project management is a team activity; as such, the variety of players who take the field in participating in the processes all have opportunities to either generate or reduce risks. Whereas project management is largely rooted in planning, most of the risks identified within this category are those associated with the efficacy of the plans created.

Project management risks include the risks of poor project plans, poor resource allocation, poor budget planning, poor schedules—all of which lead to varying levels of stakeholder dissatisfaction. The creation of this category places the onus on the project managers to bring together disparate stakeholders in the process and to unite them behind a single vision as to what the plan(s) should be.

Organizational

Project management's classic dilemma is that project managers are burdened with extensive responsibility but have no authority to carry it out. Organizational risks point directly to that issue because they are primarily bureaucratic in nature. They are borne both out of organizations' inability to support projects and their excessive zeal in dictating how projects should be carried out.

Classic battles between functional factions, resources, and competing budgets are typically waged with projects as the battleground. Because projects frequently stretch organizational capability, projects also test organizational objectives and missions, challenging management at senior levels to make what can be difficult decisions. Moreover, the cross-functional nature of projects also draws other combatants into the fray, including human resource staff, functional managers, and sometimes, the executive team.

External

External risks in the *PMBOK® Guide–2000* Edition mirror earlier definitions of both predictable and unpredictable external risks.

In later discussions, it will become more evident why the varied (and perhaps seemingly arbitrary) categories and facets of risk are critical to effective risk management organizations. For now, suffice it to say that these categories provide a sound context in which risk management can be framed. By applying these categories, managers can ensure a level of consistency in identifying and reviewing the breadth of risks their organizations face. Without them, it becomes increasingly likely for one particular risk category to be favored to the exclusion of the others.

Other Relevant Considerations

There are two other areas worthy of mention when discussing risk concepts in terms of projects. Both deal with organizational management structure.

Risk Management Perspectives

Project risk management must be viewed from two vantage points:

- *Short-term perspective:* Dealing with the current project phase and the immediate future
- *Long-term perspective:* Dealing with anything beyond the short term

Like many other aspects of risk management, the distinction between the two perspectives is somewhat unclear, and further explanation is needed to define and justify the separation. The short-term perspective normally refers to managing risk related to satisfying the immediate needs of the project, such as "This is the performance level I need to achieve today, and how are my contractors managing to achieve this?" On the other hand, the long-term perspective deals with "What can I do today to ensure that the project, in the end, will be a success?' This perspective might include, among other things, introducing engineering issues related to project support and production into the design process earlier in the project.

Short- and long-term perspectives are closely linked in achieving the desired performance level in the short term, but the project manager may be forced to sacrifice long-term capability. Projects that require new approaches or new tools may suffer in the short term yet may have higher productivity and performance levels in the long term. Nevertheless, as with any good management decisions, short- and long-term implications must be well understood. The project manager can provide a risk response early only if these implications are known.

Another look at the two perspectives is illustrated in Figure 3, which depicts an overall design selected for a project having certain risk elements. This was a decision that obviously had long-term implications. The current task for the project manager is to complete this design within the existing resource constraints. The project manager has selected some technical, cost, and schedule parameters to manage risk on an operational, day-to-day basis (short-term risk management). While focusing on the short term, the project manager must also keep an eye on long-term implications.

Computer buyers face this same quandary on a daily basis. A low-cost option is attractive for its price but may not have the support of a more expensive unit. A midrange computer may have the support but not the technical capability to handle newly released versions of software. An expensive unit may have all of the features and support desired but may not have management's endorsement for the long term. Thus, achieving a balance between short- and long-term perspectives is indeed a daunting task.

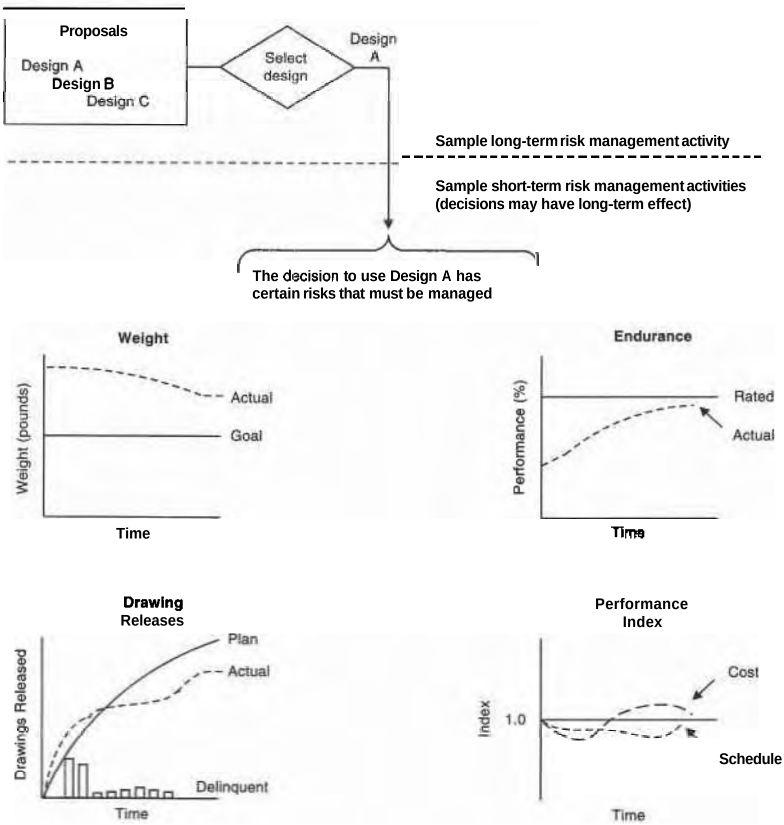


Figure 3. Short-Term and Long-Term Risk Perspectives

Realities of Project Management

Ideally, the same management team will stay with a project from the earliest phases through closeout. However, because ideal conditions rarely exist, a given project will likely employ several management and staff teams. As a result, the transition in project management personnel often creates voids in the risk management process. These voids, in turn, create knowledge gaps, whence valuable information collected earlier in the project is lost. Precious time must therefore be spent becoming familiar with the project, often at the sacrifice of long-term planning and risk management. A formal system for recording, analyzing, and acting on project risk facilitates the transition process, and when done properly, forces long-term risk management. The formal risk management approach is covered in Chapter 3.

Although it is desirable to make decisions based on long-term implications, it is not always feasible. The project manager is often forced to act on short-term considerations. One reason for this—a change in personnel—has already been mentioned. Another reason is project advocacy. Sudden shifts in organizational priorities can wreak havoc on long-term plans (a risk area in itself). This results in short-term actions to adjust to new priorities. Often, these decisions are made before long-term effects can be thoroughly evaluated. And lastly, in some instances, long-term effects are not always apparent at the time a decision must be made.

Day-to-day operational risks must be addressed to complete any given phase of a project. As much as possible, the solutions developed to handle these risks must be examined from a long-term viewpoint and must provide the project manager with a strong, structured argument to defend his or her position. As many studies have pointed out, actions taken early in a project's development have a major effect on the overall performance and cost over the life of the project. One example is illustrated in Figure 4 (DSMC 1985).

Summary

- Risk considers both probability and impact.
- Rating risk is a subjective process requiring strict guidelines.
- There are multiple ways to categorize risk, but no matter the scheme, they are strongly interrelated.
- Risk has both long-term and short-term perspectives.

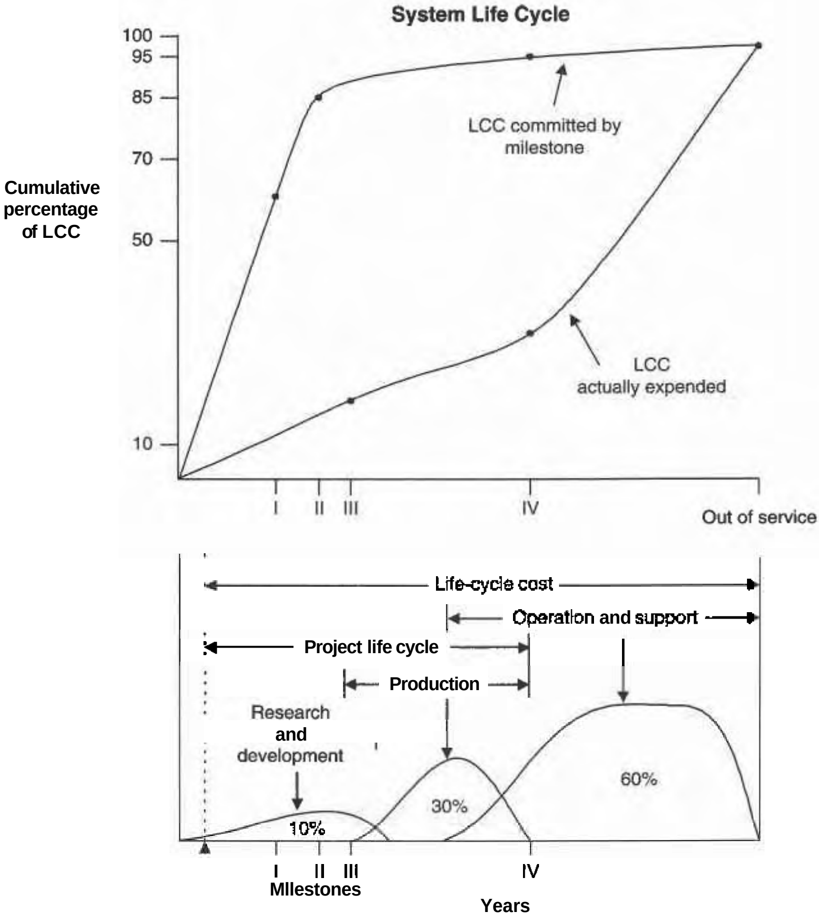


Figure 4. Life-Cycle Cost

Chapter 3

The Risk Management Structure

This chapter focuses on defining and explaining the elements of risk management and presents the recommended overall structure for implementing risk management. In the past, several different structures and definitions have been used for basically the same concept, which has been a source of continuing confusion. Figure 5 reflects a structure that mirrors the perspective of the Project Management Institute's *PMBOK®* Guide–2000 Edition within the organizational environmental context.

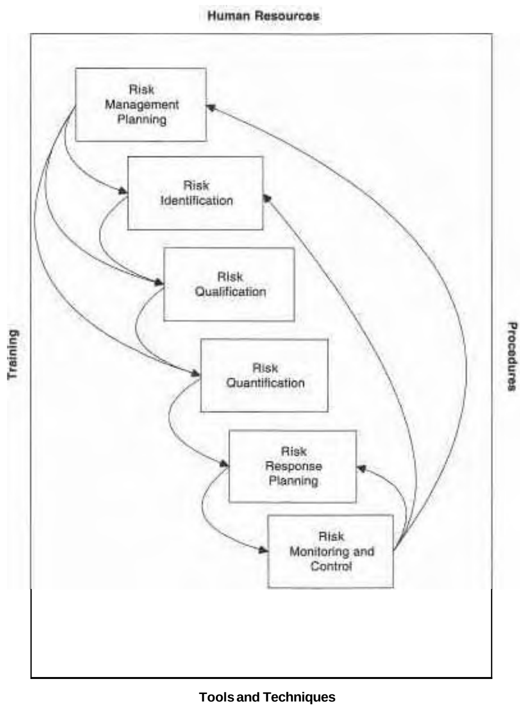


Figure 5. Risk Management Processes

Risk Management Planning

Risk—present in some form and to some degree in most human activity—is characterized by the following:

- It is usually (at least) partially unknown
- It changes with time
- It is manageable in the sense that the application of human action may change its form and degree of effect

The purpose of risk management planning is simply to compel project managers to devote organized, purposeful thought to project risk management and to provide organizational infrastructure to aid them as they attempt to—

- Isolate and minimize risk
- Eliminate risk where possible and practical
- Develop alternative courses of action
- Establish time and money reserves to cover risks that cannot be mitigated

As an integral part of normal project planning and management, risk planning is sensibly done and repeated and should occur at regular intervals. Some of the more obvious times for evaluating the risk management plan include:

- In preparation for major decision points and changes
- In preparation for and immediately following evaluations
- As significant unplanned change occurs that influences the project

Most major projects are guided by a series of plans that provide the rationale and intended processes through which projects will be executed. A risk management plan is recommended as part of this suite of guiding documents. Such a plan would publish the results or the latest status of the risk management planning process.

Compared to some other plans, risk planning has not been developed as much in terms of content and format, which allows project managers some latitude to establish documents that suit their situation. One approach to the content of a risk management plan is illustrated in Figure 6, the highlights of which are described in the following paragraphs.

System description and project summary. This material should be the same in all the project's plans. Together, they should provide a frame of reference for understanding the operational need, the mission, and the major

Part I, Description
- 1.1 Objective (from charter)
- 1.2 Project
  - 1.2.1 Project description (from the work breakdown structure or WBS)
  - 1.2.2 Key functions (from charter and WBS)
- 1.3 Required operational characteristics
- 1.4 Required technical characteristics
- 1.5 Required support (from roles/responsibilities)

Part II, Project Summary
- 2.1 Summary requirements
- 2.2 Management
- 2.3 Integrated schedule

Part III, Risk Environment
- 3.1 Organizational risk management policy
- 3.2 Stakeholder risk tolerances
- 3.3 Organizational risk management plan template

Part IV, Approach to Risk Management
- 4.1 Definitions
- 4.2 Practices
- 4.3 Timing
- 4.4 Metrics
- 4.5 Thresholds
- 4.6 Implementation
  - 4.6.1 Evaluation
  - 4.6.2 Tracking
  - 4.6.3 Roles/responsibilities

Part V, Application Issues and Problems
- 5.1 Risk identification
- 5.2 Risk qualification
- 5.3 Risk quantification
- 5.4 Risk response planning
- 5.5 Risk monitoring and control

Part VI, Other Relevant Plans

Part VII, Approach Summary

Part VIII, Bibliography

Part IX, Approvals

Figure 6. *Sample* Risk Management Plan

functions of the project. They should include the basic inputs to risk management planning, some of which are common to many other processes of project management. Specifically, the charter, the project roles and responsibilities, and the work breakdown structure (WBS) are crucial to establish the terms of the project as well as the potential parameters of project risk. They should also include the key operational and technical characteristics of the project deliverables.

The conventional elements of the charter and the WBS afford clear descriptions of the project and the nature of the deliverables. Such clarity of description will prove invaluable in ascertaining the relative magnitude of the project risk management effort. On smaller projects, there is sometimes the temptation to completely circumvent the risk management process. Although the process should be scaled back to reflect the level of project effort, risk management can never be completely ignored. A well-crafted project charter and WBS will provide information on the scope essential for determining how much risk management will be sufficient and how much constitutes "too much."

The roles and responsibilities information is also essential. Skilled, savvy, well-practiced team members can frequently remove significant levels of risk from the project. They can render the need for intense project monitoring virtually moot. By contrast, less skilled team members may have neither the background, understanding, nor appreciation of potential concerns and may, as a result, increase the requirement for intensely procedural risk management.

Risk Environment

In every project, there is a risk environment. There are risks that will have to be faced, and there are a host of different ways to deal with them. Risk management planning is the effort, organizationally, to draw together the risk policies, practices, and procedures of the organization into a cohesive whole that will address the nature of risk peculiar to the project. In addition to the inputs of the WBS, project summary, and roles and responsibilities, there are inputs specific to risk planning. According to the Project Management Institute, they are organizational risk management policy, stakeholder risk tolerances, and a template for the organization's risk management plan. In many organizations, these conventions simply do not exist. They are, nevertheless, essential to risk management success.

The levels of depth and detail and their effect on the project risk management effort should be communicated in the organizational risk management policies. In some organizations, such policies are scant, if they exist at all. Risk management policies will offer insight into the amount of information and risk reporting that is required on projects, as well as general guidance on risk qualification, quantification, and response development. That guidance may include, but is not limited to, organizational definitions and descriptions of approaches to the risk procedure, guidance on risk reserve allocation, explanations of risk probability and impact descriptions, and clarification on proper application of risk response strategies.

Stakeholder risk tolerances are a vital input because different members of the customer, project, and management teams may have different perspectives on what constitutes "acceptable" risk. This is rarely preordained or predetermined. Project managers must gather this information by vigorously pursuing the key stakeholders to identify what they are and are not willing to accept. This extends beyond simple thresholds for cost and schedule. Some stakeholders have passionate perspectives on project visibility. Some want to ensure the project is regularly in the public eye and consistently in the best possible light. Others, by contrast, want to ensure that project publicity is kept to an absolute minimum and consider any public exposure "bad exposure." Thresholds can be established for a variety of issues, ranging from satisfaction survey responses to team attrition to technology exposure. Failure to develop an acute awareness of the stakeholder's tolerances may lead to unidentified risks or improperly assigned impact levels.

In some organizations, risk management is sufficiently well entrenched that there are standard forms and formats for risk management plans. This is more common in organizations where there is a project management office (PMO) or project support office (PSO). These formats encourage consistency and knowledge transfer as risk management history is conveyed continually from project to project and from team to team.

These inputs may take some time to amass. Gathering these data is frequently done in concurrence with other project efforts, such as budget estimating and high-level scheduling. Ideally, these efforts would precede the planning steps as the insights from risk management planning may have a significant impact on the outcomes.

Approach to risk management. This section is actually developed during planning meetings with the project team. This plan is not specific to the project risks but instead addresses the framework in which those risks will be addressed. (Project risks are addressed in the subsequent steps in this process.) During these meetings, team members should work to build documentation that will encourage consistent adherence to the risk management policy and procedure within the organization and to ensure that there is an unchanging vision as to the levels of risk that are deemed tolerable. Participants should review all the available inputs and acknowledge (and document) any deviation from organizational practices.

The meeting (and subsequent research and analysis efforts) should produce an overall risk management plan, a risk approach within which the project will function. This framework includes oversight on the definitions, practices, timing, metrics, risk thresholds, evaluation, tracking, and roles and responsibilities associated with the risk management effort. A preliminary risk budget may also be developed, although more in-depth documentation and budget support is frequently developed during or after risk quantification.

Definition of terms is crucial. People differ in their interpretations of terms like risk, probability, workaround, contingency, and most risk language. Thus, creating a common understanding of those terms and how they will be applied will ensure that risk issues are managed consistently.

Organizational risk practices should be distilled to a methodology specific to the project. Such a methodology may include a variety of types of information, but at a minimum, should include the frequency of risk reviews, tools to be deployed, and a list of valid resources for project risk data. Methodologies for risk management will not be identical from project to project, but there should be some similarities within an organization. Organizations should strive to use tools consistently and ensure that their outputs are recorded in common repositories. Such effective storage of project risk information leads to more effective knowledge transfer over the long term and across projects.

Risk timing is the effort to establish consistency in the frequency of risk reporting, reevaluation, and review throughout the project life cycle. In some cases, short-term projects may require a risk review only at the beginning and end of the project. However, more involved or longer-term efforts may require risk reviews at a variety of interim points. The frequency of those points varies according to project complexity.

Optimally, risk metrics are an organizational phenomenon. Risk metrics relate to the specific organizational interpretations of such issues as risk probability, risk impact, and related qualitative and quantitative measures. These metrics address how project team members will determine the threshold for high probability and what rate of occurrence denotes low probability. Similarly, these scoring practices set down the differences among low, moderate, and high impacts on issues including budget, cost, requirements, organizational politics, and customer relations. This ensures team members share the same point of view on levels of risk acceptability.

Any discussion of risk evaluations in the plan will establish the format, level, and frequency of risk reassessments. Establishing such formats again ensures consistency in terms of data depth, data retention, and understanding of critical risk information on the project.

Application issues and *problems*. This section includes the procedures and process for the following (at the project level):

- Risk identification
- Risk qualification
- Risk quantification
- Risk response planning
- Risk monitoring and control

Other relevant plans. Every major project should be governed by a set of plans, including the project plan. Other plans may include quality, communications, contracting, testing, and training (to mention only a few). Typically, these plans are not written from a risk viewpoint. But when read with risk in mind, they provide valuable information and may suggest items of risk. These plans should be reviewed before, during, and after preparing the risk management plan. Moreover, the risk management plan may also suggest items to be addressed in the other plans. Although the risk management plan deals with analyzing and managing risk, risk should be identified and highlighted as appropriate in any plan.

Approach summary. In developing the risk management plan, there may be global concepts and principles that will be applied. However, such thinking may not be self-evident in the supporting documentation. Any overarching goals or driving objectives should be clearly identified as a summary statement. Summary statements should not provide any new information but should instead capture the essence of the strategies reflected in the information already provided.

Bibliography. Perhaps the most important aspect of any plan bibliography is the location and identification of any supporting documentation. If such information is retained electronically, the bibliography should include the file names and server locations.

Approvals. Approvals for *all* risk documentation should be identified here. These approvals should include, but not be limited to, the sanctioning authority for the risk management plan, as well as a list of names and titles for those individuals responsible for authorizing updates to the plan and its supporting documentation.

Risk Identification

A critical step in the risk management process, risk identification is an organized, thorough approach to finding real risks associated with a project. It is not, however, a process of inventing highly improbable scenarios in an effort to cover every conceivable possibility. Risks cannot be assessed or managed until they are identified and described in an understandable way.

Perhaps the key failing of project managers in risk identification is the actual description of risk events. Many project managers attempt to identify risks simply as "schedule" or "cost." (The schedule in and of itself is not a risk.) A risk event is something that may happen to the benefit or detriment of the project. (If it happens in favor of the project, some describe it as an "opportunity event.") Risk events are most effective when they are described clearly and in depth. A high-quality risk event description will describe the potential occurrence and how it would influence the project. On a construction project, the risk that a "wall will collapse, causing a delay" is different from the risk that a "wall will collapse, killing someone."

In the *PMBOK® Guide–2000* Edition, PMI® designates the information from the risk management plan as a critical input to risk identification. Other inputs include project planning outputs, risk categories, and historical information. All this information can spur thinking about different risk issues and concerns when evaluated using the tools and techniques of risk identification.

The tools and techniques that are applied in risk identification are as varied as the projects they serve. However, some groups of tool and technique types are most commonly applied. According to PMI®, they include documentation reviews, information-gathering techniques, checklists, assumptions analysis, and diagramming techniques.

Documentation reviews. On the surface, this would seem to be an easy task. However, because different stakeholders have different perspectives, it becomes a thought-provoking and controversial process. For example, a comparison of the requirements and the WBS will often provide a gap analysis, identifying risks that requirements will not be met. A study of the high-level schedule may point to unrealistic deadlines or potential performance gaps. A review of the procurement plan or resource plan may highlight shortcomings in organizational or project capability or capacity. Reviews of organizational or project strategy documentation may illustrate potential disconnects between the project and the organization's purpose.

Information-gathering techniques. Expert interviews, analogy comparisons, the Delphi technique, brainstorming, the Crawford Slip Method, and SWOT (strengths, weaknesses, opportunities, and threats) analysis are especially useful techniques in risk identification. The objective is to obtain straightforward, clear narrative statements describing project risks. Mathematic techniques are inappropriate here because the objective is to gather data about what might happen, not the degrees of probability and impact. Part II details the techniques for analyzing risk.

Checklists. The purpose of any project is to achieve a specified set of goals. The project must be scrutinized systematically to identify those events that may reasonably occur and threaten project goals. The search should emphasize showstoppers—those events that will have a major effect on the project.

The top-level risk matrix (see Table 4) is a tool designed to organize this process. It can be developed using any of the sets of risk categories and is applied at the total project level as a starting point. The concept can be

	Project Phase			
Risk Facet	Concept	Development	Implementation	Closeout
Technical Goals Strategy Risks				
Programmatic Goals Strategy Risks				
Supportability Goals Strategy Risks				
Schedule Goals Strategy Risks				
Cost Goals Strategy Risks				

Table 4. Top-Leuel Risk Matrix

refined and carried to greater detail as needed. In an organization with well-developed risk practices, specific questions will be developed to reflect organizational propensities for risk as they relate to the risk category's or facet's goals and strategies.

Assumptions analysis. The mere documentation of assumptions often drives project teams to a clearer sense of the risks that may befall a project. Assumptions are the environmental hypotheses or scenarios that are established for planning purposes and are assumed to be real or valid. The validity of the assumptions may determine the validity of the project itself. Assumptions analysis involves listing the assumptions under which the project plan is evolving and then validating those assumptions through research.

Assumptions analysis clarifies where information on risk analysis will be valid and where it will be based on uncertainty. Uncertainty exists when the project team can never reasonably establish the probability of possible outcomes.

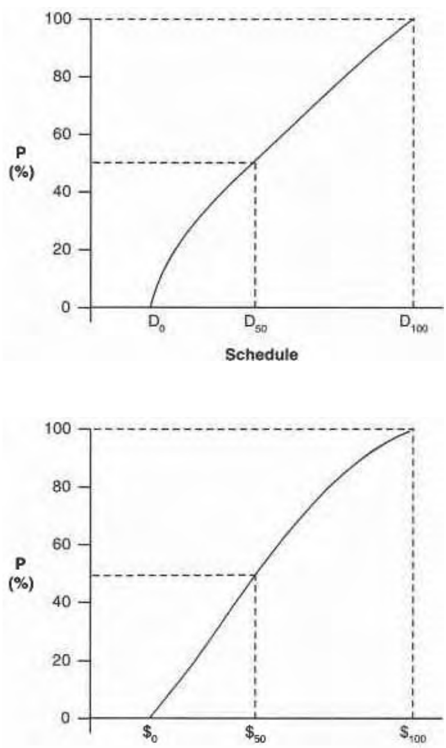
Diagramming techniques. Because of the nature of relationships in projects and their effects on risks, diagramming techniques will sometimes provide insights that are not available from raw project data. Network diagrams, cause-and-effect diagrams, flowcharts, and force field charts can all provide insight based on relationships that are not otherwise readily evident. Application of the techniques is discussed in Part II.

Risk identification is an iterative process. At the end of any risk identification cycle, risk events will be identified. Ideally, some of the triggers or symptoms that warn of risk will also be flagged.

Risk Qualification

The identification process produces a well-documented description of project risks. As analysis begins, it helps to organize and stratify the identified risks.

Baselining risk. Risk exists only in relation to the two absolute states of uncertainty: total failure (usually expressed as 0 percent probability) and total success (usually expressed as 100 percent probability). Risk will always fall somewhere within this range. Risk qualification is a first, best effort to sort risk in relation to its probabilities and impacts. The process is simplified significantly by defining the total failure and total success so that the full range of possibilities can be understood. Defining one or both of the performance measurement baselines (cost and schedule) helps set a benchmark on the curves (see Figure 7).



cost

Figure 7. Risk Baselines

It is certainly desirable (but difficult) to describe the technical content as an absolute percentage of either 0 percent or 100 percent. Few organizations have the rigor to apply those values to technical performance. Those that do may apply them through a technique known as technical performance measurement (TPM). But in most organizations, the technical issues are tied closely to cost and schedule, so those values are applied with the assumption that technical content has been addressed. After defining a baseline position, it becomes easier to qualify and quantify the degree of risk for each impact area.

Rating schemes and definitions. The degree of risk assigned in a given situation reflects the personality of the risk analyst. Twenty people can look at the same situation and each would come up with a different risk value. Consequently, a risk rating scheme built against an agreed-to set of criteria helps minimize discrepancies.

The scales of probability and impact can (and probably should) be simple—such as high, medium, low—applying the notion that the degree of risk is a consideration of probability of occurrence and severity of impact. Figure 8 is a diagram for a risk rating mechanism. Defining a risk becomes a matter of identifying impacts, deciding on a scale, and then shaping the boundaries. With a defined risk rating scheme in place (at least tentatively), the task of evaluating and qualifying each identified risk may be accomplished using this structure.

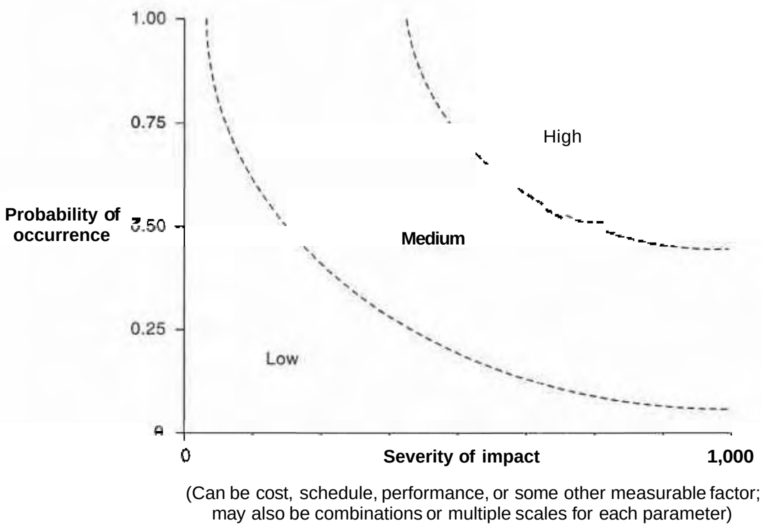


Figure 8. Risk Rating

Organizations need to establish consistent terms and terminology for probability because impact levels vary radically from project to project. One project's two-week delay may be a minor issue, whereas another's two-week delay is a showstopper. The same cannot be said of probability. Organizations need consistent values for probability to support congruent applications of the principles. Thus, if terms and values statements can be established for probability, it will facilitate project managers' efforts to qualify their risks consistently.

A high probability can be expressed as a percentage (80%), as a values statement (extremely likely), as a comparison (as often as the Bay Bridge is backed up at rush hour), or as a frequency level (in at least four out of five instances). The same can be done for low probability. Moderate probabilities are frequently described most simply as the range between the high and low values statements. Many organizations also accommodate extremely remote risks (acts of God, civil unrest, as examples) with a supplemental probability value for improbable or abnormal risk. These probability values are assigned at well below 1 percent to account for those issues that are remarkably rare but which potentially pose a dramatic risk to the project or organization as a whole.

Impact weights are conventionally established on a project-by-project basis as different projects have significantly different effects on the organization. Impact may be established for cost and schedule as percentages, as absolute values, or as values relative to specific tasks or functions. Impact may also be established for other cultural issues within the organization. In some organizations, political, socioeconomic, customer relationship, or image risks may weigh just as heavily as cost and schedule. As such, the more that can be done to establish high, medium, and low values for such risks, the easier it will be to ascertain the relative levels of risk on a given project.

Probability and impact do not necessarily share the same weight in a probability/impact risk rating matrix. When using this tool, probability may be weighted less heavily than impact (or consequence) to allow the organization to acknowledge its concern for those risks that, while unlikely, can cause significant detriment to the project. On such a scale, probability values may be incremental, whereas impact values may be subjectively weighted, as shown in Figure 9.

This type of scale allows for the qualitative evaluation and comparison of seemingly similar risks. If both scales use equal increments, a risk having a high probability of occurrence but a low impact is weighted identically to a risk with a low probability of occurrence but a high impact. In some

Impact \ Probability	Low probability (1)	Moderate probability (2)	High probability (3)
Low impact (1)	Low probability, low impact (1x1=1)	Moderate probability, low impact (2x1=2)	High probability, low impact (3x1=3)
Moderate impact (3)	Low probability, moderate impact (1x3=3)	Moderate probability, moderate impact (2x3=6)	High probability, moderate impact (3x3=9)
High impact (6)	Low probability, high impact (1x6=6)	Moderate probability, high impact (2x6=12)	High probability, high impact (3x6=18)

Figure 9. Probability/Impact Risk Rating Matrix

organizations, that's acceptable; but in others that have a greater concern for impact, the scale in Figure 9 may be more appropriate.

Rating schemes are discussed in greater depth in Chapter 22.

Assumptions testing. During risk identification, assumptions were identified and validated. During qualification, assumptions are tested. Such testing is performed *not* to establish the validity of the assumption; presumably, that has already been done. Rather, the assumptions tests evaluate stability and consequences.

- Stability — This is the evaluation of the potential for change in a given assumption. Some assumptions, by their very nature, will change; they will not remain stable. This assessment should be used to determine the degree of stability for a given assumption.
- Consequences — This is the evaluation of the potential impact to the project if the assumption proves invalid.

Risk modeling. In some instances, project risk will be qualified using risk models. Generally, such models are organizationally specific and are applied consistently to all projects during risk qualification. Risk model development and application is discussed in Chapter 23. Risk models and the other risk qualification practices support development of an overall risk ranking, one of the critical outputs from this stage in the process. This allows the project to be compared to other similar efforts in terms of risk. It also supports other comparative analyses for project prioritization, contingency funding support, or basic go/no go decision making.

Using analogies. Analogy comparison is an attempt to learn from other projects or situations and is used for many actions, such as cost estimating and scheduling. It is important to distinguish between analogous projects and projects with analogous risks. Analogy comparison is discussed in detail in Chapter 8.

Risk qualification sets the stage for significant risks to be quantitatively evaluated. It also affords project managers a tool to evaluate those risks that do not lend themselves to more quantitative analysis.

Risk Quantification

Quantitative risk analysis is the effort to examine risk and assign hard metric values to both the project risk as a whole and to the most significant risks (as established through risk qualification). Project managers conduct risk quantification to establish the odds of achieving project goals, to justify contingency reserves, to validate targets associated with the triple constraint, and to conduct in-depth "what-if' analyses.

In a perfect world, the pool from which quantitative risk information is drawn is deep and rich with data. It includes information from the previous processes discussed here as well as any statistical data repositories existing within the organization. To augment those data, project managers use a variety of tools, including expert interviews, decision tree analyses, Program Evaluation and Review Technique (PERT) assessments, and simulations.

Expert interviews. The technique for interviewing technical experts to rate risk quantitatively is discussed in detail in Chapter 4.

Decision tree analysis. Decision trees are classic project risk tools that provide a wealth of information in an easy-to-interpret format. They are particularly helpful in risk quantification as they provide information on the options, the probabilities of events associated with those options, the expected value of those options, and the potential impacts of all possible outcomes. Decision trees are discussed in greater depth in Chapter 17, Decision Analysis–Expected Monetary Value.

PERT. The Program Evaluation and Review Technique takes the network analyses (briefly discussed under Risk Identification) a step further by embedding multi-data-point duration estimates to establish risk values for schedules. This concept is addressed further in Chapter 20.

Simulations. Both cost and schedule risks can be evaluated using risk simulation tools, the most popular of which is the Monte Carlo analysis. These tools provide ranges of possible outcomes and the likelihood of achieving those outcomes. Cost and schedule risk simulations are explored in Chapter 24.

Risk quantification provides project managers with both a sense of the overall level of risk in the project and a value (in terms of cost or duration) for that risk. Often, that value becomes the contingency reserve or a component of the contingency reserve. The quantification process can also provide probability assessments that manifest themselves as "confidence levels." A confidence level is a measure of the likelihood or percent probability that the project organization will be able to achieve a given target.

One of the most useful outputs of the analysis process is the watch list or the prioritized risk listing. The watch list can serve as the worksheet that managers use for recording the risk management progress (Caver 1985). An example of a watch list is shown in Table 5. This prioritized risk list provides a convenient means to track and document outputs from the risk analysis process. It can be generated either by conducting pairwise comparisons of qualified risks or by comparing values generated in risk quantification. In risk quantification, as the watch list is being built, only the risk item and impact area are listed. After responses are developed, they are incorporated here as well.

Event Item	Area of impact	Risk Response
Loss of vendor	Production cost	Qualify second vendor
		Obtain technical data as a deliverable
Incomplete logistic support analysis	Support cost	Contractor support for 2 to 3 years
		Warranty on high-risk items
		Emphasis on contractor reviews
		Logistics reviews
Immature technical data package with many engineering changes for design fixes	Production cost with high first-unit cost	Production engineers on contractor design team
		Fixed-price contract
		Competition
		Producibility engineering planning
		Production readiness reviews
Long lead-time items delayed	Production schedule	Early identification of long lead-time items
		Emphasis on early delivery
		Transfer or leveling from less urgent programs

Table 5. Sample Watch List

Some project managers will generate this information and store the identified risks, their probabilities, impacts, overall risk levels, and priorities in the same database as their work breakdown structure. This can be accomplished in most of the project management software packages by using some of the available spare text or numbers fields that frequently go unused. If, however, these fields are used, a central authority (like the project office) should coordinate their use to ensure that they are used consistently from project to project and from functional organization to functional organization. In most tools, the underlying information will look similar to this:

WBS #	Task Name	Text 12	Number 12	Number 13	Number 14	Number 15

When renamed, the fields take on a different look and now support the project:

WBS	Task Name	Risk Event	Probability	Impact	Overall Risk	Priority

Cumulative probability distribution, another useful product of risk analysis, is illustrated in Figure 10. The cumulative probability distribution curve is a common, conventional method that depicts cost, schedule, and performance risk. Project managers can use cumulative probability distributions by determining an appropriate risk level (threshold) for the item and then determining from the curve the corresponding target cost, schedule, or performance. Project managers may also alter variables to determine sensitivities of the project to those variables. These are typical outputs of many automated risk tools that are discussed in Chapter 24. Appendix C explains probability curves in more detail.

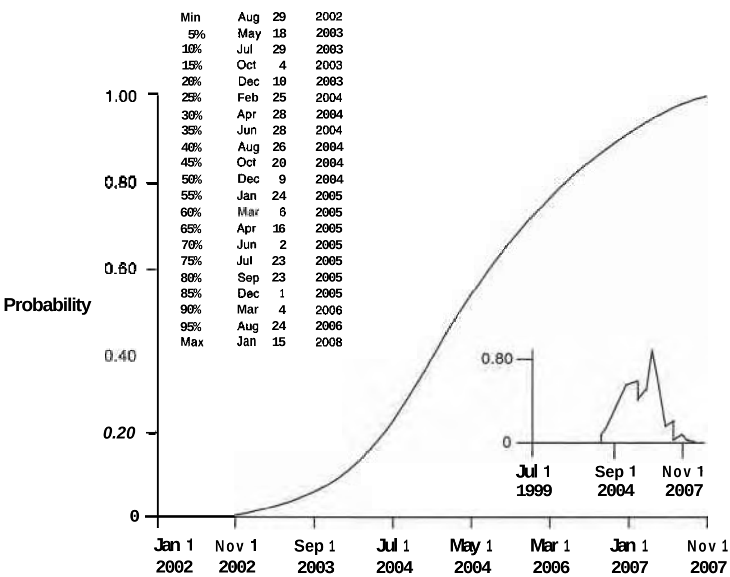


Figure 10. Sample *Cumulative* Probability Distribution

Risk quantification, which generally provides an in-depth understanding of the sources and degree of risk, can be portrayed quickly in a few charts. This generates an effective communication of project status to decision makers. Chapter 26 has suggestions for communicating risk information.

Risk quantification provides extensive information on which risks are the most important and which pose the greatest potential threats to the project. Ideally, the outputs from qualification and quantification will include a comprehensive, prioritized risk listing. Even then, there will be those team members who challenge such a list, arguing that it represents either individual or organizational bias. Because of that possibility and because of the reality that all the risks involve at least some degree of uncertainty, the final determinations must reside with the project manager. When it comes to prioritization, the project manager should be the ultimate decision maker in establishing which are the most worrisome risks.

Risk Response Planning

Risk response development is a critical element in the risk management process that determines what action (if any) will be taken to address risk issues evaluated in the identification, qualification, and quantification efforts. All the information generated to date becomes critical in determining what the organization will do that is in keeping with the risks, the organization's tolerance, the project tolerances, and the customer culture.

To some measure, risk is a cultural phenomenon. Different countries, regions, and organizations have different cultural tolerances for risk and risk responses. Determining what limits exist early in the risk response planning process is important to ensure that time is not wasted on approaches that are intolerable. Risk thresholds frequently are as significant here as they are in establishing basic probability and impact for the risks.

All risks have causes; sometimes multiple risks within a given project arise from a common cause. In developing risk responses, the project team should work to identify any common causes as those causes may have common risk responses.

Generally, response strategies fall into one of the following categories:

- Avoidance
- Transference
- Mitigation
- Acceptance

Risk Avoidance

In many situations, a lower risk choice is available from a range of risk alternatives. Selecting a lower risk option or alternative approach represents a risk avoidance decision. For example, "I accept this other option because of less potentially unfavorable results." Certainly, not all risk can or should be avoided. On occasion, choosing a higher risk can be deemed more appropriate because of design flexibility, enhanced performance, or the capacity for expansion.

Communication is critical to risk avoidance. Eliminating an approach or requirement will be in vain if the rationale for the action is not clearly documented. Others may augment the project with approaches that reintroduce the risk.

Risk Transference

Also known as "deflection," risk transference is the effort to shift responsibility or consequence for a given risk to a third party. Transference rarely serves to eliminate the risk. Instead, if creates an obligation for mitigation, acceptance, or avoidance on another individual or organization. Risks can be transferred to a variety of organizations and individuals outside the project, including:

- Insurers (including warranty firms, guarantors, and bondsmen)
- Subcontractors
- Vendors
- Partners
- Customers

Surprisingly, project managers frequently overlook the customer as a potential party to risk transference. Nonetheless, the customer is one of the few recipients of a transferred risk who can completely assume the risk from the project organization.

Risk deflection often benefits the project as well as the customer. The type of contract, performance incentives, and warranties may be structured to share risk with others and in part, deflect risk.

Risk Mitigation

Risk mitigation is the most common of all the risk handling strategies. It is the process of taking specific courses of action to reduce the probability and/or reduce the impact of risks. This often involves using reviews, risk reduction milestones, novel work approaches, and similar management actions. The project manager must develop risk mitigation plans and then track activities based on those plans. All these actions are built into the project plan (cost plans, schedule plans) and ultimately into the work breakdown structure (WBS).

Through risk mitigation, the project manager may emphasize minimizing the probability that the risk will occur or minimizing the impact if the risk occurs. Depending on the specific risk, either approach may be effective.

Risk *Acceptance*

Acceptance, also known as retention, is the decision to acknowledge and endure the consequences if a risk event occurs. It is broken down into two basic types of acceptance, active and passive.

Passive acceptance is the acceptance of risk without taking any action to resolve it, cope with it, or otherwise manage it. The only actions required in passive acceptance are documentation of the risk, as well as acknowledgement by management and the team (and the customer, if appropriate) that the risk exists and that the organization is willing to endure its consequences, should the risk occur.

Active acceptance acknowledges the risk as well, but calls for the development of contingency plans, and in some cases, fallback plans. Contingency plans are implemented to deal with risks only when the risk events come to pass. This may include detailed instructions on how to manage risks retroactively or may be as simple as a contingency reserve budget established for the project.

Contingency reserves are frequently fodder for discussion because some view them as project panaceas and others see them as a crutch for those who cannot manage effectively. These reserves are sometimes referred to as contingency allowances. Organizations should not establish universal rules for applying contingency, such as flat percentages or fixed monetary (or schedule) amounts. Instead, contingency reserves should reflect the degree of risk acceptance in a project, as well as the overall levels of risk associated with the project. Organizations may set contingency values by applying culturally acceptable metrics to the risk models (discussed in Chapter 23). They may also set contingency reserves through negotiation with the project manager or by using the expected values of the project's quantified risks as analyzed earlier. Nonetheless, if contingency reserves are to be applied, they must reflect the realities of the project as a *unique* effort toward a specific objective, thus requiring a specific level of risk support.

Fallback plans are implemented in active acceptance to deal with managing accepted risks if the contingency plans are insufficient.

Fallback plans represent the safety net that ensures the entire project will not collapse in failure.

Selecting the proper strategy may require project managers to identify specific strategies for each risk. It may also require that managers identify single strategies that may apply to a broader subset of risks or to common causes. A popular tool for identifying such opportunities is the risk response strategy matrix. This matrix encourages the examination of risk responses both in the context of other risks in the project as well as in the context of the other risk responses. The risk response strategy matrix is examined in Chapter 26.

Ideally, the project team that has completed risk response planning will have established a contingency reserve for the necessary funds and time to deal with project risk. They will have an adjusted WBS that reflects issues that surfaced during risk response analysis and incorporates any new activity the strategies require. They also will have communicated the risks, risk strategies, and any residual (or leftover) risks to the management team to ensure there is buy-in on the approach. Moreover, they will have contractual agreements to support any deflection or transference. As a by-product, there is also the possibility that new risks will arise as a result of the new strategies. Those ***new*** risks should be examined using the same process as the earlier risks—identification, qualification, quantification, and response planning—as appropriate.

Risk Monitoring and Control

After risks are identified, qualified, and quantified, and clear responses are developed, those findings must be put into action. Risk monitoring and control involves implementing the risk management plan, which should be an integral part of the project plan. Two key challenges are associated with monitoring and control. The first is putting the risk plans into action and ensuring the plans are still valid. The second is generating meaningful documentation to support the process.

Implementing the risk plans should be a function of putting the project plan into action. If the project plan is in place and the risk strategies have been integrated, then the risk plans should be self-fulfilling. Ensuring that the plans are still valid, however, is not as simple. Risk monitoring involves extensive tracking of the risks and their environment. Have the plans been implemented as proposed? Were the responses as effective as anticipated? Did the project team follow organizational policy and procedure? Are the project assumptions still valid? Have risk triggers occurred? Have new external influences changed the organization's risk exposure? Have new risks surfaced?

Answers to these questions may drive radically different approaches to the project and to its risks. Alternative strategy development, reassessments, reviewing contingency plan implementation, or replanning may be essential to project survival or success.

Different tools serve the evaluation requirements of risk monitoring and control. Basic project management tools, such as earned value analysis, provide insight on the relative levels of variance and the tasks that drive the variance. Technical performance measurement (TPM) is a quality management tool that examines the performance of the organization in terms of each individual work package objective. Dubbed by some as the "earned value of quality," TPM affords insight on performance variance and the potential influences of risks that have occurred.

As the project progresses, there are risk-specific evaluations to facilitate risk control. Formal risk audits examine the project team's success at identifying risks, assessing probability, and developing appropriate strategies. The frequency of risk audits is largely determined by the duration of the project and the criticality of the deliverables involved. A project with mission-critical deliverables will, by its very nature, undergo more frequent audits than a project developed for a support mission.

Risk reviews, though less formal than risk audits, are vital nonetheless. Risk reviews allow for an examination of the risks, probabilities, impacts, and strategies, largely to determine if supplemental action or review will be required. As with audits, the criticality of the project and its duration determine in large part the frequency of such reviews.

The challenge is dealing with risk events as they occur. Flaws in carefully structured plans become evident when those plans are implemented. Some strategies work very effectively; others prove far less effective. Thus, it often becomes necessary to begin the cycle anew, which involves either reconsidering risk responses or probing even further back in the process to reevaluate identified risks.

However, the process cannot possibly manage all risks. Some risks will occur without having been preemptively identified. Those that do will be managed "on the fly" without careful consideration and review. The workarounds, or unplanned responses to negative risk events, provide project teams with a last chance to deal with problems because they are reactive rather than proactive and rarely have the level of support that well-considered risk responses do. Thus, because workarounds are developed without a long-term planning window, they are also frequently more costly or time-consuming. In essence, workarounds are contingency plans without the planning.

As risk control and monitoring are applied, data are generated. Responses succeed and fail. Some risks materialize and some do not. Probabilities shift and time alters impact values. These changes may drive changes in the organization's existing risk identification checklists and should also be captured in a risk database along with any new information. Such a database need not rely exclusively on database tools such as Microsoft Access® or FoxPro® but may be catalogued in the project management software with the project plan. As discussed earlier, text and numbers fields in the project management software can be used to support risk identification as follows:

WBS #	Task Name	Text 12	Number 12	Number 13	Number 14	Number 15

Renamed, the fields take on a different look and now support the project:

WBS	Task Name	Risk Event	Probability	Impact	Overall Risk	Priority

This same approach can also augment risk response information and the effectiveness of the strategies deployed:

WBS #	Task Name	Text 12	Text 13	Text 14	Text 15	Text 16

Renamed, the fields take on a different look and now support the project:

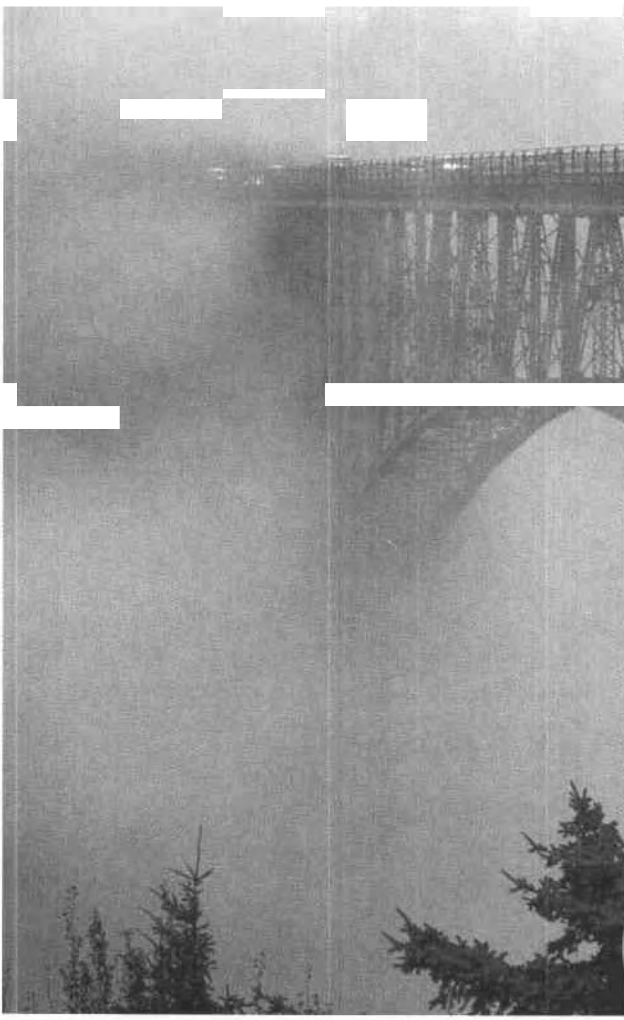
WBS #	Task Name	Risk Event	Strategy	Owner	Outcome	Log Date

As with the earlier example, retention of this information with the project plan significantly increases the probability that others will reuse this information as the project plan is appropriated for use on other, similar efforts. Risk strategies and their outcomes are critical elements of an organization's intellectual property. Failure to properly store them in an accessible fashion is to diminish the value of the project and the project team in their contributions to technical capital.

Summary

- Risk planning is the development of organizational and project-specific infrastructure to support the risk planning and management processes.
- Risk identification is the process of identifying project risks.
- Risk qualification is the process of sorting risks by general probability and impact terms to facilitate analysis of the most critical risks.
- Risk quantification is the process of quantifying risks against a well-defined rating scheme and honing that quantification to assess overall project impact.
- Risk response planning involves evaluating and refining risk mitigation strategies.
- Risk monitoring and control is the implementation of those strategies and the evaluation and recording thereof.
- Risk management is a continual process throughout any project.

Risk Management Techniques



PART TWO

Part II

Risk Management Techniques

The second major part of this book introduces specific techniques that have proven useful to both customers and project managers in carrying out the risk management process.

Each chapter describes techniques for accomplishing the basic steps of the risk management process: risk planning, risk identification, risk qualification, risk quantification, risk response development, and risk monitoring and control. Many of these techniques can serve more than one step of the process. For example, an in-depth evaluation of a critical path network is useful in initial overview evaluations, risk identification, and risk response development. The resource requirements, applications, and output capabilities of each technique are summarized in Table 6. Multiple technique applications are distinguished in Table 7 between predominant use and secondary use.

Moreover, each technique needs to be evaluated in context using consistent criteria to ascertain whether it is the most effective technique to apply. Those criteria include—

- Technique description
- When applicable
- Inputs and outputs
- Major steps in applying the technique
- Use of results
- Resource requirements
- Reliability
- Selection criteria

Technique	Resource Requirements					Applications							Outputs		
	Cost (resource-months)*	Proper facilities and equipment	Implementation time (months)*	Ease of use	Time commitment	Project status reporting	Major planning decisions	Contract strategy selection	Milestone preparation	Design guidance	Source selection	Budget submittal	Accuracy	Level of detail	Utility
Expert interviews	0.1-3	Y	0.1-3	E	S	H	H	M	H	M	H	L	L-H	M	H
Planning meetings	0.1-1	Y	0.1	E	S	H	H	L	L	H	L	M	M	H	H
Risk practice methodology	0.1-3	N	0.1-3	M	M	H	M	L	L	NA	NA	M	H	H	H
Documentation reviews	0.1	Y	0.1	H	S-M	H	H	L	L	H	M	H	L-H	L-H	H
Analogy comparisons	0.2-2	Y	0.2-2	M	S	L	H	H	L-M	M	H	L-M	L-M	L-H	M
Plan evaluation	1-1.5	Y	0.2-1.5	M	H	H	H	NA	L	M	L	L	H	H	M-H
Delphi technique	0.2-0.5	Y	1-2	H	S	M	H	H	L	H	L-M	NA	H	H	H
Brainstorming	0.1	Y	0.1	H	S	L	L	NA	NA	H	NA	NA	L	L-H	H
Crawford Slip Method	0.1	Y	0.1	H	S	L	L	NA	NA	M	NA	NA	L	H	H
SWOT analysis	0.1	Y	0.1	H	S	NA	M	NA	NA	L	NA	NA	L	L	H
Checklists	0.1	Y	0.1	H	S	M-H	L	L	L	NA	M	NA	H	M	H
Project templates	0.5	Y	0.5	E	M	H	H	H	H	H	M-H	L	M	L-H	H
Assumptions analysis	0.1	Y	0.1	H	M	M	H	H	M-H	H	M	H	M-H	L-H	H
Decision analysis/Expected monetary value	0.5-1	Y	0.2-0.6	M	S-M	M	H	H	M	M	M	M	L-H	L-H	M
Estimating relationships	0.1-3	Y	0.1-3	E	M	L	L	L	NA	NA	NA	H	L	L	L
Network analysis	0.1-3	Y	0.1-3	H	S-M	H	H	M	H	M	H	L	H	L-H	H
Program Evaluation and Review Technique (PERT)	0.1-3	Y	0.1-3	H	S-M	H	H	L	H	L	NA	NA	H	L	H
Other diagramming techniques	0.1-3	N	0.1-3	E-H	M	NA	M	NA	L	H	L	L	M	H	H
Rating schemes	0.1-1	Y	0.1-0.2	H	S	L	M	L	NA	NA	L	L-H	M	H	H
Risk modeling	0.1	Y	0.1	H	S	M	H	M	NA	L	NA	M	H	L	L-H
Monte Carlo simulations	0.2-0.4	N	0.2-0.5	E	M	L	H	NA	NA	M	L	L	L	L	L
Risk factors	0.1-0.4	Y	0.1-0.5	E	S	M	M	NA	NA	L	L	M	L-M	L	H
Risk response matrix	0.1-0.2	Y	0.1	H	S-M	NA	M	M	NA	M-H	M-H	L	H	H	H
Performance tracking	1.5	Y	1.5	M	M	H	H	M	M	H	M	M	M	M	H
Risk reviews and audits	0.1	Y	0.1	H	S	H	H	L	NA	M	L	H	H	M-H	H
	N = No (Not normally available) Y = Yes (Normally available) E = Easy H = Heavy M = Moderate S = Slight					H = High M = Medium L = Low NA = Not applicable							H = High M = Medium L = Low		

'Note that the thresholds of cost and implementation time are 0.1 and 3 resource months: how much effort it will take to implement the technique. Any activity that spans that range may be seen as something that expands (or shrinks) based on project size.

Table 6. *Risk* Analysis Technique Selection Matrix

The chapters in Part II discuss and rate each risk technique in the context of these criteria. This analysis will not make selecting a technique an automatic decision, but it will provide project managers with an informed perspective to evaluate and choose approaches suited to the objectives of the risk management effort within a project's ever-present resource constraints.

The selection criteria for each technique receive extensive attention. Within the selection criteria, the three primary areas of analysis are resource requirements, applications, and outputs. The resource requirements include five subset areas of information for analysis:

- Cost refers to the cost of implementation in terms of resource-months.

Technique	Predominant/Secondary Use					
	Risk Management Planning	Risk Identification	Risk Qualification	Risk Quantification	Risk Response Planning	Risk Monitoring and Control
Expert interviews	○	●	○	○	○	
Planning meetings	●	○	○		○	
Risk practice methodology	●		○	○		
Documentation reviews	○	●				○
Analogy comparisons		●	○	○	○	
Plan evaluation		●				○
Delphi Technique	○	●	○	○	○	
Brainstorming		●			○	
Crawford Slip Method (CSM)		●			○	
SWOT analysis	○	●			○	
Checklists	○					●
Project templates	●		○			○
Assumptions analysis		●	○	○		
Decision analysis–Expected monetary value				●		
Estimating relationships	○			●		
Network analysis		○		●	○	
Program Evaluation and Review Technique (PERT)		○		●		
Other diagramming techniques				●		
Rating schemes	○		●	○		
Risk modeling	●		○			
Monte Carlo simulations				●		
Risk factors	○		●			
Risk response matrix	○				●	
Performance tracking	○					●
Risk reviews and audits	○					●

Legend:
● = **Predominant use**
○ = **Secondary use**

Table 7. Technique Applications

- *Proper facilities and equipment* is an equally crucial issue to technique implementation, raising the question as to whether most organizations have easy access to the facilities and equipment necessary to carry out the implementation. In most cases, the answer will be an attribute: either a project has these facilities (Y) or it does not (N).
- *Implementation* time is, in part, a function of the information developed under the cost criterion. If fewer resources are available, the project may drag on much longer than anticipated. If more resources are available, the time required may be trimmed.
- *Ease of use* refers to the level of training and education required before the technique can be implemented. It may also refer to the level of effort that may be involved in simply implementing the technique. Ease of use is designated at easy (E), heavy (H), moderate (M), or slight (S).
- *Time commitment* relates to the amount of oversight and involvement required of the project manager. If a project manager must make a long-term commitment, this level may be considered heavy (H). If the project does not require an extensive commitment, the project manager's involvement may be slight (S) or moderate (M).

In the requirements for applications, each area is evaluated on the level of support the technique can provide: high (H), medium (M), or low (L). There are seven subsets of information:

- *Project status reporting* refers to monitoring plans, costs, and schedules to ensure that standards are met and problems are identified for timely corrective action.
- *Major planning decisions* are those decisions in which a project manager may be willing to invest significant resources and personal attention.
- *Contract strategy selection* typically occurs several times through the life of a project. Different techniques can bring extensive influence to bear on the types of contracts selected for any given project.
- *Milestone preparation* is the development of significant and appropriate milestones within any project. Some techniques can facilitate this process whereas others cannot.
- *Design guidance* refers to the level of insight that the technique under consideration can potentially provide for any given project.
- *Source selection* is the effort to determine which sources may be potential vendors for the project. The level of guidance a technique can provide in this area may range from nonexistent to significant.

- *Budget submittal* is the final area of concern under application. Many tools have the ability to generate copious financial data; other techniques are not financially oriented. A technique's ability to contribute to an accurate assessment of the project budget is evaluated here.

Outputs, in terms of information, is the last area reviewed in each technique's selection. As with the applications issues, ratings of outputs are high (H), medium (M), or low (L). Three primary issues require consideration:

- *Accuracy* deals with the basic theoretical soundness of a technique and the presence of weakening assumptions that may dilute the value of information obtained in the analysis. Most techniques present an obvious trade-off between ease-of-use or time commitment and the accuracy of analysis results.
- *Level of detail* concerns the extent to which outputs provide insight into cost, schedule, and technical risks. Techniques and how they are applied vary in the breadth, depth, and understanding that the outputs yield.
- *Utility* is a subjective factor that rates outputs in a general context of its usefulness to the project manager. Both the effort involved and the value of information are considered.

It is important to note that some techniques have more applicability to specific project phases than others. Likewise, the techniques do not all yield the same information. Each technique's applicability for each project phase and the type of information likely to result are indicated in Table 8. Because this table is a general summary, specific applications in some instances will continue to be exceptions to the guidance represented in it. Both project phase and the type of information desired must be considered in technique selection. For example, although networks do not help analyze risks for repetitive processes, they do have great value in planning and control to establish such processes.

Each chapter of Part II opens with a thorough discussion of a specific technique. The remainder of the chapter evaluates the technique by summarizing key characteristics to consider when deciding whether that technique is appropriate for your organization when dealing with the risk process involved.

Technique	Project Phase				Information Yield				
	Concept	Development	Implementation	Closeout	Technical	Programmatic	Supportability	Cost	Schedule
Expert interviews	+	+	+	+	+	❍	+	❍	❍
Planning meetings	−	❍	+	+	+	❍	+	−	−
Risk practice methodology	+	+	+	+	❍	+	+	❍	❍
Documentation reviews	+	+	+	+	❍	+	+	❍	❍
Analogy comparisons	❍	+	+	+	+	❍	❍	+	❍
Plan evaluation	−	❍	+	+	+	❍	+	−	−
Delphi technique	+	+	❍	−	+	❍	❍	❍	❍
Brainstorming	+	+	❍	❍	❍	❍	❍	❍	❍
Crawford Slip Method (CSM)	+	+	❍	❍	❍	❍	❍	❍	❍
SWOT analysis	+	❍	❍	❍	❍	+	+	❍	❍
Checklists	❍	+	+	+	+	❍	+	−	−
Project templates	❍	+	+	+	+	❍	+	−	−
Assumptions analysis	+	+	❍	❍	+	+	+	❍	❍
Decision analysis–Expected monetary value	−	+	❍	❍	+	❍	❍	+	❍
Estimating relationships	−	−	−	+	−	−	−	+	−
Network analysis	−	+	+	❍	+	❍	+	+	+
Program Evaluation and Review Technique (PERT)	−	+	+	❍	+	❍	+	+	+
Other diagramming techniques	❍	+	+	❍	+	❍	+	+	+
Rating schemes	+	+	+	+	+	❍	+	−	−
Risk modeling	+	+	+	+	+	❍	+	−	−
Monte Carlo simulations	−	+	+	−	−	❍	❍	+	+
Risk factors	−	❍	+	+	−	−	−	+	−
Risk response matrix	−	+	+	❍	❍	❍	❍	❍	❍
Performance tracking	−	+	+	+	+	❍	+	+	+
Risk reviews and audits	−	−	+	+	+	+	+	+	+

Legend:
− = **Relatively weak**
❍ = **Average**
\+ = **Relatively strong**

Tabk 8. Project Phase Technique Application

Chapter 4
Expert Interviews

Obtaining accurate judgments from technical experts is one of the most critical elements in both risk identification and risk qualification because—

- The information identifies areas that are perceived as risky.
- The interviews provide the basis for taking qualitative information and transforming it into quantitative risk estimates.

Reliance on technical expertise here is mandatory. Because every project is unique, all information necessary for an accurate risk assessment cannot usually be derived from previous project data. However, obtaining the information from experts can be frustrating and can often lead to less than optimal results.

Nearly all risk analysis techniques require some expert judgment. However, it can sometimes be difficult to distinguish between good and bad judgment, and this aspect makes the approach and documentation even more important than usual. The project manager or risk analyst performing the task is likely to receive divergent opinions from many "experts," and as a result, the project manager must be able to defend the ultimate position he or she takes.

Technique Description

The expert interview technique is relatively simple. Basically, it consists of identifying appropriate experts and then methodically questioning them about risks in their areas of expertise as related to the project. (Some methods for extrapolating this information are outlined in Appendix D.) The technique can be used with individuals or groups of experts. The process normally obtains information on risk associated with all three facets of the triple constraint: schedule, cost, and performance.

When Applicable

This technique is recommended for all projects. Expert interviews focus on extracting information about what risks exist and how severe they may be. Interviews are most useful in risk identification but may apply in other processes as well. When questioning experts about risks on a project, it is logical to pursue potential risk responses and alternatives, as well as information pertaining to probability and potential impact.

Inputs and Outputs

Expert interviewing has two prerequisites. First, the interviewer must prepare by researching the topic and thinking through the interview agenda. Second, the interviewee must be willing to spend the time necessary to disclose the information to the analyst or manager. Results of such interviews can be qualitative, quantitative, or both. Expert interviews nearly always result in inputs that can be used to develop a risk watch list. They may also result in formulating a range of uncertainty or a probability density function (PDF) for use in any of several risk analysis tools. The range or function can be expressed in terms of cost, schedule, or performance.

Major Steps in Applying the Technique

Because expert interviews result in a collection of subjective judgments, the only real error would be in the methodology used for gathering the data. If the techniques used are inadequate, then the entire risk identification and quantification process will be less reliable. Unfortunately, no technique exists for ensuring that the best possible data are collected. However, several methodologies are available, but many must be eliminated because of time constraints. One combination of methodologies that seems to work well consists of the following five steps:

- *Identify the right individual(s).* Identifying the correct subject matter expert is crucial. It is relatively easy to make a mistake and choose an expert who knows only a portion of the subject matter. If any doubt exists about an expert's level of expertise, it is worthwhile to find one or two other candidates. The time used to identify individuals to interview will be well spent. A preliminary telephone screening usually lasting only a few minutes can give the analyst a sense of the interviewee's level of expertise and can help provide focus as questions are developed for the interview. When establishing the "right" individual(s), do *not* overlook the customer and its staff as potential interviewees. Frequently, customers will have the best available risk perspectives on a project because of their levels of organizational awareness.

- *Prepare for the interview.* Participants save time if they all prepare adequately. Both interviewer and interviewee must consider what areas to cover during the interview. The interviewer must know and practice the methodology that will be used to quantify the expert judgment and should develop an agenda or topics list to ensure that the discussion has clear direction. In addition, the interviewer should understand how the expert functions in the organization and how long he or she has been in the field. The interviewer must also keep the ultimate goals of risk identification, qualification, and quantification in mind during preparation. This requires some time during the interview to allow the expert to offer personal thoughts on areas that may be outside his or her field.

- *Target the interest area.* The first portion of the actual interview should focus on verifying previously identified risk areas. This time should be kept brief unless there appears to be disagreement that would require additional information. Next, the interview should concentrate on the individual's area of expertise, which will confirm that the correct individual is being interviewed. More interview time can then be spent gathering information. If the interviewer discovers that the "wrong" expert is being interviewed, the interview can be changed or ended, thus saving valuable time.

- *Solicit judgments and general information.* It is important to allow time for the expert to discuss other areas of the project after completing the target interest areas. If for nothing else, the information gained can be used when interviewing other experts to stimulate thoughts and generate alternative opinions. Someone familiar with one area may identify risks in another area because in some cases those working in an area fraught with risks may be oblivious to those risks. This information generally becomes more refined as more subject matter experts are interviewed. Experience shows that if the expert is cooperative, the information given is generally accurate. Although additional clarification may be required or the expert may be unwilling to attempt quantification, identification of the risk remains valid nevertheless.

- *Qualify and quantify the information.* This may be the most sensitive aspect of any risk analysis. After risk areas have been identified, an estimate of their potential impact on the project cost, schedule, and performance must be made. This requires that the expert consider the probability of a given risk event's occurrence and its potential impact. If the expert cannot provide a numeric value for the information, suggest ranges of probability as well as ranges of impact consistent with the organization's values for qualification. For many risks, precise application of a numeric value may be impossible. In such instances, however, it may be reasonable to establish qualitative ranges.

Use of Results

The uses of expert interview results are as varied as the experts who provide the information. Some expert interviews will be used to establish the basic framework of the risk plan, including probability and impact ranges and internal terms and terminology. Other expert interviews may serve basic project risk identification. And still others will lead to qualitative and quantitative assessments of the risks under evaluation. However, only rarely will *any* discussion on risk be conducted without some recommendations being offered on how the risks themselves might be managed and which response strategies might be appropriate.

Resource Requirements

Conducting an expert interview is a relatively easy task. Virtually anyone can ask a series of questions and note responses. To generate *high-quality* data, however, each participant in the interview must possess some fundamental qualities. The interviewer must have the ability to assimilate information without bias and to report that information accurately and effectively in the context of the greater risk analysis. In addition, the interviewer should have the ability to follow up on shared insights that may expand or limit the range of issues to be discussed. The interviewee, in turn, must have the subject matter expertise directly related to the risk issues under consideration. If either party lacks these fundamental skills, the expert interview cannot be wholly effective.

Reliability

When conducted properly, expert interviews provide very reliable qualitative information. Transforming qualitative information into quantitative distributions or other measures depends on the skill of the interviewer. Moreover, the technique is not without problems. Those problems include:

- Wrong expert identified
- Poor quality information obtained
- Expert's unwillingness to share information
- Changing opinions
- Conflicting judgments

Selection Criteria

As with each chapter on techniques, the expert interview technique is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare expert interviews with other techniques, review Table 6.

Resource Requirements

What resources a technique requires is often the dominant consideration in the selection process. Interviewing experts requires three specific resources. The first is time. Although interviewing is one of the most common techniques for risk identification, qualification, and quantification, it is frequently misapplied because of time limitations. Planned interviews are sometimes shortened or skipped altogether. Methodically examining an entire project requires the time of several experts from both the project organization and the customer organization.

The second key resource requirement is the interviewer. Frequently, experts provide information that is not readily usable for a watch list or quantitative analysis. To encourage the expert to divulge information in the right format and at the right level of depth, some modest interviewing skill is required. If an interviewer lacks this skill, the techniques can still yield *some* valuable information if enough time is taken.

The third key resource is the interviewee or expert. It is vital to remember that the expertise required of this individual is project-specific. He or she need not have a keen awareness of risk management practice or of interviewing strategy and techniques. The only requisite traits that this individual should possess are a willingness to share information and the ability to translate his or her technical expertise into a language that other parties in the organization can interpret and understand. Whereas some experts will have information specific to an extremely limited subject matter area, others will have the ability to provide information that spans the breadth of the project. Both have value, depending on the information needs of the organization and the project.

- *Cost* for expert interviews may range from minimal (1 to 2 days) to extended (2 to 3 months), depending on the needs of the project. The more skilled the interviewer is, the less time required to accomplish the same level of depth in expert interviewing. Thus, it often behooves the project manager to pay a little more for a qualified interviewer for a shorter period of time.

- *Proper facilities and equipment* for expert interviews are generally minimal unless the interviews must be formally maintained. For a normal expert interview, the equipment will require no more than a few chairs, a notepad, pencil or pen, and a tape recorder. However, in an extreme case, an expert interview may feature a bank of television cameras and a recording studio. If a panel of experts is brought together for the interviews, a stenographer or court recorder may be used to generate a verbatim transcript of the information shared. But for the most part, expert interviews tend to be relatively easy to manage in terms of equipment and facilities.

- The *implementation time* for an expert interview is a crucial consideration. However, if resources and facilities are available, the time should not be extensive. In this case, because there are normally only one or two expert interviewers, the time to implement is reflected in the time required under "Cost."
- *Ease of use* is one of the most attractive features of expert interviews because virtually anyone with minimal training can conduct a passable interview. The key, however, is in developing interviewers who are truly skilled enough to draw out deeper and more meaningful responses from the interviewees. The most effective interviewers are those who can put together a relatively open-ended question and get back a clear and specific response. One way to achieve this is by listening carefully to the interviewee's answers and providing feedback to clarify any outstanding issues.
- The project manager's *time commitment* is sometimes based on the skill levels of the project manager as an expert interviewer. The time required of the project manager, assessed on a gradient of slight to moderate to heavy, is slight as long as he or she is not personally required to conduct the interviews or train the interviewers.

Applications

As stated earlier, the expert interview has the advantage of being applicable in a wide variety of situations. The applicability of the interviews is assessed on a scale of high, medium, and low.

- *Project status reporting* refers to monitoring plans, costs, and schedules. Although the monitoring process is not a primary application of the expert interview, gathering the information essential to status reports is often a function of the interviews. From that perspective, project status reports would be difficult (if not impossible) to develop without some interviewing skills.
- *Major planning decisions* often hinge on the opinions of a few key individuals associated with the project. As such, the expert interview may expedite the process and ensure full participation with the individuals involved.

- *Contract strategy selection* does not rely as heavily on expert interviews as it does on other techniques, but the interviews can play a valuable role in building the support data to feed those other techniques.
- Applying expert interviews in *milestone preparation* is direct and important. Because the objectives are to ensure that planning has been comprehensive and the system is ready to move forward into its next phase, in-depth consultation with both internal and external customers is vital.
- *Design guidance* is frequently a function of expert interviewing. The interviews are useful for making decisions ranging from considering technology alternatives for major systems to choosing components. To understand how uncertainties relate to one another and how the alternatives compare, expert interviews are often used in the data gathering stage.
- *Source selection* is a prime application for expert interviews. In many cases, interviews determine which candidates to eliminate for a sub-contract or consulting position. In addition, if the expert interview is conducted properly during source selection, it can open new avenues for later negotiation with the source.
- *Budget submittal* is a crucial step in project management, but it is not well supported by expert interviews because budgets work almost exclusively from purely quantifiable data.

Expert interviews also serve other applications. They can be used to establish the organization's risk tolerances and thresholds, as well as the general culture for risk responses. The interviews can be used to explore specific risk events or general risk strategies. As a tool, interviews have perhaps the greatest breadth of any of the basic risk management tools.

Outputs

Outputs of the expert interview are most often a collection of notes or an individual's evaluation and documentation of those notes, which have been organized in a comprehensible fashion. Outputs can include both qualitative data and individual perspectives on quantitative data.

- *Accuracy* deals with the basic theoretical soundness of expert interviewing. Because many consider expert interviewing to be extremely easy with a limited time commitment, its accuracy is often called into question. The bottom line remains that its accuracy is only as good as the blend of interviewer *and* interviewee. If they are both well versed in their respective skill areas, the interview can have high accuracy. If, on the other hand, they have limited skill levels, the interview may have low accuracy. In general, the expert interview must be considered less than purely quantitative because of the inevitable existence of individual bias.

- *Level of detail* is not the greatest strength of the expert interview, but interviews may provide incredible depth that is not achievable through other techniques. Interviews may also be so superfluous that the information is useless. Once again, the talents of the human resources drive the ultimate level of detail.
- *Utility* is a subjective factor that takes into account both the effort involved and the value of the information. For most expert interviews, the documentation developed after completing the interviews becomes a crucial element in the project's records.

Summary

In determining the effectiveness of expert interviews, it is vital to evaluate the skills of both the interviewer and the interviewee. That information provides the best sense of how well (and how accurately) the insights required will be developed. Although team members with limited skills sets can reasonably handle expert interviews, those who understand the critical nature of the expert interview and the numerous applications for the technique will achieve the best results in the end.

Chapter 5
Planning Meetings

Technique Description

Planning meetings are conducted to ensure the organization has a consistent vision in terms of the project's risk methodology, roles and responsibilities, timing, thresholds, reporting formats, and approaches to tracking. Planning meetings focus on bringing together key stakeholders on risk to determine the risk practices to be pursued and the approach to be used in pursuing them.

When Applicable

This technique is recommended for all projects. Planning meetings ensure a general team acceptance of risk management as a practice. The technique is most effective in the initial risk planning stages but will apply in other processes as well. When conducting risk reviews and evaluations, the basic risk plan may be reconsidered.

Inputs and Outputs

Planning meetings have a number of inputs. Foremost among them, existing risk data should be researched and made available during planning meetings. In some organizations, such data will be scant; in others, they will be voluminous. Participants should come to the meeting with clear expectations that they will share their own perspectives on risk thresholds and organizational policy. Any risk templates or policies that exist organizationally must also be brought to the table for this process. When complete, the session(s) should close with a clear risk methodology for the project in question, as well as roles and responsibilities, timing, thresholds, reporting formats, and approaches to tracking. The information should be well documented and available to all key project stakeholders.

Major Steps in Applying the Technique

Because planning meetings result in a project-specific version of what should be organizational practice, the key concerns rest with the interpretation of the existing information. If, however, the existing information is misinterpreted, the possibility exists that the risk management plan will not accurately reflect the organization's risk tolerances and thresholds. It is also possible for the project team to err excessively on the side of caution *or* instability. Some basic practices to ensure consistency are embedded in the following processes:

- *Review the project charter.* The project team needs to ensure that there is unanimity of vision on the project objectives, as well as on the overall approach. In addition, the team must ensure that there is clarity on the duration and scope of the project manager's authority. The level of authority in part defines the capacity of the project team to manage risk effectively, whereas the project manager's ability to manage resources dictates the number and quality of the personnel responsible for risk management.

- *Assess the existing organizational risk handling policies.* Participants will save time if they take advantage of the information that already exists on managing risk. Tools, techniques, and templates all work together to streamline the process. Predefined application of those tools expedites the decision-making process if team members are in a quandary as to how to ensure thorough identification, qualification, quantification, and response development. Limits on reserves, insurance, warranties, and other fundamental strategy issues may also be identified here. The project manager should make certain that all germane policy issues are clearly documented and noted in preparation for and during the meeting.

- *Identify resource support.* In most organizations, some risk responsibilities have owners before the project ever gets under way. For example, legal departments take responsibility for all contractual issues. Human resource departments assume responsibility for health, welfare, and compensation risks. Senior management assumes risks that fall into the area of management reserves, the unknown unknowns of the project universe. In different organizations, different players have predetermined roles and responsibilities for risk. Those players should be noted for future reference so that their expertise may be tapped and they can be aware of their role in working with the specific risks relative to the project in question.

- Establish *risk tolerances.* Perhaps the single most daunting task of the planning meeting is that participants from a variety of organizations that support the project should clearly identify what their risk tolerances are in terms of cost, schedule, performance, and other mission-critical areas. In many cases, individuals will find it difficult to deal with this abstraction as they wrestle with the notion of "how much is too much." In order to overcome this difficulty, the project manager may wish to identify a sample set of scenarios to test their tolerance on various risk issues. A manager who cannot simply say "I won't accept a cost overrun of greater than 20 percent" may be able to share the same information when it is posed as a scenario (such as, "If a team member came to you and reported a 10 percent overrun, would you shut down the project? A 20 percent overrun? A 30 percent overrun?"). Such scenarios are not limited to cost or schedule alone. It is important to know what the thresholds are for performance issues and for other issues of importance (politics, customer satisfaction, employee attrition, for example). Risk tolerances should be identified for all key stakeholders as wide variations in perceptions of risk can potentially skew data analysis later in the risk qualification process.

- Review the WBS. As with most project management processes, the work breakdown structure is a key input to risk management. The WBS also clarifies the needs of the project at both a summary and a detailed level. The WBS generates insight on where and how the process will flow effectively and where there may be a temptation to circumvent best practice. Since any work associated with the project risk management plan will ultimately be incorporated into the WBS, a clear understanding of its content to date is appropriate here.
- Apply organizational risk templates. Not every organization has risk management templates. Some risk templates provide general guidance, whereas others explain each step of the process in excruciating detail. The general rule for risk templates is that if they exist, use them because they normally reflect best practice in the organization as well as lessons learned.

Outputs from these meetings should include a clear approach as to how risk management will be conducted. At both micro and macro levels, stakeholders should have a clear understanding of how the remaining steps in the process will be carried out and by whom. According to the *PMBOK® Guide*–2000 Edition, the following elements become components of the risk management plan:

- The methodology for project risk management will include a basic outline of both process and tools for the remainder of the risk management effort. This may be a rudimentary explanation that risk management will consist of a risk identification meeting, some quick qualification, and a response development discussion. It may also be a complex series of steps including plans for prequalification of risk data, reviews using Monte Carlo analysis, and integrated analyses of risk strategies. In any case, the methodology should clarify the *timing* of when various steps in the process are going to be applied and the individuals who will have *responsibility.*

- The risk management plan should have indicators as to how the risk *budget* will be established for both contingency reserve (reserves for overruns within the project) and management reserve (reserves for issues outside the project purview). While the final monetary figure may not yet be assigned to the risk, the approach to risk budgeting should be documented.
- The planning meeting should clarify what risk documentation approaches will be applied, including documentation *formats.* Any risk *tracking* requirements should also be clarified during the session.
- Although organizational risk *thresholds* are critical inputs to planning meetings, one of the outputs of the meetings should clearly be risk tolerances at the project level. Project-specific risk thresholds give team members an indication of when differing levels of intervention are required.
- Either in line with the thresholds or as a separate issue, the planning meeting(s) may generate specific metrics for *scoring and interpretation.* Common values for such concepts as "high probability" or "moderate impact" ensure that risk qualification will run more smoothly. Similarly, the application of risk models, discussed in Chapter 23, may be described here.

Use of Results

After planning meetings are over, the information should be distilled and documented for easy retrieval by anyone responsible for project planning. Some information will be used immediately (as with the application of risk model assessments), whereas other information will be used throughout the risk management process (such as risk thresholds).

Resource Requirements

Planning meetings require a panel of participants. That alone makes it a challenge. In many organizations, merely bringing together the key stakeholders early in a project can be the single greatest impediment to a well-run planning session. In addition, the planning session will require a facilitator with the capability to educe information on individual and organizational risk thresholds. That often requires the exploration of issues, scenario development, and analysis and interpretation of information. The facilitator should have the ability to build on the information and insights the participants provide. In a perfect situation, the planning meeting will have a secretary or recorder responsible for capturing the risk plan information as it evolves. The recorder should be able to thoroughly document all planning meeting discussions.

Reliability

The reliability of the process hinges largely on the ability of the facilitator to elicit information from a group of participants. Drawing out scoring metrics and interpretation, for example, requires patience and a clear understanding of the information and insight being extracted. The reliability of the information and the risk plan that the planning meeting generates also depends on the depth of information and infrastructure already in place in the organization.

Selection Criteria

As with each chapter on techniques, planning meetings are assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare planning meetings with other techniques, review Table 6.

Resource Requirements

Although the risk planning meeting generally requires less than a half-day session, the assembled time is a critical resource, particularly given the number of participants involved. The time spent together is important to clarify and resolve issues, as is *full* participation. Often, the challenge is ensuring that all participants are available and will be present at the same time.

The other key resource for a well-run session will be the facilitator. While the project manager may sometimes assume this role, it is not uncommon to bring in an external facilitator familiar with the process and with the organization. His or her chief skill will be to ensure involvement by all participants and to facilitate group understanding of the process.

- *Cost* for the risk-planning meeting will consist of the hourly wages for the participants and any fees associated with the facilitator.

- *Proper facilities and equipment* for a planning meeting will ideally include an off-site meeting area (to minimize disruption) and the tools for recording the minutes of the meeting. Flip charts (or erasable boards) and a high-resolution digital camera will allow for inexpensive information capture from any group discussions.

- The *time needed to implement* a planning meeting is normally a half day of coordination to ensure all participants are aware of (and available for) the session, and a half day for implementation and postmeeting documentation capture.
- *Ease of use* is high, as there are very few individuals who have not participated in meetings, which generate a relatively low-threat environment. As the goal of the planning meeting is not to critique but rather to gather and structure data, a skilled facilitator's presence makes the meetings relatively easy to run.
- The project manager's *time commitment* is based in part on his or her role. If the project manager also serves as the facilitator and recorder, the level of commitment is more significant. If a consultant or internal facilitator is running the session, the project manager's time commitment is slight.

Applications

The planning meeting, as a component of building a sound project risk infrastructure, is primarily launched early in the project, ideally during the concept or ideation process.

- *Project status reporting* refers to monitoring plans, costs, and schedules. This meeting will largely determine the structure of such status reports, particularly as they relate to risk. The levels of reporting and reporting requirements should be established during the planning meeting. The applicability here is high.
- *Major planning decisions* are frequently based on the relative levels of risk involved in the project. They may also be rooted in the risk reviews, which are scheduled and structured during this process. The impact of planning meetings on planning decisions should be high.
- *Contract strategy selection* does not rely heavily on planning meetings since procurement discussions in such meeting are normally extremely limited.
- The planning meeting may establish review schedules for milestones, but otherwise, planning meetings do not have a significant role in *milestone preparation.*
- *Design guidance* is an issue that can be and frequently is addressed in planning meetings because it often represents opportunities to bring together key players in an environment where they may freely exchange ideas.

- *Source selection* is not a prime application for planning meetings as procurement representatives are rarely in attendance at such sessions. Although meetings are appropriate for source selection, planning meetings are not normally focused on the procurement process and thus have limited utility for source selection.
- Planning meetings partially support *budget submittal,* but they are by no means the exclusive venue for preparing for such submittals. Planning meetings clarify the infrastructure essential to the project (and thus the base investment for the project as well). But planning meetings can rarely accomplish the in-depth research necessary to generate the quantifiable data associated with budgets.

Planning meetings also serve other applications. They can be used to establish the organization's risk tolerances and thresholds, as well as the general culture for risk responses. The meetings can be used to explore specific risk events or general risk strategies. They present a wonderful opportunity to build the team and make team members risk-aware.

Outputs

Outputs of the planning meeting are most often a set of minutes (or, in the extreme, a transcript of the meeting). Outputs can include qualitative data as well as group and individual perspectives on quantitative data.

- *Accuracy* addresses the viability and soundness of planning meeting data. Accuracy in the planning meeting environment is generally a function of the levels of information and insight available to the team members in attendance. Although meetings are easy to hold, there are limits to their accuracy if the wrong attendees have been enlisted to participate:. Accuracy can best be ensured with a diverse participant set, all equally committed to a thorough analysis of project risk. Divergent viewpoints limit the planning meeting propensity for groupthink and encourage full discussion on such issues as risk probability and impact. The skill of the facilitator will directly influence accuracy inasmuch as he or she will largely be responsible for directing discussions toward issues that are germane to the risk analysis. Even though planning meetings are a common and appropriate technique, outputs are not purely quantifiable.
- *Level of detail* is a strength of the planning meeting if adequate time is allowed to explore project risks, their probabilities, and impacts. As multiple perspectives are brought to bear, there are greater opportunities to investigate in depth the risks and their potential impacts. As with accuracy, the skill of the facilitator will be a determining factor as to whether a desirable level of detail is achieved. More than the

planning meeting duration, facilitator skill determines the degree to which this technique will extract and distill the appropriate information.

- Utility takes into account both the effort involved and the value of the information. Planning meetings have high utility since the team members who participated in the process will likely be the same individuals responsible for using the information. Because they generate the information, they are both more aware of it and more likely to be able to apply the outputs.

Summary

The facilitator is one key to an effective planning meeting. However, a good facilitator will work specifically to identify risk issues in the organization and the potential impact of those issues with the team. A skilled facilitator will studiously avoid the desire of some team members to wallow in organizational issues, turning a healthy risk analysis into a "whine-fest." Instead, a skilled facilitator will focus directly on the issues, symptoms, and triggers that the team members identify and will explore in depth all facets of the project's risks. Those individuals without a visible stake will also achieve the best outcome.

Chapter 6
Risk Practice Methodology

Organizational risk practices are frequently perceived as ad hoc phenomena, created on a project-by-project or on a project manager-by-project manager basis. Nothing could be further from the truth. Organizational risk practices are those that are consistent and work to ensure that—

- Risk management is applied.
- Risk management is applied to consistent levels of depth.
- Risk management is applied taking advantage of organizational best practice.

Although each project's risks are different (due to the unique nature of projects), a risk management methodology ensures a measure of consistency. Application depends on the project itself, but a sound methodology will encourage some deployment consistency. That consistency should also promote long-term knowledge transfer across projects.

Methodologies are practices that are rendered consistent within and across an organization in an effort to allow for greater continuity from project manager to project manager, project to project, and team to team. Misapplication of methodologies can sometimes lead to organizational infighting and blame, where the processes the methodology prescribes are viewed as responsible for failure to identify or mitigate particular risks.

The organization, the project office, or a pioneering few project managers with a passion for analyzing risk often establish methodologies. They can be developed from an organization's grass roots or they can evolve from edicts from senior management. In either case, they hinge on buy-in at some level of the organization, and they must build on that buy-in to integrate other divisions, factions, and suborganizations within the organization.

Technique Description

A risk methodology is made up of a series of pro forma steps that are to be followed based on the needs and the structures of the project(s) in question. Methodologies are as distinctive as the organizations that support them, but they have some basic components in common. Most methodologies will outline clear process steps, forms, and practices. Most will dictate (on a scaled basis) the frequency with which these components are applied. They may be stored and shared either in hard copy or electronically, but they do afford the organization a common repository both for the forms as well as for their completed counterparts.

As a skeletal example, such a methodology may include guidance and direction similar to the framework in Table 9. This methodology is not designed as a template but as a representative of what a sound risk methodology might include.

Table 9 does not show the level of detail that would be found in a risk methodology for a real project but provides a sense of what types of information that might be incorporated.

When Applicable

This technique is recommended for all projects (but, of course, only in organizations where methodologies are either in development or in place). Because the methodology represents the accumulated practices of the entire project organization, it is generally circumvented only in the most extreme circumstances. It is applicable on an as-described basis (such as whenever the methodology itself says it is appropriate, it is appropriate).

Inputs and Outputs

Application of a risk management methodology has one key prerequisite: a guide, a handbook, or an instruction on how the methodology will be applied. Without such guidance, any organizational development efforts for a risk methodology are rendered moot. The guidance may point to any number of other tools and techniques, such as expert interviewing, brainstorming, simulation analyses, or others discussed in this text. The key rationale for having a methodology is to ensure a measure of consistency in their application. Outputs from the process will include documentation for each step of the processes that the methodology identifies. Outputs will be methodology-specific.

Major Steps in Applying the Technique

Because each methodology is different, the steps used will vary as well. However, some modest commonalities can be applied:

Step	Process Guidance	Timing	Special Considerations
Risk review	This step involves a thorough search of the sample database for past project experience with the same customer, product, or service. Outputs should be documented in the Risk-Review-Outputs directory of the PM office support folders	Prior to risk modeling and at any phase-gate reviews	Note that not all customers within a given business entity are the same. A different project sponsor may radically change the level of project risk and opportunity.
Risk modeling	The sample risk model should be scored by at least two project team members who should represent potentially competing interests within the organization. Scoring guidance is provided with the tool.	Prior to project acceptance and prior to risk contingency funding approval	The risk model is designed to provide relative scores on potential project risks. It is not intended to provide guidance on a risk-by-risk basis but instead to afford the organization a perspective on the general level of risk.
Risk identification	Sample prefers application of the Crawford Slip and brainstorming techniques, while other approaches, such as nominal group and the Delphi technique, may be appropriate. Identification should involve at least four team members, preferably including at least one from the customer organization.	Early in the concept phase, at phase-gate reviews, and any time the project undergoes significant change	Changes in personnel and requirements are frequently just as harmful to the project and generate as much risk as changes in external influences, such as technology or physical conditions. When in doubt as to the appropriateness of risk identification, it should be conducted.
Risk qualification	All identified risks should be evaluated according to the *sample* scales for impact and probability. These scores should be documented and logged in the project risk subdirectory in the project office repository. The scoring metrics reflect the organization's risk thresholds.	After risk identification and at regular intervals (at least once each quarter of the way through the project)	If the sample scale discounts risks that are obviously high probability or high impact, contact the project office to identify the shortcomings in the practice and any recommendations for metrics to overcome those shortcomings.
Risk quantification	All H-H risks (as identified in risk qualification) shall be quantified to establish the expected value (*probability* x impact) of the risks and any contingency funding appropriate to their application.	After risk qualification	Sources for impact and probability data should be thoroughly documented. If such data is the result of expert interviews or other nonquantitative techniques, validate the data to the degree possible by getting second (and third) opinions
Risk response development	At a minimum, strategies should be developed for the top 20 risks in the project. Strategies should be mapped against a strategy response matrix to ensure consistency and effectiveness of coverage.	After risk qualification and quantification	Those individuals or groups responsible for implementation should ideally develop strategies.
Lessons learned documentation	While mast of this information will have been captured during the other stages in the risk process, it is important to clase out the project with a comprehensive review of lessons learned. This should incorporate specific, actionable steps that can be pursued by other project managers on future efforts.	Regularly, as a component of the other steps, and at project termination	Lessons learned should capture a contact name, e-mail, and telephone number to ensure effective tracking.

Table 9. *Sample* Risk Methodology

- *Review all the steps before applying any of them.* Since many steps are contingent on other steps, it is important to have a comprehensive overview before attempting application of any single step. Because outputs of a single process may serve as inputs for many others, a holistic perspective is essential to proper utilization.
- *Check any information repositories.* As both inputs and outputs will have common homes, it is important to make sure that the information stores identified in the methodology are current and that they contain the variety and types of information the methodology describes.
- *Affirm forms and formats.* Because function frequently follows form, it is important to know what forms and formats are appropriate for the project and whether those forms and sample applications in the formats are available. It is often reasonable to review application practice with those who have used them in the past to ensure the practices are still applicable and valid.
- *Identify archival responsibility.* Someone in the organization will ultimately have to take responsibility to complete the forms, archive the information, and track risk information required under the methodology. The archivist can be either the greatest strength of such a methodology or its greatest weakness. In many organizations that have worked to implement methodologies, the initial implementation has gone smoothly, only to have poor follow-through and weak archiving damage the long-term application. In addition, the archivist frequently becomes responsible for identifying informational gaps, and in many ways, takes on the role of caretaker for the methodology.
- *Establish a regular review.* Although an effective archivist can be the strength of a good methodology, regular reviews ensure that no single imprint is impressed too heavily on the data generated through the methodology. Different perspectives on the information developed and retained ensure that the organization takes advantage of the breadth of its organizational memory rather than the depth of a single individual.

Use of Results

Much of the information generated in an expert interview is used in transitional or new project settings as it rarely bears fruit for the project on which it's being collected until long after that project is under way. The only advantages from risk methodologies for new projects stem from information generated on *past* projects. As methodologies are put into practice, the history that they create becomes valuable only as it is applied. The old axiom, 'Those who do not learn from history are condemned to repeat it," applies in both the business world and the project world just as readily as it applies to governments and civilizations.

Information from methodologies provides the background and history that allows a new team member to integrate into the project more quickly. It also permits a replacement project manager to better understand the breadth of what has transpired. The information should clarify the strengths of the relationships, as well as the weaknesses, and should afford the project team visibility on what is going on with other divisions, functions, and partners serving the same project. The methodology facilitates communication and does so in a fashion that ensures that everyone in the organization knows where certain data types are stored and how they can be accessed.

Resource Requirements

Although resource requirements for following methodologies are methodology-specific, two critical roles are the manager responsible for implementation and the project archivist. The project manager should ideally be someone who clearly understands both the informational requirements of the methodology and the rationale for collecting that information. Without a clear understanding of why the information is being collected, the project manager will have difficulty defending what is frequently a time-intensive process. The archivist's role, as cited earlier, is in many ways the cornerstone of a successful methodology. Capturing information thoroughly and in a timely fashion leads to a much higher probability of success. Archivists who write in bullets and cite oblique references may satisfy the technical requirements of the methodology but will fall short in terms of serving most methodologies' intents. Complete sentences and exhaustive references to external sources build organizational memory, which is a key goal of a comprehensive risk methodology.

Reliability

Methodologies are as reliable as their historians. If an organization rewards their practice and uses information from the methodologies, then the methodologies are highly reliable. If instead the information is perceived as data for data's sake, then reliability will drop significantly as fewer and fewer team members actively pursue the support information. Methodologies are frequently the fruit of a self-fulfilling prophecy. When maintained and used well, they tend to attract better information and more thorough inputs. If, however, they are not maintained well, fewer people will see their value and will actively make contributions. Weak inputs can drive a downward spiral from which a methodology cannot recover. If there is evidence that team members are actively investing time and energy in data entry, the reliability of the methodology, on the whole, is probably high.

Selection Criteria

As with each chapter on techniques, the risk methodology technique is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare risk practice methodology with other techniques, review Table 6.

Resource Requirements

Some resource requirements for methodology applications are actually somewhat more abstract than for some other tools and techniques discussed in this volume. Specifically, the methodology infrastructure should be in place, a management champion should exist for that infrastructure, and time and personnel must be allotted to meet the methodology's requirements.

The infrastructure requirements are both physical and documentation based. The physical infrastructure requirements include a common data storage facility for risk information (and ideally, a data administrator to maintain the facility). The documentation infrastructure includes any program forms and formats that become the conduits for data entry.

The second key resource requirement is a management champion. Without executive support, the long-term implications of a risk methodology can easily be lost in the short-term demands of a project. An effective management champion will know the reasons behind the methodology and the implications of subverting it. He or she will defend the application of the methodology in the face of adversity and will encourage peers to do likewise.

The other key resources are time and personnel. The archivist and project manager responsible for data gathering and data entry have weighty responsibilities to support the methodology, and without clear support and time, they will be unable to carry out those responsibilities.

- Cost for methodology implementation largely depends on the project. In a large-scale, multiyear effort, the costs of implementation are negligible. In a short, multiweek intervention, the costs of implementation may be perceived as significant. The more consistent the organization is in implementing the methodology and the more effective the organization is in facilitating quick, clear data entry, the less time is required to generate the same level of benefit.

- *Proper facilities and equipment* for a methodology generally include a network server or Internet-based interface that allows for consistent data collection and storage. Any forms or formats that have been developed will also be required, but they will ultimately be part of the interface itself. The system and organizational demands on facilities are initially moderate, becoming easier over time.
- The *time needed to implement* a risk methodology is methodology-dependent but, in the ideal, should be in proportion to the magnitude of the project. If the infrastructure is already in place, the time needed to implement should be limited.
- *Ease of use* on a methodology is moderate. While the steps should be clearly spelled out, the actual application and documentation requirements take time and energy. The documentation requirements also require a deft touch for ensuring that all critical information has been captured. Again, the longer a methodology has been in place and the more consistent its application, the easier it becomes to use.
- The project manager's *time commitment* is largely based on the skills and abilities of the individual identified as project archivist. A skilled archivist will guide the project manager to fill any informational gaps and will reduce the time and energy involved in research and analysis. A less skilled archivist may need extensive support from the project manager and may significantly increase the amount of time the project manager will have to invest in data gathering and recording.

Applications

The methodology can be applied most effectively when it brings consistency from project to project and from project manager to project manager. The applicability of the methodologies is assessed on a scale of high, medium, and low.

- *Project status reporting* refers to monitoring plans, costs, and schedules. The monitoring process is frequently a key function of the methodology and is a basic rationale as to why such methodologies are put in place. Project status reports rely heavily on methodologies, particularly for comparative analyses.
- *Major planning decisions* should be rooted in history. Where is the history gathered? In the repositories the methodology supports. Thus, the methodology and major planning decisions should be inextricably linked.
- *Contract strategy selection* does not rely heavily on methodologies, although any documentation or history on the application of the

various types of strategies may prove advantageous to those responsible for contract strategy selection. Still, the relationship between the methodology and contract strategy selection is extremely limited.

- Again, methodologies play a tangential role in *milestone preparation*. There is only limited information about milestones captured in most methodologies, and unless that is a focus of the methodology in question, there will be very limited applicability.
- Methodologies do not directly support *design guidance,* although the insights from past data collection efforts may prove fruitful.
- Methodologies do not support *source selection* unless there are specific elements built into the methodology to address procurement or contracting processes.
- The methodology may support *budget submittal* if there are specific risk perspectives reflected in the methodology that focus on building contingency reserves or establishing budgetary practices.

Methodologies also serve other applications. Perhaps most importantly, they focus on the organization's lessons learned. They ensure consistent data collection and a clear means to report risk activity and to catalog specific project risk behaviors. As a tool, methodologies allow organizations to capture information that would otherwise be lost.

Outputs

Outputs of the methodology take on the forms prescribed within the methodology itself. Many organizations generate such information in electronic copy, storing it on the organization's server or Web site. The outputs can include both qualitative data and individual perspectives on quantitative data.

- *Accuracy* of information from the methodologies is generally perceived as high, even though it is frequently borne out of a variety of qualitative techniques. The reason for this perception of high accuracy is that the information is generated in a consistent fashion and is stored in a common repository. That works to create a sense of order (that might not exist if a single project manager simply generated the information for a single project).
- *Level of detail* is a strength of methodologies as the descriptions of the steps within the methodology work to drive information to the level of detail appropriate for the information concerned.
- *Utility* is a subjective factor that takes into account both the effort involved and the value of the information. Because organizations have

seen fit to collect whatever information is gathered under the methodology, the utility of the data must be assumed to be high.

Summary

Methodologies are not the result of the work of an individual project manager. Whereas the inputs reflect a single-project experience, the structure is a direct reflection of the informational needs and the vision of the supporting organization. And although an organization may have no long-term goals for the information, even a short-term rationale (such as multiproject resource management or risk contingency reserve determination) can make development of the methodology a sound, reasonable business practice.

Chapter 7 Documentation Reviews

In some projects, a documentation review is seen as an opportunity to infer information that otherwise does not exist about a project. In other projects, however, it is a sincere effort to ensure that the natural risks inherent in any given activity are identified, no matter where they are embedded within the project. Documentation reviews allow for thorough and consistent analysis of the breadth of support documentation in the project, ranging from the statement of work to the work breakdown structure to the project charter. Essentially, any project documentation may reflect an element of risk and should be reviewed as a simple best-practice evaluation of the project in its entirety.

Project documentation may vary from project to project, but any significant documentation either on the client side or from the project organization's data pool may harbor risk information that would be missed without a thorough review.

A project documentation review is more than a simple reading of the project's documents, but it is not a dissection or parsing of every word ever generated about the project. Rather, it is a balanced analysis of the project documentation to identify any assumptions made, generalities stated, or concerns expressed that are not otherwise flagged in the requirements or the statement of work.

Although documentation reviews can include any number of different documents in the project, certain documents should be reviewed at a minimum: the WBS (if developed), the statement of work (or memorandum of understanding), the project charter, and any cost/schedule documents. Even though documents may be in various stages of development, they should be reviewed if they dictate project outcome or reflect project intent.

Technique Description

A project documentation review is a thorough reading of the pertinent documentation with one critical issue always in play: Does the information in this document identify potential risks that we may face on this project? This review can take place in a group setting or by having individuals analyze the documentation with which they have the greatest familiarity.

In a WBS, for example, a documentation review would involve a read-through of all activities (at all levels), and for each one, asking the concurrent question: What are the risks?

The technique requires no special skills, only familiarity with the processes described by the documentation under review and a sense of what potential risks exist therein.

When Applicable

This technique is recommended for all projects when their initiating documents are complete. It is not essential that the WBS be fully developed, but it is helpful to continue the reviews as the project documentation evolves. Any risks ascribed to discoveries from a piece of documentation (or components thereof) should be cataloged and matched up with that piece of documentation.

Inputs and Outputs

Inputs for documentation reviews are rather obvious: project documentation. As stated earlier, any documentation designed to lend clarity to the project, its processes, or its objectives should be included in such a review.

Outputs will be identified risks, risk sources, and triggers captured during the analysis. They should be documented, catalogued, and readily available to anyone conducting further reviews of the same documentation at a later date.

Major Steps in Applying the Technique

Since documentation reviews are rather generally applied, the steps may vary somewhat based on the type of documentation undergoing review. However, there is some consistency that spans most of these reviews:

- *Identify the available pool of project documentation.* This does not include every engineer's note and Post-it® written about the project. It should incorporate only information that directly contributes to the understanding of the project, its requirements, and the relationships between and among internal and external entities.

- *Identify appropriate parties to review the documentation.* Some documentation will be so highly technical that only one or two staffers would have any idea if any elements represent risk. The key is to match the individuals responsible for the document to the document.

- *Read the documentation with an eye to risk and document.* As the document reviewer analyzes the documentation, it is important to keep the perspective on what risk(s) will this generate." If that context can be kept in mind, there are wonderful opportunities to plumb new depths in finding risks from planning, contracting, and internal support perspectives.

- *Catalogue any risk issues.* As new risks, triggers, or symptoms are identified, the information should be captured and linked to the original documentation. In that way, anyone reviewing the documentation will be able to spot the issues that have already been highlighted.

- *Communicate any new risks.* Finally, the identified risks should be shared through any communications channels established in the project communications plan or in the project risk methodology. If the risks are not communicated to the other parties on the project, the chances that the information will be used effectively are slight.

Use of Results

Information gathered during the documentation review may represent the bulk of common risk knowledge on the project. If the common risks that are identified are the same risks that historically have caused the project organization the highest levels of concern, this may be the technique with the lowest level of technical support required and the highest yield.

The information this technique provides should include virtually all the obvious project risks. It should also generate a second set of risk information that is more project-specific and more directly related to the documented understanding of various project parties. In best-practice organizations, outputs from documentation reviews will be directly linked to the original documentation used in the analysis.

Resource Requirements

Resource requirements for documentation reviews are specific to the documentation but are basically those individuals who have a level of understanding and familiarity with the documentation sufficient to identify anomalies and common concerns. Although the project manager will share responsibility for ensuring the information is properly focused, the reviewer has the primary role in the review. The best reviewers will be those who can both identify risk issues and communicate them in ways that are significant and meaningful to the project team as a whole.

Reliability

Documentation reviews are as reliable as the information used to develop them. If the project has a rich documentation pool and those who understand the scope and nature of the work tap that pool, then the review's reliability will be extremely high. If, however, the data pool is shallow or the reviewers are highly inexperienced, then outputs from the documentation review are less likely to be reliable.

Selection Criteria

As with each chapter on techniques, the documentation review technique is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare documentation reviews with other techniques, review Table 6.

Resource Requirements

The basic resource requirements for documentation reviews include the documentation and the personnel. The documentation needs to be centrally archived, available to the reviewers, and clearly related to the project, its approaches, and its personnel.

Documentation for such an effort may include, but is not limited to—

- Work breakdown structure
- Project charter
- Contract
- Memorandum of understanding
- Statement of work
- Requirements documentation
- Network diagrams

The personnel assigned to review each of the documentation elements should be those individuals with a clear understanding of and experience with the documentation. They should be individuals who have the ability to communicate what elements of the documentation they identified as risks and their reasons for doing so.

- Cost for documentation reviews, particularly when weighed against the yield, is relatively small.

- *Proper facilities and equipment* for documentation reviews normally consist of a common data repository, such as a network server or an Internet-based interface, that allows for consistent data collection and storage.
- *The time needed to implement* documentation reviews tends to be one of the most attractive aspects of the technique. It is normally seen as a short-term effort that can be completed as team members have the time available to perform the work.
- *Ease of use* is high for documentation reviews because they generally involve a simple read-and-review cycle. The most challenging and time-consuming aspect of the process is the documentation required to capture the reviewers' insights.
- The project manager's *time commitment* depends on the degree to which the project manager performs the task independently. The more team members that are given responsibility for tasks associated with a documentation review, the less time required on the part of the project manager.

Applications

Documentation reviews are most effective when the data pool is deep and readily accessible. They allow for interpretation of project assumptions, and to a degree, validation of some information that is generated during the project life cycle.

- Documentation reviews strongly support *project status reporting* since the reviews will normally identify any shortcomings in the existing base of project status information (as well as any unusual reporting requirements).
- *Major planning decisions,* because they are based on project history, rely heavily on project documentation reviews. The reviews afford the organization an opportunity to clarify the foundation for such decisions and ensure that there is a clear interpretation of the documentation being evaluated.
- *Contract strategy selection* may rely somewhat on documentation reviews, although the two are not inextricably linked. Because the documentation reviews generally include the contract, some overlap here is almost inevitable. However, the degree of support is moderate at best.
- *Milestone preparation* will get only nominal support from documentation reviews although the reviews may provide some insight as to the level

of effort that is entailed in preparing for major project deliverables and events.

- *Design guidance* should rely heavily on documentation reviews since the reviews should point to customer expectations, the overall project objectives, and the detailed implementation approach.
- For similar reasons, documentation reviews can support *source selection* because the nature of the project work and the history of performance in achieving similar goals may go a long way toward establishing the best available sources for project performance.
- Again, for many of the same reasons, documentation reviews support *budget submittal*. The documentation will include information on past performance, issues, and concerns, and as such, may provide strong support for budget submittals.

Documentation reviews constitute a key component of best-practice project management. Best-practice managers rely on history to determine future courses of action. They understand the value of the information that exists in a project and do not presume to do things the same way each time they take on a new endeavor. To discern between situations where the same old approach is appropriate and a new action is called for, they must know and understand the parameters of the situation. Documentation reviews afford such a level of understanding.

Outputs

The outputs of the documentation review are more documentation. They comprise supporting documentation that clarifies, interprets, and identifies risk, and establishes common understanding of existing documentation.

- *Accuracy* of documentation reviews is largely reviewer-dependent. A cursory review with no context to interpret the information may leave the organization with less valuable (and less accurate) information. On the other hand, a more exhaustive parsing of the documentation may generate far more accurate insight.
- *Level of detail* is highly reviewer-dependent. Some reviewers know how to examine project information for risk insights that will add to the understanding of the project. Others will keep the detail too high-level to be of any significant value.
- *Utility* is high for documentation reviews because the newly discovered information is maintained and stored with the original documentation. It expands the organization's understanding of risk values and keeps risk visible in tandem with information where risk is sometimes seen as a secondary issue (as with the project charter).

Summary

To some degree, documentation reviews seem like the tedium of an ordinary project where ordinary practices include reviewing the paperwork. In some ways, that may be an apt description. But documentation reviews go beyond those limiting walls. Documentation reviews provide levels of depth and clarity that we might otherwise never capture. They provide a clearer vision as to what the project is intended to accomplish and how it will do so.

Chapter 8
Analogy Comparisons

The analogy comparison and lessons-learned techniques for risk identification, qualification, and quantification are based on the idea that no project—no matter how advanced or unique—represents a totally new system. Most projects originated or evolved from existing projects or simply represent a new combination of existing components or subsystems. A logical extension of this premise is that the project manager can gain valuable insights concerning various aspects of a current project's risk by examining the successes, failures, problems, and solutions of similar existing or past projects. The experience and knowledge gained or lessons learned can be applied to the task of identifying potential risk in a project and developing a strategy to handle that risk.

Technique Description

The analogy comparison and lessons-learned techniques involve identifying past or existing programs similar to the current project effort and reviewing and using data from these projects in the risk process. The term similar refers to the commonality of various characteristics that define a project. The analogy may be similar in technology, function, contract strategy, manufacturing process, or other area. The key is to understand the relationships among the project characteristics and the particular aspects of the project being examined. For example, in many system developments, historical cost data show a strong positive relationship with technical complexity. Thus, when searching for a project in which to analyze cost risk for comparison, it makes sense to examine data from projects with similar function, technology, and technical complexity. The use of data or lessons learned from past programs may be applicable at the system, subsystem, or component level. For instance, although an existing system's function and quantity produced differ, its processor may be similar in performance characteristics to that of a current project, thereby making the processor a valid basis for analogy comparison. All in all, several different projects may be used for comparison to the current project at various levels of the end item.

When Applicable

Project managers can apply lessons learned or compare existing projects to new projects in all phases and aspects of a project any time historical data are useful. These techniques are especially valuable when a system is primarily a new combination of existing subsystems, equipment, or components. The value increases significantly when recent and complete historical project data are available. When properly done and documented, analogy comparison provides a good understanding of how project characteristics affect identified risks and serves as necessary inputs to other risk techniques.

Inputs and Outputs

Three types of data are required to use this technique:

- Description and project characteristics of the new system and its components (or approach)
- Description and project characteristics of the existing or past projects and their components (or approach)
- Detailed data (cost, schedule, and performance) for the previous system being reviewed

The description and project characteristics are needed to draw valid analogies between the current and past projects. Detailed data are required to evaluate and understand project risks and their potential effect on the current project.

Often, the project manager needs technical specialists to make appropriate comparisons and to help extrapolate or adjust the data from old projects to make inferences about new projects. Technical or project judgments may be needed to adjust findings and data for differences in complexity, performance, physical characteristics, or contracting approach.

The outputs from examining analogous projects and lessons learned typically become the inputs to other risk assessment and analysis techniques. The review of project lessons-learned reports can identify a number of problems to be integrated into a project's watch list. The length and volatility of past development projects provide information that helps build realistic durations in a network analysis of a new project's development schedule. Data from the lessons-learned review become the source of information for risk identification, qualification, quantification, and response techniques.

Major Steps in Applying the Technique

The major steps in using analogous system data and lessons learned include identifying analogous programs, collecting data, and analyzing the data gathered. Figure 11 shows a further breakdown of this process.

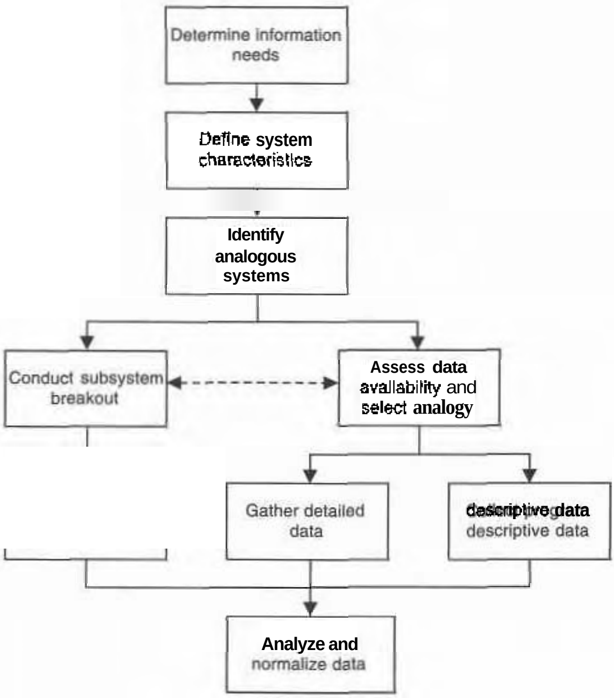


Figure 11. Analogy Comparison

The first step is to determine the information needs in this phase of risk management. Information needs can range from preliminary risk assessment on a key approach to a projectwide analysis of major risks associated with the effort. The second step is to define the basic characteristics of the new system. With the new system generally defined, the analyst can begin to identify past projects with similar attributes for comparison and analysis.

Because they are interdependent, the next steps in this process are generally done in parallel. The key to useful analogy comparisons is the availability of data on past projects. The new system is broken down into logical components for comparison while assessing the availability of historical data. The same level of detailed information is necessary to make comparisons. Based on the availability of data, the information needs of the process and the logical structure of the project, analogous systems are selected and data are gathered.

The data gathered for comparison include the detailed information being analyzed, as well as the general characteristics and descriptions of past projects. General project description data are essential to ensure that proper analogies are being drawn and that the relationship between these characteristics and the detailed data being gathered is clear. For the analogy to be valid, some relationship must exist between the characteristic being used to make comparisons and the specific aspect of the project being examined.

Often the data collection process and initial assessment lead to further defining the system for the purpose of comparison. After this is accomplished, the last step in the process is analyzing and normalizing the historical data. But comparisons to older systems may not be exact. The data may need to be adjusted to serve as a basis for estimating the current project. For example, in analogy-based cost estimating, cost data must be adjusted for inflation, overhead rates, general and administrative (G&A) rates, and so on, for accurate comparison. As a result, project managers frequently require technical assistance to adjust data for differences between past and current projects. The desired outputs provide some insight into the cost, schedule, and technical risks of a project based on observations of similar past projects.

Use of Results

As stated earlier, outputs from analogies and lessons learned typically augment other risk techniques. The results may provide a checklist of factors to monitor for the development of problems or a range of cost factors to use in estimating. Analogies and lessons learned generate risk information. Regardless of whether the information is used in a detailed estimate, in a technology trade-off study, or at a system level for a quick test of reasonableness, the results are intended to provide the analyst with insights for analysis and decision making.

Resource Requirements

Using analogous data and lessons-learned studies to gather risk data is a relatively easy task. Selecting proper comparisons and analyzing the data gathered may require some technical assistance and judgment, but the task is probably not beyond the capabilities of the project manager. However, the time and effort needed for an analogy comparison can vary widely.

The resources required depend on the depth of data gathering, the number of different projects, and the availability of historical data. Consequently, a project team can expend much effort for a limited amount of information. That is why an initial assessment of data availability is important in selecting analogous programs to compare.

Reliability

Using analogy comparisons and lessons learned has two limitations. The first, availability of data, has already been discussed. If common project characteristics cannot be found or if detailed data are missing from either the old or new systems, the data collected will have limited utility. The second limitation deals with the accuracy of the analogy drawn. An older system may be somewhat similar, but rapid changes in technology, manufacturing, methodology, and so on, may make comparisons inappropriate.

Selection Criteria

As with each chapter on techniques, analogy comparison is assessed using selection criteria relating to resource requirements, applications, and outputs for this technique. To compare analogies with other techniques, review Table 6.

Resource Requirements

- The *cost* associated with the analogy comparison techniques is relatively low if the organization has been fastidious about retaining information from past projects. If there is a broad database from which to draw information, the analogy techniques can be easily applied, assuming that the new project is even in part analogous to an older project. Unfortunately, most new projects are not wholly analogous and must be evaluated against piecemeal information. If the data are available, the resource time consumed may be as little as a week or less. However, if the data are sketchy, it can take multiple resource-months to gather the data from the various departments or projects within the organization.

- *Proper facilities and equipment* are rudimentary consisting of little more than a server hosting historical project data and client computers with the appropriate database access tools, word processors, and project management applications.

- The *time needed to implement* this approach is a direct function of the number of sources from which data are available and the number of team resources assigned to the activity. With a team of three or four data gatherers, even the most complex set of information may be compiled and reviewed in as little as a week or two. With a single individual assigned to the task, the resource-hours assigned in the "Cost" category apply.

- *Ease of use* appears to be a major advantage of the analogy approach, but that ease can be deceptive. Some project managers will be tempted to make across-the-board, one-for-one analogies for the entire project. But that is applicable only in the rarest of cases. The technique is appropriate, however, only if it is applied in the context of the new project under consideration. This may be evaluated in terms of the scale of the projects being compared, the time frames in which they are developed, or the resources applied against both. Thus, this technique often appears easier than it is.

- The project manager's *time commitment* in this technique is a factor of how heavily involved the project manager wishes to become in analyzing the data. If the project manager wants to spend as little time as possible approving the work of the team, the level of effort is nominal. It is recommended that the project manager invest at least several hours analyzing the analogous projects driving the conclusions.

Applications

- For *project status reporting,* the analogy comparison technique can serve only as a defense of certain numbers that may have been used to establish the baseline for the project. Otherwise, analogy comparisons have little value when assessing the new project's current status.

- *Major planning decisions* should rely very heavily on an organization's lessons learned. History is an excellent teacher, and using the organization's historical experience with similar projects can prove invaluable. If certain approaches have been attempted, it is vital to find out whether they succeeded or failed.

- As with planning decisions, the issue of *contract strategy selection* can be developed using analogy comparison techniques. If work with a similar client, similar project, or similar resources has failed in part due to using one contract strategy, it is worthwhile to consider alternate strategies.

- *Milestone preparation* is not an area in which analogy comparisons have much value unless a project was noted as exceptional in part because of its outstanding use of milestones. Generally, milestones are seldom major influences in a project's success or failure. In the rare case in which milestones *have* played a key role, the analogy technique may apply.

- Although *design guidance* does not rely exclusively on analogy comparisons, analogies should be an essential component of any design decision.

Too often, organizations fail to scrutinize the failings of past designs, only to learn later that the project at hand is failing for the same reasons as a project just a year or two before. Analogy comparisons will not provide the complete picture on design guidance, but they will provide a sense of corporate history and experience.

- Many organizations (like the U.S. government) make analogy comparisons a key component of *source selection.* Terms such as "past performance," "performance history," and "preferred vendor" all reflect some analysis of analogous projects. These are valuable analyses because organizations should not repeat the mistake of dealing with a less-than-acceptable vendor.

- For *budget submittal,* the analogy comparisons technique has limited application except as a background for some of the numbers that may have been incorporated into the budget. Although analogies may be found, some independent extrapolation or evaluation of the data must also be conducted.

Outputs

- The *accuracy* of the analogy comparison technique is less than ideal. This technique relies not only on the accuracy of past data but also on the accuracy of the interpretation of those data, which incorporates two variables into the overall assessment of the data for the new project. Thus, the level of accuracy comes into question.

- The *kvel of detail* that the technique generates is practically a direct function of the volume of data the organization stores. If an organization is meticulous in its project record keeping, the level of detail can be tremendous. If, however, the organization has a limited, purely anecdotal history, the level of detail becomes low at best.

- The *utility* of the outputs is based on both the quality of the analogous documentation and the relevance of the analogy. If both are high quality, the information obtained has the potential to be extremely useful. If, however, the relevance or quality is in dispute, the usefulness diminishes significantly.

Summary

In evaluating the potential use of analogy comparisons for an organization, the first step should always be an assessment of the volume and quality of the documentation to be used for analogies, including how recent it is. If the organization does not effectively maintain this information, the analogy comparison technique may prove useless for virtually any application.

Chapter 9
Plan Evaluation

This technique highlights and isolates risk disparities in planning. It evaluates project plans for contradictions and voids. Traditional, formal plans used to guide a project include the following:

- Project
- Quality
- Communication
- Contracting
- Testing
- Training

Other documents are also essential to the success of the project and to such evaluations:

- Work breakdown structure (WBS)
- Project specifications
- Statement of work (SOW)
- Contracts
- Other baseline documents

Although plans outline project implementation steps, other documents represent critical communication with stakeholders about what is to be done. Flaws, inconsistencies, contradictions, and voids in these documents inevitably lead to project problems and introduce significant risk. Figure 12 illustrates the linkage between three key documents.

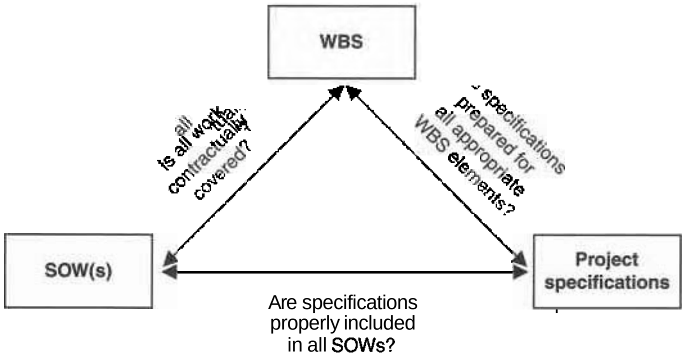


Figure 12. Plan Evaluation Technique

Technique Description

The plan evaluation technique simply suggests a thorough, recurring internal review of all plans for correctness, completeness, and currency, with a cross-check for consistency.

Using the WBS for Risk Identification

Proper development of a WBS represents a major step in risk control because it constitutes much of the project definition. Its quality—indeed its very existence—provides the planning framework that sets the standard for the future of the project. As a WBS is completed, a careful examination is appropriate:

- Are all elements of the WBS necessary and sufficient?
- Is there a WBS dictionary, and does it adequately explain the content of each element?
- Does the WBS represent what is to be done rather than who is to do it?
- Are all elements of the WBS present?
- Is the contracting strategy reflected in the project WBS?
- Is any work to be done not reflected in the WBS?

The WBS offers a framework for organizing and displaying risk factors. The technique of downward allocation and upward summarization through the WBS can be used to highlight discrepancies in most of the project's performance parameters, such as efficiency, reliability, cost, and capability.

The WBS provides a sensible structure for treating technical risk. A systematic review for risk identification and preliminary rating of each WBS element will yield much information for the risk analyst.

The relationship between the WBS and the specifications is so important that mapping the relationships is a valuable exercise for the risk analyst. Mapping will highlight inconsistencies between the work to be done and the performance to be achieved.

The project WBS eventually becomes the aggregate of all contract information, including subcontractors' plans. The risk analyst should review the WBS with the question "Who is doing what?" as a test of reasonableness of the contracting strategy. Finally, the WBS represents the framework for cost and schedule performance (although it is *not* a representation of the schedule itself). A survey of both cost and schedule reporting in the context of the WBS identifies possible blind spots in cost and schedule information. As part of this survey, the analyst can gain valuable insights by comparing the numbering schemes for the WBS, scheduling system, and cost-reporting system. Ease of translation among and ease of summarization within each of these numbering systems can indicate how well traceability among the WBS, schedules, and cost data can be maintained. Incompatibility introduces management risk into the project.

To extract additional risk from the WBS, any variety of techniques may be used, with each one posing the question, "What are the risks for this WBS element!" Expert interviews, brainstorms, and the Crawford Slip Method can all generate that information.

Using Specifications for Risk Identification

Some of the previous discussion deals with the important relationship between the WBS and the specifications and the need for compatibility. When that compatibility exists, the performance to be achieved can be related to the work to be done. Because the specifications represent the source of all technical performance requirements, they are the single most important source of information for the risk analyst attempting to identify, organize, and display items of technical risk. Each performance parameter of a given WBS element represents a possible focus for an expert interview on technical risk.

As with the WBS, a survey of the specifications is appropriate for risk identification:

- Do the specifications overlay the WBS so that performance requirements are specified for WBS elements?
- Are all performance parameters identified even though they may not be specified (that is, given a discrete value)?

- Can the risk of achieving the specified value for the performance parameter be sensibly discussed?
- Is there a technical performance measurement scheme for each performance parameter?

Using Statements of Work for Risk Identification

The SOW is the single most important communication between the project organization and the customer. If the WBS and the specifications are complete and well developed, SOWs are fairly straightforward. The risk analyst is searching primarily for gaps in coverage and should consider the following:

- Does the SOW cover whole parts of the WBS that can clearly be evaluated against the specifications?
- Does the SOW represent work that matches the project organization in terms of politics, contractual capabilities, and legal capabilities?
- Is all work contractually covered?
- Are the SOW requirements properly related to the specification?

Developing a Technical Risk Dictionary

A dictionary in project management can expand understanding and provide documentation and background on a specific project area. Thus far, this chapter has addressed the need to gather all project information with common descriptions into a common database. A technical risk dictionary, as conceptualized in Figure 13, offers the risk analyst a single place to gather this information for facilitating the risk identification and definition processes.

Until recently, creating a technical risk dictionary has been a formidable editorial task. Advances in project management software, coupled with advances in documentation management, allow for integrated data within a single database, and in some cases, a single file. In most popular project management software packages, there are sufficient available text and numbers fields so that the bulk or whole of the risk dictionary can be maintained in the same file as the project plan itself. If the text and numbers fields are to be used this way, then the same text field used for one element in one project (for example, Text13=Performance Risk) should be used for the same purposes in all projects within the organization to facilitate knowledge transfer.

Such information maintenance practices afford project managers a "home" where their risk information can readily be shared with the team,

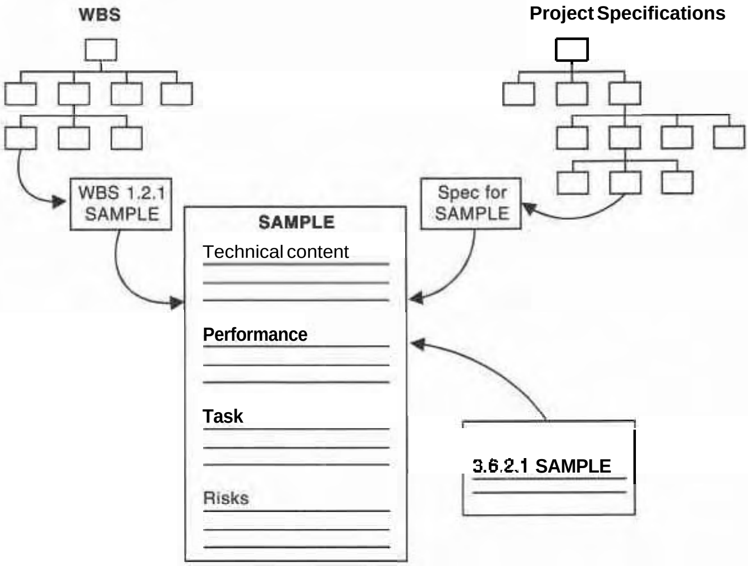


Figure 13. Technical Risk Dictionary

and where risk identification and management can be integrated into day-to-day operations.

Using Other Plans for Risk Identification

"Risk Identification" in Chapter 3 discusses the use of a top-level risk matrix to highlight and isolate risks. The matrix relies heavily on goal definition and strategy development. The presumption is that the strategies expressed in the project plans are directed at meeting the project goals. Comparing the two can identify risks. The same thinking can be applied to lower-level risk matrices associated with any other plans (communication, quality, testing, and so on) that are developed.

When Applicable

The plan evaluation technique is directed specifically at risk identification and is best used for technical risk. Its utility for cost and schedule risk is considerably lower. However, this technique could highlight missing information concerning deliverables that would affect cost and schedule risks. It is most applicable to the implementation phase of a project. As a risk identification technique, it requires the existence of the plans to be evaluated. As a strategy tool (to identify what risks can be avoided), it can be used during the project planning process.

Inputs and Outputs

Plan evaluation operates on the collective body of documentation broadly referred to as project plans and includes primarily those documents listed earlier. Outputs typically include—

- Top-level risk matrix
- Lower-level risk matrices
- Technical risk dictionary
- Updated versions of project plans

Major Steps in Applying the Technique

The major steps in plan evaluation are as follows:

- Evaluate the WBS for completeness and correctness
- Evaluate specifications for completeness, correctness, and compatibility with the WBS
- Evaluate SOWs for completeness, correctness, and compatibility with the WBS and for inclusion of specification references
- Evaluate other plans and develop a lower-level risk matrix for each

Use of Results

Plan evaluation is designed to improve the quality of and reduce the risks associated with the project plan. The technique also produces descriptive documentation on the technical performance, programmatic risks, and supportability risks associated with the project. The technical risk dictionary describes technical risks in a centralized location, cross-referenced with the WBS. This technique can produce a single "official" list (a watch list) of project risks that will receive active management attention.

Resource Requirements

This technique requires a great deal of thought as well as experienced, knowledgeable personnel who are thoroughly familiar with the content of the total project. The project manager (or deputy project manager) leading a team of senior staff members would constitute the ideal team for this technique.

Reliability

The completeness and the farsightedness of the project plans drive the reliability of plan evaluation. If the numerous support plans are all well defined for a low-risk project, only a handful of project risks will be uncovered. If, however, the support plans are well defined for a higher risk project, there is a likelihood that significantly more risks will come to the fore.

The major caution for using this technique is to avoid forcing detailed project definition too early. Some inconsistencies exist due to poor planning, but others exist because of a legitimate lack of information.

Selection Criteria

As with each chapter on techniques, plan evaluation is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare plan evaluation with other techniques, review Table 6.

Resource Requirements

- With plan evaluations, *cost* constraints are extremely flexible. If the project manager determines that a comprehensive review of every piece of project planning documentation is appropriate, numerous resources will be required for an extended period of time. If, by contrast, the project manager determines that a high-level summary review is appropriate, the resources required will drop significantly.

  Heretofore, the discussion in this chapter has focused on in-depth analyses, so the assumption is that the analysis will be comprehensive. However, comprehensive evaluations may prove to be prohibitively costly because key resources will be required to justify their existing plans and reevaluate the plans' efficacy. To do a comprehensive evaluation, each team member responsible for a component plan will have to spend several days to a week analyzing his or her documentation and documenting those analyses. Consequently, using the full complement of plans described at the beginning of the chapter, an effort for a 1-year period may require 4 to 6 resource-weeks.

- *Proper facilities and equipment* are limited to a sufficient number of personal computers to support all team members involved in the review. Team members will need access to the material planning documentation, including the supporting documents (which would require word processing applications) and the project management software program and files. This technique is not equipment-intensive.

- The *time needed to implement* this approach is highly dependent on the number of resources applied. To be effective, one resource should be designated for each major piece of documentation to be evaluated. However, most organizations are not willing to commit that level of staff to a single evaluation effort. Thus, the work will be spread across a more limited base. In the ideal, this effort should be accomplished in 2 or 3 days using a skilled, broad-based team. Yet with fewer resources, the effort may take as long as 4 to 6 resource-weeks.

- *Ease of use* is an issue with this technique because the project manager will clearly understand the level of effort required to analyze outputs, but management and team members may not appreciate the in-depth analysis essential for a clear understanding of the information. For some team members and stakeholders, the entire package may present information that does not meet their specific needs. For others, the material may be presented in a way they cannot understand. Thus, the proper sorting and filtering of the information is vital to the ease of use for this technique for all its recipients.

- The project manager's *time commitment* is significant. Because the project manager normally understands the details of the plans, he or she becomes the focal point for all questions and clarifications that team members require. The project manager's ready availability facilitates the efforts of the technical personnel responsible for their respective support plans or project plan components.

Applications

- Plan evaluations are essential to *project status reporting* because without a thorough review of the project plans and their variances to date, it is impossible to evaluate project status in an accurate historic context. In many ways, plan evaluations almost force the project team into developing status reports because that is the best application for the technique.

- *Major planning decisions* should depend on a sense of project history and may be subject to the evaluations of specific project plans. The difference in the application with major planning decisions is that major planning decisions may focus on one particular aspect of the project (such as schedule, cost, or performance) and thus may not require the level of depth described in this chapter. The planning decision may also hinge on a single type of support plan or a single component of the project plan. Either way, plan evaluation ultimately provides the ideal support in major planning decisions, whether from a component of the plan or from the comprehensive plan evaluation.

- Although *contract strategy selection* relies on the evaluation of the initial project plan, it is not normally considered a key application for plan evaluation. Plan evaluations are usually conducted after the project is being implemented to assess the effectiveness of the plan versus reality.

- As with contract strategy selection, *milestone preparation* is most often a step conducted at the beginning of the project. However, there is a slightly closer link between milestone preparation and plan evaluation than what occurs with the contract strategy selection. Specifically, many plan evaluations will lead to corrective action, which often includes adding supplemental milestones to ensure that the corrective action is effective. As such, there is a modest correlation between this application and the technique.

- Plan evaluations can support *design guidance* only during the early phases of the project, and even then, only to a limited degree. To provide guidance, the plans must show some direct link between the original design selected and the project plan or its supporting plans. If no such link exists, the plan evaluation technique does not apply.

- In *source selection,* there is little applicability for plan evaluation unless the selection occurs at midproject or in the context of multiple projects. The plan evaluation technique can afford insights into the needs of the project and the shortcomings of the existing vendor base. But for initial source or vendor selection, there is little applicability.

- The plan evaluation technique does not affect *budget submittal* unless (as with source selection) the budget is an interim budget being submitted at midproject. In any other scenario, the plan evaluation technique has extremely limited applicability.

Outputs

- *Accuracy* is a cornerstone of the plan evaluation technique. It is wholly designed to discover inaccuracies and to address them. Although much of the evaluation is subjective, the results tend to make plans better reflect the project as it evolves.

- The *kvel of detail* in the plan evaluation technique is exhaustive. The information drawn from the various plans and the assessment of those plans is most effectively realized when all the plans are assessed for their effectiveness to date. Although a simple WBS review might require moderate scrutiny, the level of effort and the depth of information developed in a comprehensive plan evaluation are extensive.

- For areas in which the plan evaluation technique is logically applied, its *utility* is extremely high. Unfortunately, project managers may be tempted to use plan evaluation as a panacea for analyzing all project risk. Although plan evaluation applies well in some areas, it is inappropriate in others. The evaluation data are so in-depth and diverse that they have the potential to be misinterpreted or misused.

Summary

In an ideal world where seasoned professionals of long tenure support a project manager, plan evaluations would produce few results for a significant level of effort. All planning documents would be created in proper sequence, each with reference to all that preceded it. Eminently logical contracts would be matched with masterful work statements and perfect specifications. In reality, however, as team members shift in and out of projects and as schedules and objectives change, plans often represent the only key to organizational memory. Because planning is conducted early in a project, any link to organizational memory later in the effort becomes significant.

The plan evaluation technique is extremely useful due to its clear strengths in so many applications and its relative value in terms of resource consumption and outputs. As long as the project manager uses the tool appropriately, it is one of the most powerful techniques available.

Chapter 10
Delphi Technique

Although people with experience of particular subject matter are a key resource for expert interviews, they are not always readily available for such interviews and, in many instances, prefer not to make the time to participate in the data gathering process. The Delphi technique works to address that situation by affording an alternative means of educing information from experts in a fashion that neither pressures them nor forces them to leave the comfort of their own environs.

The Delphi technique has the advantage of drawing information directly from experts without impinging on their busy schedules. It also allows for directed follow-up from the experts after their peers have been consulted.

Technique Description

The Delphi technique (created by the Rand Corporation in the 1960s) derives its name from the oracle at Delphi. In Greek mythology, the oracle (of the god Apollo) foretold the future through a priestess who, after being posed a question, channeled all knowledge from the gods, which an interpreter then catalogued and translated. In the modem world, the project manager or facilitator takes on the role of the interpreter, translating the insights of experts into common terms and allowing for his or her review and reassessment. The cycle of question, response, and reiteration is repeated several times to ensure that the highest quality of information possible is extracted from the experts.

When Applicable

This technique is recommended when the project's experts cannot coordinate their schedules or when geographic distance separates them. The Delphi technique is also appropriate when bringing experts together to a common venue may generate excess friction.

Inputs and Outputs

The inputs for the Delphi technique are questions or questionnaires. The questionnaire addresses the risk area(s) of concern, allowing for progressive refinement of the answers provided until general consensus is achieved. The questionnaire should allow for sufficient focus on the areas of concern without directing the experts to specific responses.

Outputs from the process are progressively detailed because all iterations should draw the experts involved closer to consensus. The initial responses to the questionnaire will generally reflect the most intense biases of the experts. Through the iterations, the facilitator will attempt to define common ground within their responses, refining the responses until consensus is achieved.

Major Steps in Applying the Technique

The technique relies heavily on the facilitator's ability both to generate the original questions to submit to the experts and to distill the information from the experts as it is received. The process is simple but is potentially time-consuming:

- *Identify experts and ensure their participation.* The experts need not be individuals who have already done the work or dealt with the risks under consideration, but they should be individuals who are attuned to the organization, the customer, and their mutual concerns. Experts can be defined as anyone who has an informed stake in the project and its processes. Commitments for participation should come from the experts, their direct superiors, or both.
- *Create the Delphi instrument.* Questions asked under the Delphi technique must be sufficiently specific to draw out information of value but also sufficiently general to allow for creative interpretation. Because risk management is inherently an inexact science, attempts to generate excessive precision may lead to false assumptions. The Delphi questions should avoid cultural and organizational bias and should not be directive (unless there is a need to evaluate risk issues in a niche rather than across the entire project spectrum).
- *Have the experts respond to the instrument.* Classically, this is done remotely, allowing the experts sufficient time to ruminate over their responses. However, some organizations have supported encouraging questionnaire completion en masse during meetings to expedite the process. No matter the approach, the idea is to pursue all the key insights of the experts. The approach (e-mail, snail mail, meetings) for gathering the experts' observations will largely determine the timing for the process as a whole.

- *Review and restate the responses.* The facilitator will carefully review the responses, attempting to identify common areas, issues, and concerns. These will be documented and returned to the experts for their assessment and review. Again, this may happen by mail or in a meeting, although the classic approach is to conduct the Delphi method remotely.
- *Gather the experts' opinions and repeat.* The process is repeated as many times as the facilitator deems appropriate in order to draw out the responses necessary to move forward. Three process cycles are considered a minimum to allow for thoughtful review and reassessment.
- *Distribute and apply the data.* Once sufficient cycles have been completed, the facilitator should issue the final version of the documentation and explain how, when, and where it will be applied. This is important so that the experts can observe how their contributions will serve the project's needs and where their issues fit in the grander scheme of risks and risk issues up for discussion.

Use of Results

The Delphi technique is frequently used when there are only a handful of experts who have an understanding of the project. It is also used when certain experts have insights about a particular aspect of the project that cannot be ignored. Although some other risk identification, assessment, and response development tools have broad application, the Delphi technique is a more exacting tool, drawing out only the responses or types of responses desired. The information acquired from the Delphi technique can be used to support risk identification, qualification, quantification, or response development.

Resource Requirements

The Delphi technique requires that a project have both a skilled Delphi facilitator and experts to support the process. The facilitator must have the ability to present the premise clearly in the Delphi questionnaire and then must have the capacity to refine and distill the inputs from the participants. The participants, in turn, must have an awareness of the area on which they are being consulted.

Reliability

The technique generates relatively reliable data (for a qualitative analysis) because multiple experts subject the information to at least three iterations of reviews. The iterative nature of the process and the requisite reviews tend to enhance accuracy, although the use of inappropriate experts or the development of poorly couched questions may produce less than optimal results.

Still, because there are multiple reviewers, some built-in safeguards ensure a measure of reliability.

Selection Criteria

As with each chapter on techniques, the Delphi technique is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare the Delphi technique with other techniques, review Table 6.

Resource Requirements

The Delphi technique requires little more than basic office supplies. The infrastructure for the technique is minimal, as it is little more than a specially processed expert interview.

From a personnel perspective, the facilitator's greatest talent must be in distilling the information from one iteration of the approach to the next, achieving a balance of the information presented, and at the same time, not alienating the experts involved.

Participants in a Delphi technique analysis can derive comfort in the fact that their contributions, for the most part, will be anonymous because their inputs will never be directly presented to the other experts. The facilitator will filter and distill it first. Nonetheless, the participants should be reasonably skilled at documenting their contributions, as that is where the Delphi technique generates its value.

- *Cost* for the Delphi technique is minimal. Because most participants can complete the questionnaire at their leisure, there is little time pressure on the participant's side. The facilitator is also generally not time-constrained in this practice and thus has some latitude to complete this effort when there is time to work on it. Even though the cost is minimal, the time to complete a Delphi technique process can be extensive, as it can continue for weeks if unmanaged.
- *Proper facilities and equipment* for the Delphi technique consist of little more than office supplies for participants to record and return their responses to the facilitator. In some more modern sessions, the Delphi technique is conducted in real time using e-mail and deadlines. Although the facilities infrastructure for such an approach is more expensive, most organizations already have such capabilities in-house.
- The *time needed to implement* the Delphi technique is the single most significant drawback of the approach. Despite that e-mail has created a faster way to accomplish the work, the technique still may take several days to complete. For some organizations, however, the quality of the data generated makes this trade-off worthwhile.

- Although the *ease of use* for the participants is high, the facilitator has to be skilled at distilling and paraphrasing information. The facilitator must also ensure that the process stays on track. It is very easy to allow the Delphi technique to falter because of the time frames and distance involved.
- The project manager's *time commitment* is slight, with intense, short bursts of activity each time a cycle of responses is received.

Applications

The Delphi technique has broad utility because of its use of the experts' skills and insights. The applicability of the technique is assessed on a scale of high, medium, and low.

- *Project status reporting* is an area where the Delphi technique can provide more balanced insight than other tools can. Some projects falter because there is not a common understanding of the work accomplished, but the Delphi technique by its nature can reorient a team. Since the tool draws out consensus of the experts, it can facilitate in-depth analyses of project status. The tool's value here is medium.
- Because the experts in an organization tend to make *major planning decisions,* the Delphi technique can be seen as viable here. Particularly in situations where there is significant conflict over planning decisions, the Delphi technique has high applicability due to its capacity to get a common vision from a group of experts.
- *Contract strategy selection* is an area where experts are frequently tapped to make decisions, and likewise, conflict can be significant. As with planning decisions, the Delphi technique can serve extremely well in these situations.
- Applying the Delphi technique in *milestone preparation* would probably have limited use. Whereas milestone preparation is a function of needs analysis, multiple experts are normally not required to ascertain the best times for milestones.
- *Design guidance* is a prime application for the Delphi technique. It is a creative endeavor requiring multiple perspectives. As such, the Delphi technique is a classic tool for bringing different approaches to the fore and selecting the best possible approach.
- *Source selection* may be an application of the Delphi technique. If the experts in the technique are familiar with the needs of the procurement and if they are attuned to the organization's limitations, the Delphi technique may be appropriate. However, the tool's utility here is medium at best.

- *Budget submittal* is a quantitative process, and thus cannot take full advantage of the Delphi technique.

The Delphi technique is peerless in allowing for thoughtful review of the subject matter experts' insights. As such, organizations may be able to use this technique to establish risk responses, to identify risks, or to assess risk performance to date. However, the drawbacks associated with the timing of the process tend to limit its utility. When time is not of the essence, the Delphi technique can create some of the most thorough qualitative analyses available to the project manager.

Outputs

The outputs of the Delphi technique are sets of modified responses to the questionnaire. Although participants generate those responses, the facilitator has the ultimate responsibility to produce final outputs based on an amalgam of responses from subject matter experts to each question or issue.

- The *accuracy* of the Delphi technique is qualitatively rooted but is perhaps the single most accurate qualitative tool since it draws on multiple experts to establish its conclusions.
- *Level* of *detail* is a strength of the Delphi technique because there are rarely limits on the insights that the experts can share. As the process goes through multiple iterations, the level of detail can increase if the questions are expanded or the follow-up is particularly detailed or provocative.
- *Utility* is a subjective factor that takes into account both the effort involved and the value of the information. The Delphi technique tends to generate highly utilitarian information as it is revised several times before the outputs are finalized.

Summary

The Delphi technique is time-consuming. But it is a sound, structured practice for drawing out insights from professionals who might otherwise not contribute to the project's body of knowledge. It affords the facilitator the opportunity to review multiple perspectives before coming to grips with the middle-of-the-road perspective that Delphi tends to generate. The technique can be applied in a variety of situations, but for each, the time constraint must be given serious consideration.

Chapter 11
Brainstorming

Brainstorming is a classic technique for extracting information. Although it may not be the most efficient tool or the most thorough technique, its familiarity and broad acceptance make it the tool of choice for many risk analysts. And whereas it may be viewed as a generic tool, the fact: that most participants are aware of the process and the tool's nuances make it desirable in a variety of risk management settings. Because risk is a future phenomenon, and everyone has the ability to intuit some aspect of the future, brainstorming as an ideation tool is a logical application.

Brainstorming can be used in a variety of risk management practices, including efforts to identify risks, establish qualification schemes, clarify quantification assumptions, and generate potential risk responses. It can draw on project team members, management, customers, and vendors. Virtually any stakeholder can contribute.

A brainstorm is more than a basic core dump of information. It is the expression of ideas that then feeds other ideas and concepts in a cascade of data. It encourages team members to build on one another's concepts and perceptions. It circumvents conventions by encouraging the free flow of information.

Technique Description

Brainstorming is a facilitated sharing of information, without criticism, on a topic of the facilitator's choosing. It educes information from participants without evaluation, drawing out as many answers as possible and documenting them. There are no limits to the information flow or direction. Brainstorming is designed to encourage thinking outside of conventional boundaries so as to generate new insights and possibilities.

For risk identification, as an example, the facilitator might ask "For the y component, what are the risks? What bad things could happen?"

Participants can then fuel their imagination with ideas as the facilitator documents or catalogs each new suggestion.

The technique requires limited facilitation skills and familiarity with any premise being presented to the group (for clarification purposes).

When Applicable

This technique is applicable in virtually every step in the risk management process. Its broad utility makes it appealing in a variety of settings:

- Risk identification to establish a base pool of risks
- Qualification to work toward terms and terminology as to what constitutes high, medium, and low in the various categories of risk
- Qualification to capture environmental assumptions and potential data sources
- Response development to generate risk strategies and to examine the implications thereof

Inputs and Outputs

Inputs are the basic premise of a brainstorm itself: a single comprehensive idea to be presented to the group of participants.

Outputs will depend on the premise presented but may include identified risks, risk sources, triggers, qualification approaches, assumptions, risk responses, or other data captured during the analysis. The outputs should be documented and catalogued for future application.

Major Steps in Applying the Technique

Since brainstorms are well understood in most environments, this analysis will focus on their application in a risk setting.

- *Establish the basic premise of the risk brainstorm and prepare the setting.* This involves making certain that a means exists to capture and catalog the information as it is presented. Few facilitators are sufficiently skilled to both record information and elicit responses from a group at the same time. Questions posed to the group should not be biased in any direction.
- *Identify appropriate participants.* This is sometimes a function of group dynamics rather than project insight. Some individuals function well in a group setting and contribute readily; others do not. Identify individuals who are likely to contribute and add value to the ideas being presented. A negative attitude or an overzealous contributor can spoil an otherwise effective brainstorming session.

- *Explain the rules of brainstorming to the group.* Emphasize that *all* ideas will be recorded because all ideas have some measure of value. Reinforce that everyone should have the opportunity to participate and that no pressure should be brought to bear that would stifle anyone. Any critiques of information or insight should be postponed until after the brainstorm.
- *Solicit information from the group.* Share the premise(s) of the brainstorm and draw out information from the participants. As an idea is shared, it should be repeated (to ensure accuracy) and documented (preferably in view of the large group as a whole). Participation should be allowed to flow freely within the group, but the facilitator should ensure that all participants have equal opportunity to provide their contributions.
- *Review the information presented.* As the group runs out of insights or as the session nears a close, the premise should be re-presented after a thorough review of all the ideas shared thus far. Any new insights should be captured at this time. In some organizations, this will be used as the one and only opportunity to critique the ideas presented earlier in the brainstorm.
- *Communicate the information.* After the session is complete, the information distilled from the brainstorm should be circulated to all participants for their records. This affirms that the information was actually captured and provides a sense of how the information will ultimately be used. If data from the brainstorm are to be captured within the project plans or the risk plans, the data should be sorted and filed with the project documentation.

Use of Results

Information gathered during the brainstorm will vary in levels of quality. For example, some risks identified may be on the fringe ("Locusts could attack, devouring all the project documentation"); and others may be overly obvious ("If the vendor delivers late, we could run into schedule delays"). The information will be used best when it is assessed for validity and then documented and applied within the project plan.

Brainstorming frequently captures the most obvious risks or the most self-explanatory qualification approaches. But this technique will also generate information that might otherwise be missed entirely. Thus, a key role for the facilitator is to ensure that the information is captured well and applied appropriately.

Resource Requirements

Resource requirements for brainstorms include a facilitator, a group of participants, and the physical facilities to assemble them and document their outputs. The best participants will be those who are willing to set aside any biases they may have toward a particular perspective and who are willing to contribute freely on the premise presented.

Reliability

Brainstorms generally have low reliability. Although some of the insights generated will be extraordinarily valuable, it is a matter of "sifting the wheat from the chaff." To arrive at a handful of key nuggets of information, the facilitator of the brainstorm may also catalog dozens of lesser ideas.

Selection Criteria

As with each chapter on techniques, brainstorming is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare brainstorming with other techniques, review Table 6.

Resource Requirements

The basic resource requirements for brainstorming include the participants, the facilitators, and the materials with which their insights will be captured. The tools for data capture are normally nothing more than flip charts, an erasable board, or a laptop computer.

The personnel participating in the brainstorming session should have a basic understanding of the premise(s) that the brainstorm addresses and a willingness to share their insights. They should also be individuals who have the ability to communicate in a fashion that allows others to understand what they are sharing but without sounding critical of others' inputs.

- *Cost* for brainstorming is relatively small. The sessions are generally conducted in conjunction with other project activities.
- There is normally no capital investment required in terms of *proper facilities and equipment* for brainstorming. Most facilities have documentation equipment and a meeting room adequate to the task.
- The *time needed to implement* brainstorming is not as abbreviated as some might think. This technique is not inherently a quick endeavor but will depend on the participants and their willingness (or eagerness) to share information. Exhausting the pool of ideas of some groups may be a relatively short effort; yet for others, exhausting their creative energies can take several hours.

- *Ease of use* is high as most business professionals have, at one time or another, participated in one or two brainstorming sessions. Familiarity encourages use, and as such, brainstorms are widely applied. The key challenge for most facilitators, however, will be to control the group's urge to critique inputs as they are provided.

- The project manager's *time commitment* largely depends on whether the project manager is the facilitator of the session, which happens in many cases. The project manager then becomes responsible for developing the premises for discussion and for postsession information distillation. As such, there is a modest commitment on the part of the project manager when a brainstorm is conducted.

Applications

Brainstorms are effective when they are directed at a clear, easily discernible goal, which is crucial. Without an objective for the outputs, risk brainstorms can easily deteriorate into complaint sessions.

- *Project status reporting* receives limited support from this technique because quantifiable data are normally preferable for status reports. Whereas some types of qualified data may be appropriate in this area, outputs from brainstorms are not among those types.

- *Major planning decisions* are not closely tied to brainstorms, although some of the implications of such decisions could be reviewed in a brainstorming environment. Once again, the qualitative nature of the technique limits its utility here.

- *Contract strategy selection,* like major planning decisions, may benefit from a brainstorm in terms of a review of implications. However, brainstorms are not a key tool to be applied here.

- *Milestone preparation* receives only nominal support from this technique as the general nature of a brainstorm's outputs does not lend itself to the specificity associated with milestone preparation.

- *Design guidance* may draw strongly on brainstorms because there is frequently a need to examine the breadth of options at an organization's disposal. Because design is a creative endeavor, the creative energies of brainstorming may work to the organization's advantage here.

- Brainstorming generally does not support *source selection* except for open discussions of the implications of selecting certain sources.

- *Budget submittal* is not normally seen as a brainstorming situation because both inputs and outputs in the budget process are highly quantitative.

Although brainstorms have limited utility for many of these areas, they are virtually without equal in environments where quick analysis is needed and individuals with a willingness to participate are available. For risk identification, qualification scheme discussions, and risk response development, brainstorming can produce volumes of valuable information from which the best available responses can be derived. Brainstorms afford new perspectives, and new perspectives are essential to the success of any risk management effort because risk management is a foray into the unknown.

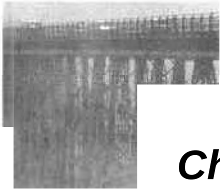
Outputs

The outputs of brainstorming are generally a list of insights on the premise presented.

- *Accuracy* of brainstorms is generally seen as low. Because many weak ideas are generated with the good, some view brainstorming as highly inaccurate. If, after the brainstorm, the facilitator can cull through and select the truly valuable data, the accuracy of the process can increase significantly. On the whole, the process generates imprecise and potentially ambiguous data.
- *Level of detail* is normally premise-dependent. If the premise of the question put forth in a brainstorm is nebulous, the level of detail will be weak. If the premise is focused, the level of detail for outputs will be more focused as well.
- *Utility* is high for brainstorming despite its other shortcomings. Because the tool and the application are familiar in a variety of different areas, project managers frequently lean toward brainstorms as the tool of choice.

Summary

Brainstorms often open the door to a free and candid discussion of risk and risk issues. For that alone, they add value. But, in addition, they add to the body of knowledge about a given project or risk area. They encourage new perspectives and new understanding of risk. They can also lead to new approaches in risk qualification, quantification, and response development. In all those regards, the brainstorm serves as a foundation tool for risk management.



Chapter 12
Crawford Slip Method

Gathering data is one of the greatest challenges in risk management as there is a propensity for risk identification and risk information gathering to become a negative influence on team members and their attitudes about the project. The Crawford Slip Method (CSM)[5] is a classic tool for gathering information without the negativism inherent in many risk discussions.

CSM has a variety of advantages over other information gathering techniques. These include its ability to aggregate large volumes of information in a very short time and its complete avoidance of groupthink, where team members become embroiled in a particular tangent and cannot extract themselves.

Technique Description

With proper facilitation, CSM is an easy technique to apply. The basic approach involves establishing a clear premise or question and then having all participants in the process document on a slip of paper their response to that premise. Using the same premise, the process is repeated 10 times (per Crawford) in order to extract all the information available. Although there may be a great deal of similarity among the initial slips, those generated later tend to identify issues and risks that otherwise would never have surfaced. Applications for risk management often cut the number of cycles to 5 because team members frequently lack the fortitude to formulate 10 responses to each premise.

When Applicable

This technique is recommended when team members are available to provide inputs, but there are limits to their desire to share information in a

[5] C. C. Crawford developed the Crawford Slip Method at the University of Southern California in 1926.

group setting. CSM is also appropriate when there is a need to generate a large volume of information in a short span of time.

Inputs and Outputs

The key input for CSM is a clear premise. If the premise or question posed to the group is not detailed, clear, and well crafted, the method will generate either poor or the wrong outputs. The premise should clearly state the information sought and the environment or assumptions surrounding the information. It should be documented for the facilitator so that he or she can refer to it while working through the iterations of the process.

Outputs from the process will be a significant number of slips of paper from the participants, preferably arranged according to the premises presented. The participants may arrange or organize the slips during the working session, or the facilitator may arrange them at some later time. The quality of outputs will correlate directly to the precision with which the premise was stated and the direction provided to the participants. Poor explanations on how to write risk statements or how to identify the information in question will invariably lead to inferior outputs.

Major Steps in Applying the Technique

The technique relies heavily on facilitator skill and the ability of the facilitator to follow the process. That process requires the facilitator to direct a nonspecific or nonthreatening question to the group and allows for individual responses, one at a time, on paper from each participant. This process ensures consistent levels of inputs from each participant and also builds the largest volume of information possible. The process, in its simplest form, consists of six steps:

- *Bring together those participants with an awareness of the issue at hand* Even though complete subject-matter expertise is not essential, awareness is. Those participating in any type of risk information gathering effort should have at least a superficial awareness of the concerns and issues in the project.
- *Identify the primary rationale for the process.* Regardless of whether CSM is being applied to identify risks, identify risk triggers, recognize risk sources, or develop risk responses, participants need to be aware of the reason for their involvement. Because the process is designed to draw on their insights, they clearly need to know what insights they will be expected to share.
- *Issue slips of paper.* Although literature on CSM specifies the exact size of the paper to be used and the number of slips appropriate to the

method,[6] for project risk analysis, these decisions rest largely in the hands of the project manager. In many instances, ordinary "stickie" notes will be sufficient and effective to serve the purpose. The number of slips will determine the volume of the outcome.

- *Explain the process.* The facilitator will tell participants that they will be expected to contribute one idea per slip of paper and that the facilitator will specify what information is to go on the slip and when. In intervals of roughly one minute each, the facilitator will state a question or premise (such as, "What risks do we face on the Nancy Project?"). The participants will write down their thoughts, set that slip aside, and prepare to write another idea on the next slip.
- *Begin the process and cycle through it iteratively.* The facilitator will then walk participants through the process. Each participant should have one response per slip, and no slips should be lost. The number of cycles will determine how much information is generated.
- *Gather and/or sort the data.* Once sufficient cycles have been completed, the facilitator may simply gather the data and terminate the session; or he or she may instruct participants to sort their slips either into pre-ordained categories or into groups that seem to have natural affinities. The information gathered now represents a current body of insight from individuals familiar with the project.

Use of Results

The uses of CSM results generally are applied in establishing an initial pool of risk events associated with the project *or* the options available to respond to risks on the project. The body of information will sometimes be sufficient to develop preliminary risk reports (general overviews of the body of risks on a project), or it may require distillation prior to such use. When being used to develop risk responses, CSM may serve to generate a volume of options that may be reviewed later using tools such as the risk response matrix (Chapter 26).

Resource Requirements

Once understood, CSM is perhaps the simplest of the high-volume information gathering techniques. If the facilitator knows the premise of the session and has the ability to communicate precisely the types of outputs participants are to produce, the sessions tend to be extraordinarily productive. Often, the key rests not in the CSM facilitator but in the

[6] Gilbert B. Siegel and Ross Clayton, Mass Interviewing and the Marshalling of Ideas to Improve Performance (Lanham, Md.: University Press of America, 1996).

participants selected to participate in the process. Their level of awareness will be a determinant of the quality of information produced. If they have project awareness plus a basic understanding of the risks that the project may face (or how to resolve them), they may be able to make significant contributions through CSM.

Reliability

The technique tends to produce highly variable data, largely because of the volume of information produced. Although that may be perceived as a weakness of this approach, in this situation it is actually a strength. Risks are frequently discounted as being "too remote" or "too far-fetched" until they actually occur. Because the process generates such a large volume of risk data, it tends to capture ideas from the sublime to the ridiculous; and because the process is anonymous, it frequently captures information from those who would not readily participate in a more public venue, like a brainstorm.

Selection Criteria

As with each chapter on techniques, CSM is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare CSM with other techniques, review Table 6.

Resource Requirements

The resources essential to CSM are extremely limited. The technique requires paper slips, pens or pencils, a facilitator, and participants. It may also employ a predetermined set of risk or risk response categories for sorting information, but that is optional.

The basic tools of CSM are office supplies. Although books on what is sometimes referred to as the "mass interviewing technique" suggest specific sizes for the paper, such decisions largely rest in the hands of the facilitator. The paper should be sufficient in size to capture the information requested and manageable for any later sorting required.

As mentioned earlier, facilitation skills required for CSM are minimal. If the basic premise questions are clearly established and the participants are told precisely what format their final responses should take, facilitation becomes extremely easy. The only management required of the facilitator is controlling participants who either fail to complete their slips or who jump ahead in the documentation process.

CSM participants should be aware that they will be expected to contribute to the process. In many other, more public idea generation techniques, such pressure is not brought to bear as more reticent participants can waive participation. In CSM, however, all participants are expected to contribute equally.

Finally, some CSM sessions will incorporate predetermined sorting criteria for cataloging the data after the session. If such sorting is required, the definitions for the categories should be clearly stated before sorting begins. Beyond the CSM-specific requirements, the demands for the technique are minimal.

- *Cost* for CSM is extremely minimal. CSM sessions are frequently measured in minutes rather than hours. While multiple participants are essential to CSM success, their time commitment for the process is limited based on the number of iterations.
- *Proper facilities and equipment* for CSM consist of a room large enough to accommodate all the participants invited to the session. There should be sufficient pencils or pens and slips of paper to ensure that all participants can respond to all iterations for the question(s) posed.
- The *time needed to implement* a CSM is perhaps its most attractive quality. Compared to any other technique discussed in this text, CSM requires less time to generate more information.
- *Ease of use* is another attractive trait since CSM can be incorporated into other meetings where the appropriate personnel are brought together to work on the project. The key is in establishing the clear premise for the session and the outputs desired from the participants. If that information is clearly expressed at the beginning of the session, the process will be relatively easy to deploy. The only challenge, however, may come from those individuals who are not anxious to take part. The facilitator may have to reinforce the rationale for the session and the value of each participant's inputs.
- The project manager's *time commitment* is extremely slight.

Applications

CSM can be used in a number of different situations, but it does not have the broadband utility of more general techniques like expert interviews. CSM's applicability is assessed on a scale of high, medium, and low.

- *Project status reporting* is not a strength of CSM. Because CSM generally focuses on educing insights about approaches or concerns, it does not attain the level of specificity required for project status reporting. Its value here would be extremely low.

- *Major planning decisions* tend to rely on quantitative data rather than volumes of qualitative information. For this process, the value of CSM is low.
- *Contract strategy selection* tends to rely heavily on quantitative information. CSM has extremely limited value in this regard.
- Applying CSM in *milestone preparation* would be largely a mis-application of the tool. Whereas milestone preparation is normally born out of a careful needs analysis, CSM is more of an ideation tool rather than an analysis tool.
- *Design guidance* may take advantage of CSM since design development is frequently a function of reviewing options and assessing possibilities. Because design guidance is more of a creative endeavor that requires inputs from diverse sources, CSM can have medium utility here.
- *Source selection* is not an application of CSM. Source selection should be conducted against a predetermined set of criteria and should not rely primarily on fresh ideas to determine the best available source.
- *Budget submittal* is a quantitative process and thus cannot take advantage of CSM.

However, CSM does serve two primary applications. It is used for risk identification, both alone and in conjunction with other project management tools (such as the work breakdown structure). In that environment, it is virtually peerless in its ability to generate large volumes of risk statements in a nonthreatening and positive way. In addition, it is impressive in its ability to capture a variety of risk management strategies and responses. CSM's ability to draw out insight without alienating the participants is striking.

Outputs

CSM's outputs are stacks of paper slips, each slip with a single idea or piece of information, which may or may not be sorted into preordained categories. Generally, the information gathered tends to be qualitative and represents individual perspectives.

- The *accuracy* of CSM is largely dependent on the insight of the process participants. It generates qualitative information that, although valuable, may not be considered highly accurate.
- *Level of detail* is a true strength of CSM, particularly in regard to the amount of time invested. Unlike other tools that are limited by the group's ability to catalog information serially, CSM allows for expedient

collection of significant volumes of data, often yielding details that would otherwise be missed.

- *Utility* is a subjective factor that takes into account both the effort involved and the value of the resulting information. The utility of CSM data is rooted in part in the background of the participants and their knowledge of the project and its risks. How CSM data are distilled, sorted, and interpreted may also drive its utility. Given the volume of information involved, effective interpretation of the data is critical to the outputs' utility.

Summary

The keys to the success of the Crawford Slip Method are the clarity of the premises presented, the backgrounds of the participants, and the distillation of the outputs. However, because of the efficiency of the process, occasionally there is a temptation to draw it out for a longer period of time than is necessary. Nevertheless, the method's strength is its efficiency. With properly staged questions or premises, CSM builds a substantial volume of valuable data in a very short time.

Chapter 13 SWOT Analysis

Strengths, weaknesses, opportunities, and threats — SWOT analysis — is essentially a directed risk analysis designed to identify risks and opportunities within the greater organizational context. The main difference between this and other analysis techniques is that SWOT reinforces the need to review risks and opportunities from the perspective of the organization as a whole rather than just from inside the project vacuum.

Technique Description

The technique consists of four brief idea generation sessions held to populate the analysis documentation with answers to these questions:

- What are our organization's strengths?
- What are our organization's weaknesses?
- What opportunities does this project present in that context?
- What threats does this project present in that context?

Using the answers to those four questions, the project manager can discern any specific cultural, organizational, or environmental issues that may either enable or cripple the project in question.

When Applicable

This technique is recommended early in the project as an overview analysis or to establish the general risk (and opportunity) environment. Because a SWOT analysis is seen as a big-picture tool, it is not designed to draw out detailed project risks. Thus, its greatest utility is near the inception of the project.

Inputs and Outputs

SWOT analysis has four key types of inputs. The inputs comprise the questions cited above. The SWOT facilitator poses these questions to either individuals or groups, eliciting as many concise, incisive responses as possible.

Those responses are then presented in a four-square grid, designed to allow for analysis and cross-reference. The grid is laid out in the following format:

Strengths	Weaknesses
Opportunities	Threats

Major Steps in Applying the Technique

SWOT analysis is a subjective tool, so practices on completing the grid may vary with the facilitator. Nonetheless, the steps for completing the tool are rather consistent:

- *Identify the SWOT analysis resource(s).* Selecting the right subject matter experts to complete the SWOT analysis is important. This is not a good tool to use with someone who is unfamiliar with the organization or the environment. Therefore, it is important to work with individuals who understand the culture in which the project will function since they will have a better sense of the strengths and weaknesses portions of the analysis.

- *Ask about the organization's strengths.* This should be within the project context, but it is still important for the facilitator to reinforce the fact that the question is not about the project but about the organization. What does the organization do well? Sometimes there is a temptation to be modest about organizational capability; this is not that time. Strengths should be articulated from the perspectives of both those working within the organization and their customers.

- *Ask about the organization's weaknesses.* Although this is in the project context, it is essential to educe as much information as possible about where the organization fails to perform well. Honesty and candor are critical. This should not be used as an opportunity to complain about the organization but, instead, to identify weaknesses that make the organization less capable in the eyes of its employees, its customers, and the public.

- *Ask what opportunities the project presents.* This should not be exclusively a monetary issue. The financial value of the project is important, but it is not the only reason for pursuing any piece of work. Are there promotional opportunities associated with the project? Are there opportunities to build the client base? Are there opportunities to win hearts and minds *inside* the organization? Be sure to examine the potentially positive influences both internally and externally.
- *Ask what threats could imperil the project.* Invariably, there are scenarios where any project could fail. The key is to define those scenarios and to identify the specific threats that exist that could do harm to the project *or,* because the organization pursues the project, do harm to the organization.

Use of Results

SWOT analyses are normally used to present project information to management. The idea behind a SWOT analysis is not to build a strong case either for or against the project (although that frequently occurs) but to present the pros and cons of a project openly. The SWOT analysis is sometimes used to encourage management to alter some environmental factors from the strengths and weaknesses sections that will directly influence the project. In some instances, the project manager also perceives it as a self-protective measure to ensure that if those environmental influences do harm to the project, management was alerted to them early and proactively.

Resource Requirements

A SWOT analysis, as with most of the qualitative tools, requires individuals with only modest knowledge of the project and the organization in which it will be performed. Obviously, the greater the depth of organizational background, the greater the depth of the analysis. The facilitator's principal skill is in asking the questions and thoroughly documenting the responses.

Reliability

SWOT analyses are highly subjective, and as such, they can be somewhat unreliable. However, because they are broadly used and generally accepted as business practice, they frequently take on an aura of acceptability that they may not merit. The more reliable and insightful the participants in the analysis are, the more valuable and reliable the analysis becomes.

Selection Criteria

As with each chapter on techniques, the SWOT analysis technique is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare SWOT analysis with other techniques, review Table 6.

Resource Requirements

The only resource requirements for SWOT analysis are the facilitator, the participants, and the grid. The key to success will be the quality of the participants.

The facilitator has two main roles: listening and documenting. Because the questions in a SWOT analysis are standardized, the facilitator's primary function is to capture the insights of the participants. A good archivist will have the ability to document information as it is being shared. As a safeguard, the facilitator should occasionally provide feedback as to what has been documented to ensure that it adequately reflects what the participants said.

The participants' primary function is to share their insights about the organization and the project. As such, the best resources will be those with familiarity in both areas.

The grid is a standard format for capturing basic project documentation. The four quadrants should ideally appear on the same page so that the insights within the four quadrants can be cross-referenced and compared during any post-SWOT analysis. The grid is sometimes expanded into a matrix (Table 10) to allow for extended cross-reference of strengths and weaknesses on one axis and opportunities and threats on the other axis. The intersecting boxes are then marked with plus signs (+) to indicate areas of specific potential improvement and minus signs (–) to indicate potential areas of harm.

- *Cost* for a SWOT analysis is minimal because the document is designed to capture incisive, short statements from the experts. As no special facilitation skills are normally required, there is no expense for an outside facilitator.
- *Proper facilities and equipment* for a SWOT analysis are minimal because the process requires only the space in which to conduct it.
- The *time* needed *to implement* a SWOT analysis is an aspect in the technique's favor. SWOT analyses are normally events lasting less than an hour. Although they can take longer with more participants, lengthier discussions may not have any significant value because the

	Opportunity We may find new staff	**Opportunity** We may discover a new process	**Threat** We may lose personnel	**Threat** We may damage the client's facility	**Threat** The client may identify an alternative vendor
STRENGTH We have **a** superb marketing team					+
STRENGTH We offer outstanding employee benefits	+		+		
WEAKNESS Management tends to micro-manage on-site personnel		−	−	+	
WEAKNESS We use outdated processes		+	−	−	−

Table 10. SWOT *Matrix*

SWOT analysis outputs are designed as a single grid populated with brief insights on the four areas.

- Ease *of use* is an attractive feature of the SWOT analysis since it is quick, requires no special tools, and generates a familiar piece of project documentation (a grid). Because no special facilitation skills are required and the grid is self-explanatory, the SWOT analysis has an extremely high ease of use.
- The project manager's *time commitment* is slight even if the project manager assumes the role of SWOT analysis facilitator. Because the analysis is brief and the questions are preordained, the time commitment of those conducting the analysis is limited as well.

Applications

The key application of the SWOT analysis is early in the project to draw attention to the organizational or environmental influences on the project. In many ways, the SWOT analysis is as much a presentation tool as an analysis tool. Because of the ability of the SWOT analysis to draw attention to the organization's issues and concerns that will potentially affect the project, the tool is more valuable than an analysis of risk alone. Because the tool presents this information concurrently, it affords the project manager the opportunity to present risk in a greater context.

- A SWOT analysis does not generally affect *project status reporting.* Unless the analysis is updated at the time of the status report, the two bear little or no correlation.
- *Major planning decisions* may rely in some measure on a SWOT analysis since the tool is good for high-level presentations of information as well as high-level analysis.
- The SWOT analysis would only affect *contract strategy selection* if specific contract types or specific types of contract work were identified as strengths or weaknesses within the analysis. Otherwise, the two are relatively unrelated.
- Using a SWOT analysis in *milestone preparation* would be a misapplication of the tool.
- *Design guidance* can take advantage of the SWOT analysis since the design may in some measure be a function of the organization's strengths and weaknesses and how they play into the opportunities and threats that the project presents. The SWOT analysis allows for high-level defense of design strategies or challenges to those strategies.
- *Source selection,* like contract strategy selection, would be affected only if specific sources or types of sources were identified as strengths or weaknesses within the analysis.
- It is not likely that a SWOT analysis will directly affect *budget submittal* as budgets are derived almost exclusively from purely quantifiable data.

SWOT analyses are powerful in presenting information in the aggregate. They juxtapose information that otherwise would not be examined in tandem. That is important since context frequently influences risks. As a tool, SWOT analyses have limited utility, but for presenting information as described herein, they are invaluable.

Outputs

The outputs of the SWOT analysis are normally posters or graphic displays that present the four-quadrant grid. The outputs are normally qualitative and reflect the biases or concerns of the facilitator and those who provided the inputs.

- The level of *accuracy* for the SWOT analysis would be low because the tool is highly subjective and relies on the perceptions of those who generated it. Whereas the analysis presents valuable insight, the accuracy of the insight hinges almost exclusively on the skills and expertise of those who provided the inputs. If they provide accurate information, the outputs will be accurate. If, however, their information can be called into question, then the outputs may be called into question as well.

- *Level of detail* for the SWOT analysis is low since the tool is designed primarily for high-level analysis. The SWOT analysis is designed to address sweeping organizational issues rather than details within the project.
- The *utility* of the SWOT analysis can be high in organizations where presentations dictate future action. The SWOT analysis is an accepted presentation format for risk information, and as such, may make risk discussions more palatable than other approaches.

Summary

Due to its high-level nature, SWOT analysis has limited utility. But because of its general acceptance in the business community, SWOT analysis can be effective in drawing management and executives into risk discussions in which they otherwise would not be interested. If management has a propensity for analyzing information at the macro level, then the SWOT analysis may be a tool of choice. Otherwise, the data evaluated in a SWOT analysis can frequently be extracted and presented using other tools.

Chapter 14
Checklists

Technique Description

Checklists are classic tools of risk identification, drawing on the experience of other project managers and past projects to ensure a level of consistency in early risk analysis. They consist of simple lists of questions or statements based on lessons learned from earlier projects, which allow the project manager to build early risk lists that reflect risks faced on previous projects.

When Applicable

This technique is recommended for all projects in organizations where checklists have been developed. Some external organizations, such as the Software Engineering Institute (SEI), have developed generic risk identification checklists for all projects in a given field (such as SEI's taxonomy-based risk identification checklist). The technique is normally applied early in a project, although checklists can also be used at midterm and final project evaluations. PMI® recommends applying checklists each time a project closing procedure is conducted.

Inputs and Outputs

The inputs to build the checklists are past experience of project teams and clear documentation of their experiences. Once the checklists have been created, however, the inputs to applying checklists are nothing more than the checklists themselves. The project manager and the project team should take the checklist and openly, honestly discuss the issues and concerns addressed by the tool.

Depending on the construction of the tool, the checklist may do little more than generate red flags to warn of categories of concern or specific risks. If the tool is software-driven and more complex, it may also provide a list of recommended basic actions to guide the project manager and the team toward best-practice experience in handling any of the risks or risk areas identified in the tool.

Major Steps in Applying the Technique

Operating under the assumption that a checklist has already been created, the process associated with checklists is among the simplest of all the risk tools:

- Review the risk checklist. Ensure that the project team is working with a checklist that is appropriate to the environment, the culture, and the project in question. Because some risk checklists are designed to address issues within a given organization or within a given project type, it is important to work with a tool that is appropriate to the project at hand.
- Answer the questions or check the appropriate boxes on the checklist. Checklists normally come with guidance to direct the user on appropriate application. Such applications are simple question-and-answer sessions or rating schemes to assess the likelihood of encountering some common risks.
- Review and communicate the guidance provided. Even though checklists normally include some direction on how to fill them out, they also include guidance on how to apply the findings. In some cases, those findings may represent nothing more than a list of commonly identified risks (or risk areas) for the project. However, some of the more advanced checklists will also embed suggestions on standard internal practice and procedure for resolving or managing the risks identified. Guidance of any nature should be communicated to the team.

Organizations looking to build their internal risk practice can frequently develop that practice by generating checklists. Checklists are often among the first steps that a project office takes to build a broader understanding of the depth of risks within the organization and the support that they can provide in ameliorating some of those risks.

Use of Results

Because checklists are first applied early in the project, outputs can be used to provide a general understanding of the nature of risks and the concerns in the project in a nonthreatening fashion. Data from risk checklists tend to cause less anxiety since the questions asked (or statements made) are applied equitably to all projects, and the outputs are normally familiar to the organization. Outputs at the end of the project should be used in any reevaluation of the checklists for additions or deletions.

Resource Requirements

Checklist reviews normally require only two participants. Ideally, at least two people should review a series of checklist responses to ensure that personal biases do not influence the outputs. The only other resources required are the checklist(s) and a tool for storing the outputs of the process.

Reliability

The reliability of the process pivots on the quality of the checklist. A sound checklist built to reflect the organization's culture, nature, and project history will build an excellent set of initial project risks. A checklist that a single individual crafts after a single project without considering the organizational culture will have limited reliability. The best checklists are those that capture experience from a variety of projects and a variety of project teams. Answered candidly, checklists of that caliber can generate extremely positive and reliable results.

Selection Criteria

As with each chapter on techniques, the checklist technique is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare checklists with other techniques, review Table 6.

Resource Requirements

The checklist has among the lowest resource requirements of any risk tool unless there are unusual resource demands peculiar to the individual list. Except when extensive research is required to answer the questions in the checklist, the time commitment is limited. And unless particular skills are required to answer the questions in the checklist, no special talents are required of the personnel working with the tool.

- *Cost* for completing a checklist is extremely low since it expedites the process of preliminary risk analysis by suggesting a host of predetermined risks that are already appropriate to the organization and its projects. The initial costs of *developing* a checklist will be more substantial, however, and will require a much higher resource commitment.
- *Proper facilities and equipment* for completing a checklist are nominal. The only real equipment required is a pencil or pen unless, of course, the checklist is on-line, in which case a computer is required.
- The *time needed to implement* checklist completion depends largely on the research required to complete the checklist questionnaire. That, in

turn, hinges on the number of questions the questionnaire asks. In any case, most questionnaires can be completed in a day at the extreme.

- *Ease of use* is high as the tool is highly directive and the questions are specific. Even the novice project manager can normally apply a risk checklist with nominal direction.
- The project manager's *time commitment* again depends on the research required to complete the checklist. If the checklist asks questions that do not require extensive analysis, the time commitment is nominal. If, on the other hand, the questions or issues statements in the risk checklist require analysis, customer questions and answers, or a thorough grounding in a new technology, the time commitment will clearly expand. Yet in most instances, the time commitment is slight.

Applications

Depending upon its design, the checklist can have a variety of applications. The key, however, is to use the checklist for the purposes for which it was built. Using the wrong checklist at the wrong time can lead to confusing and misleading outcomes.

- Risk checklists support *project status reporting* only when status is their primary intent. If the checklist is designed to investigate project data integrity or overall risk levels, it can have high applicability here.
- *Major planning decisions* are normally not based on checklists. Major planning decisions are generally tied to the specifics of a project, whereas checklists are more general in nature.
- *Contract strategy selection* may rely in some measure on checklists if the checklists are specifically designed to internally address contract types and the issues regarding certain contracts, clauses, or approaches.
- Checklists can support *milestone preparation,* like contract strategy selection, if the checklists are specifically designed to support that purpose. Generally, however, the connection here would be extremely weak.
- Checklists do not support *design guidance* unless they are specifically tailored to support design issues.
- Checklists may support *source selection* as they expose risk issues in a general sense, which may apply specifically to a source under consideration.
- A risk checklist does not support *budget submittal.*

Risk checklists are normally used to establish whether certain issues have been addressed. As with the specific project areas discussed above, it is possible to have checklists that are specific to a need. For most checklists to be effective, however, they need to be more general in application. They are used to identify risk considerations on the project as a whole and to facilitate gap analyses. In many instances, the project manager will use the questions or statements in a risk checklist as a defense for including a particular risk as a project consideration. The argument that "the checklist even asks if it's going to be a problem" is one that is not uncommon in project risk discussions.

Outputs

Risk checklist outputs are generally derived according to the guidance provided with the particular checklist. In some cases (as with SEI's taxonomy-based risk questionnaire), the outputs will be strings of yes or no answers supported by explanations as to why a yes or no answer was derived and some follow-up as to what action will be taken. In some automated tools (such as PMPulse's *VizPulse*™), the outputs will be combinations of graphic displays and lists of action items. And in still others, the checklist will merely indicate which actions have been taken and which have not.

- The *accuracy* of checklists is normally relatively high. Questions are couched in unambiguous fashion. Outputs are normally predetermined. Inputs are simple and readily answered from the base of project information. From project to project, there is consistency.
- *Level* of *detail* is wholly dependent on the depth of detail within the spreadsheet itself. Some checklists include hundreds of questions or statements, whereas others incorporate as few as 10. The level of detail is based on the type of tool applied. The greater the level of detail the checklist demands, the greater the level of detail in the analysis.
- The *utility* of checklists is extremely high because they have been reviewed, validated, and applied on multiple projects. They normally address the breadth of an individual organization's risk issues and draw on the expertise of the organization's veterans in establishing the "right" questions. They can be applied on different project types and allow for more of an "apples-to-apples" risk comparison without a significant investment of time or money for the analysis.

Summary

Checklists are powerful, easy-to-use tools for risk identification and analysis when organizations take the time to build them. The major investment in any good checklist is the initial development of the checklist and the occasional interim review of its application. Project offices or veteran project managers are frequently the arbiters of whether a checklist serves the organization's needs. Although it is impossible to build a checklist to identify every risk or to cover every category, it is possible to cover most risks endemic to an organization.

Chapter 15
Project Templates

This technique is based on the precept that in many organizations templates exist to facilitate planning and to minimize risk. Templates are essentially nothing more than fully developed plans, forms, or outlines that provide structure for an organization's project managers. These templates often manifest themselves as elements of a much larger project methodology (discussed in Chapter 5). By properly applying these templates (or merely recognizing their existence), it becomes possible to mitigate additional risk and apply best practices to existing risks.

Technique Description

The technique consists of examining a series of templates covering specific areas that may present technical risk to a project. Each template examines an area that frequently spawns risks and then describes methods (or provides examples) to avoid or control that risk. Many risk descriptions and solutions are rooted in lessons learned from other projects. Some examples of areas that such templates may cover are illustrated in Figure 14.

When Applicable

Project templates should be used for most projects, either independently or in conjunction with another technique. Templates are generally built-in response to past incidents as a means to preclude a risk that has already befallen an organization. Organizational templates specifically contain extremely valuable information because they are based on actual experience. The information can be pertinent for any size project at any phase of development. Because the technique views project management as a complete process, the solutions presented reflect the interdependency of each part of the cycle. In other words, a conscious effort is made to present a solution that lowers the total risk for the entire project, not just for short-term problems.

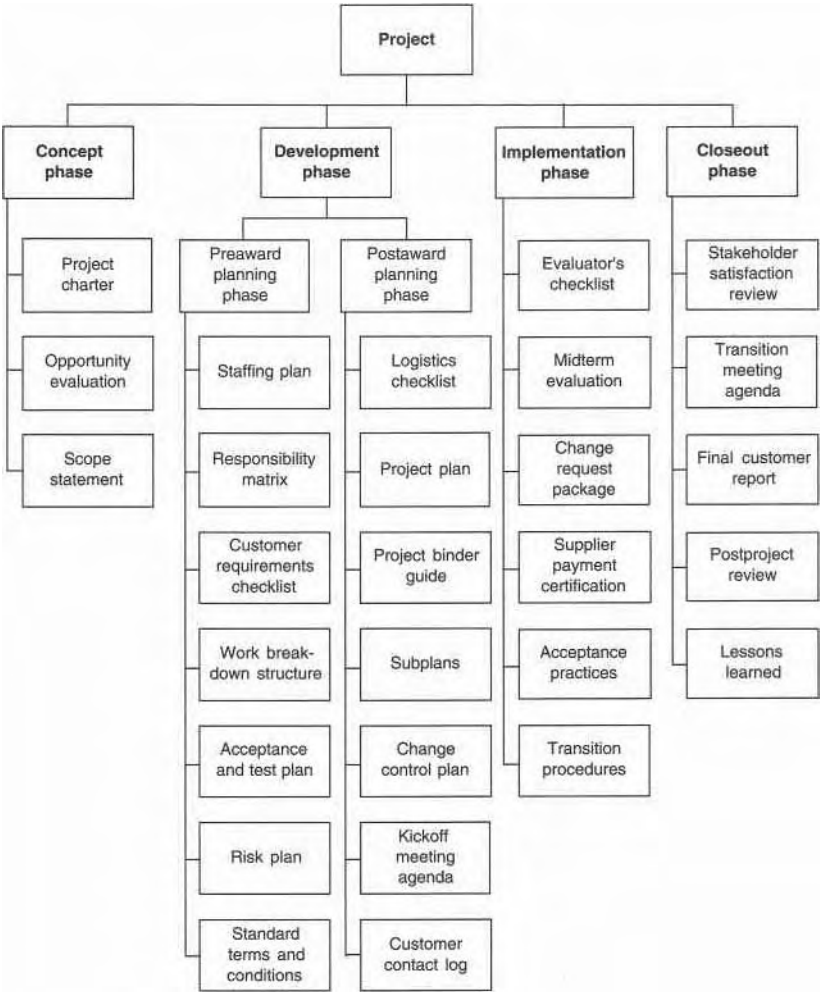


Figure 14. Common Project Management Templates, Arranged by Phase

Inputs and Outputs

Each template will require inputs specific to that template. In a perfect world, all the templates necessary to succeed would already exist in an organization, complete with guidance on how to apply them to every type of project. This effort is normally under the purview of senior project managers or a project office.

The application of templates requires discipline. Time must be committed to reading the templates as well as the organizational methodologies driving them and then to using that information to examine risk within a given project. Practical outputs of the technique are basic lists of risks built from past experience.

Major Steps in Applying the Technique

Because methodologies and templates cover areas common to nearly every project, each template should be reviewed for applicability. The project manager determines whether the template is appropriate to the project and its specific technical risks. After reviewing the template, the project manager or the team members responsible should evaluate the project in terms of solutions or risk mitigating actions that the template would prescribe. A periodic review of all templates is recommended with updates as the project progresses. In some cases, simply applying the template or reviewing its contents will be sufficient to identify (or in some cases, even mitigate) risks.

Use of Results

Results from templates can be used in a variety of ways:

- In presentations to higher levels of authority
- To influence the team members' current level of activity in an area
- For continued monitoring of progress in each project area

However, the second result is the most commonplace. In many instances, templates are used to modify team member behavior by reinforcing what data must be gathered or by encouraging certain documentation practices.

Resource Requirements

Since the inputs are template-specific, most of the inputs are also specific to the individuals responsible for the given template. For example, if procurement templates (such as Supplier Payment Certification) are applied, then some procurement staff support may be required. Although inputs may be required from a variety of functions, using templates should not necessitate substantial special skills or extra resources.

Reliability

Two cautions apply when using this technique:

- Project participants should not assume that templates contain all possible technical risks within a given area. Although common problems are frequently identified, this technique does not generate an exhaustive list of risks.

- Templates may not contain information regarding several programmatic risk areas that should also be examined.

Selection Criteria

As with each chapter on techniques, the project template technique is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare project templates with other techniques, review Table 6.

Resource Requirements

- The additional *cost* associated with project templates is small. This technique requires little additional resourcing beyond what is normally necessary to manage a project properly. The time consumed is nominal as long as the work is done continuously and incrementally.

- There are no special equipment needs for this technique because it is primarily a small administrative burden. For *proper facilities and equipment,* the only requirement is to find the files, databases, or shelves housing the information.

- The *time needed to implement* project templates is actually a function of the level of discipline of the project manager coupled with the nature of the templates themselves. Project templates must be reviewed (and comparative project progress analyzed) regularly against each of the template areas.

- Project templates have extremely good *ease of use.* They do not require special skills beyond being able to comprehend the information requested for each particular template. In fact, they are designed to prevent organizations from regenerating established protocols each time a new project arises.

- The project manager's *time commitment* to the templates is moderate because the project manager invariably will spend some time selecting the appropriate templates for the project and will also be responsible for reviewing the templates as they are completed. The time investment is well worth the return, however, because the project team develops information that virtually anyone in the organization's project support structure can understand.

Applications

Project templates can be used in most application categories in Table 6. The technique is only indirectly useful in the budget category because it deals with preventive technical aspects rather than cost issues. It can, however, provide insight into the impetus behind both cost and subcontractor actions in situations involving vendors.

- For *project status reporting,* project managers often find it helpful to build their status reports in the formats that others have designed. This convention of building on past efforts within the organization becomes more time- and cost-effective as the organization develops. As a project template, project status reports will inherently highlight some issues that have arisen in the past.
- *Major planning decisions* require a sense of organizational history, which project templates offer as well. If an organization has project templates in place either on an ad hoc basis or as part of a methodology, the templates can expose issues that have driven major decisions in the past.
- In most cases, *contract strategy selection* has some type of existing templates. Project templates encourage consistency in contract development and organization from project to project.
- *Milestone preparation* often requires the use of project templates. Templates are often structured around milestones in order to specifically meet internal or external reporting needs. Templates for these events are commonplace and thus become critical tools for the project manager. By using templates (such as closeout checklists, annual budget review formats, or decision point analysis grids), the project manager can ensure that all reports, components, or completion criteria for a particular milestone are prepared in a timely fashion.
- In terms of *design guidance,* project templates have clear utility. But there is a caveat: Project templates rely on history and the latest developments in technology design often drive design. As such, the information that the template requires may not fit within current desired designs. In most cases, however, project templates are a good fit for design guidance because even as technology changes, many of the same questions or issues continue to apply.
- *Source selection* requires rigorous procedures if vendors are to be assessed fairly and consistently. Project templates may include those procedures.
- *Budget submittal* is not a clear use for project templates. Although the templates facilitate formatting, they do not generally include relevant historic cost data. That information can be obtained only through rigorous analysis.

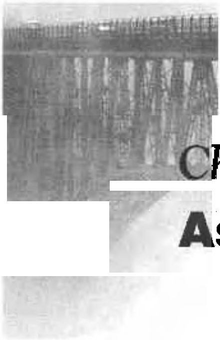
Outputs

If the user properly documents results from a review of project templates, the outputs will provide a set of traceable management data that can be used to make sound decisions on a variety of customer, personnel, and technical issues.

- *Accuracy* of the project templates technique is a direct function of the project manager's adherence to the approach. There is often a temptation to skip templates that do not seem to address the project at hand, but if that is done, it may result in missing some key problem areas.
- The *level* of *detail* obtained through project templates can potentially be exhaustive. If there is a complete methodology, the project templates will provide the project manager with a sense of all the risks in the organization's past that most of the project managers have faced. It can also provide a detailed examination of virtually all aspects of the organization. If a single template is used or only one area is covered, the level of detail can diminish significantly.
- The *utility* of project templates is in their capacity to save the project manager from rediscovering organizational issues that may have a negative effect on the project. Because such templates are normally based on the experience of an organization's more talented project managers, they save the current project manager from constantly evaluating and reevaluating the project and the organization to ensure that every potential risk area has been addressed.

Summary

When using project templates, the key is the discipline required to go through the process in small, manageable steps. If a project manager or team attempts to complete all project templates at one time, the task will invariably be overwhelming and enormously time-consuming. If, instead, the effort is conducted incrementally over time, the administrative burden is reduced and the technique becomes far less onerous for long-term utility and application.



Chapter 16
Assumptions Analysis

The critical element of assumptions analysis is assumptions identification. This technique entails conducting a thorough review of all project assumptions and validating or invalidating those assumptions. In either case, the information is published and shared across the team to communicate issues that should be considered in the project plan and in all customer and team member interactions.

Technique Description

Assumptions analysis consists of building project documentation that provides consistent interpretation of the project environment. Although the documentation may take a variety of forms, the key is to apply it consistently. If all projects within an organization use the same documentation structures to capture assumptions, it is much easier to interpret the information consistently. The technique also involves analysis of the data captured within the documentation to establish each assumption's validity.

When Applicable

Assumptions analysis is applicable at the beginning of the project and any time there is a change in the project environment. It is also applicable when major decisions must be made inasmuch as the assumptions under which the project operates often affect decision-making processes. Because decisions frequently influence assumptions sets, the earlier that assumptions can be identified and documented, the better. However, there is sometimes a tendency to shift assumptions based on project urgency. If assumptions have already been documented, that tendency can be thwarted to some degree.

Inputs and Outputs

Inputs into assumptions analysis consist of project assumptions. Those assumptions are not the exclusive province of the project manager, the project team, or the customer. They should be educed from as many different parties as can be identified. Other inputs into assumptions analysis include any background or supporting documentation that can prove or disprove assumption validity. Some of these inputs may come from the lessons learned of other projects; other inputs are drawn from project-specific research.

Outputs from assumptions analysis will frequently be embedded in the notes fields of project management software (as illustrated in the sample in Figure 15) or in the caveats and codicils within a memorandum of understanding. Ideally, they should be captured in a consistent document format.

WBS	Task Name	Assumptions
1	**Media Campaign**	The **business** need Is for a June 1 **Completion** Date
1 1	Marketing Plan distributed	This milestone was achieved by the Marketing Dept
1 2	**Corporate Communications**	**Corporate Communications will** ha **exclusively internal**
1 2 1	Corp Comm Kickoff	The kickoff will be internal personnel
1 2 2	Comm Plan	Plan delivery will be in soft copy format
1 2 3	Packaging	No custom packaging Is required
1 2 4	Datasheets	Data for datasheets will be largely developed by Marketing
1 2 5	Reseller kits	Reseller kits will be the standard format, supplemented by custom content
1 2 6	Competitive comparison	Completitive analyses will be based on the standard Acme format
1.2.7	Demo script	Demo scripts will be approved on the first draft
1 2 8	Working Model	The working model will consist of a working model o the product to be promoted by the campaign
1 3	Advertising	**All internal advertising costs** will be **assumed as part of** the contract and **will** not be **billed** separately
1 3 1	Develop creative briefs	Customer will have only one review cycle to analyze creative briefs

Figure 15. *Assumptions Documentation*

Major Steps in Applying the Technique

Assumptions analysis is a general practice that leads to both broad and specific statements about the project environment that are then used in establishing the parameters for project plans. Even though approaches may vary, the processes remain similar from activity to activity.

- *Identify environmental conditions unique to the project.* While natural organizational conditions may drive some project assumptions, unique environmental conditions tend to drive the less obvious assumptions. By identifying what makes the project unusual within the organizational environment, it then becomes possible to begin a discussion on what qualities or traits of that environment need to be clarified or rendered consistent for everyone involved in the project.

- *Determine what issues within that environment will be pone to misunderstanding or miscommunication.* Assumptions are often established or recognized through conflicts of understanding between two individuals. Thus, assumptions are more readily captured when multiple parties participate in the assumptions documentation process. By reviewing project documentation and parsing unclear terms, the project team can ferret out some of the assumptions the project requires.

- Catalog the assumptions. As shown in Figure 15, the assumptions can be captured within the project plan using the project management software. They can also be documented in forms or lists, but the documentation should be retained with the project plan and should be readily accessible to anyone performing work on, receiving deliverables from, or making changes to the project.
- As much as practical and *possible, validate* the assumptions. Not all assumptions can be validated. Some simply have to be established in their own right. But for some other assumptions, it is possible to investigate and determine whether they are accurate or reliable. The degree to which this step of the process will be conducted depends largely on the amount of time and effort that will have to be expended to validate the information (and the potential value of it).

Use of Results

The assumptions from assumptions analysis should be retrieved whenever there is a need for a better understanding of the project, its plan, or its background. Typical situations where assumptions documentation might be used include:

- Project selection
- Contract negotiations
- Resource allocation meetings
- Change or configuration control board meetings
- Project evaluations
- Customer reviews
- Performance assessments
- Project termination

The key is that assumptions documentation provides greater clarity for decision making and a mutual understanding of terms, practices, and characteristics.

Resource Requirements

The resources for the assumptions analysis technique are merely those individuals with the ability to generate an independent interpretation of project information. The key is to find those individuals whose interpretations will be widely understood and accepted by the broadest possible body of project stakeholders.

Reliability

The assumptions analysis process is reliable in that it generally increases the reliability of other activities and processes. Assumptions analysis focuses on increasing accuracy and ensuring consistent understanding of information, therefore rendering more of the project's overall information pool more reliable.

Selection Criteria

As with each chapter on techniques, the assumptions analysis technique is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare assumptions analysis with other techniques, review Table 6.

Resource Requirements

- The *cost* of conducting assumptions analysis is closely related to the unfamiliarity of the project and its environment. The more original content that is associated with the project, the more assumptions will have to be developed. The more assumptions, the more assumptions analysis must be conducted. Even so, reviewing project terms, practices, and processes should still be considered de rigueur, and thus the additional cost is relatively limited.

- There are no special equipment needs for this technique because it is primarily an administrative burden. For *proper facilities and equipment,* the only requirement is to establish the repository for documenting any assumptions.

- The *time needed to implement* assumptions analysis is tied to the novelty of the project or the nature of the environment. The more original the project or the less understood the project environment, the more time required for the analysis.

- Project assumptions analysis has extremely high *ease of* use. Since the assumptions are documented in a format that is readily accessible to the project team and since the assumptions are directly related to the areas of concern and confusion in the project, this clarification process adds value precisely where it is most needed.

- The project manager's *time commitment* to assumptions analysis hinges on the novelty of the project and the uniqueness of the environment. The more singular the effort, the more time is required in the analysis.

Applications

Assumptions analysis contributes to most application categories in Table 6.

- For *project status reporting,* assumptions frequently determine how information will be expressed in the reports as well as the status itself. While assumptions analysis does not generate status report information, it helps establish validity of the status reported.
- *Major planning decisions* require a clear understanding of the project environment, which a clear, shared grasp of the project's assumptions greatly facilitates.
- Assumptions made about client behavior, project duration, and process approach may determine, in part, *contract strategy selection.* Since all those issues may be clarified somewhat during assumptions analysis, there is a strong application here.
- *Milestone preparation* sometimes relies on a shared sense of what a given series of activities entails. Again, assumptions analysis can be extremely beneficial in this area.
- *Design guidance* is a function of understanding client requirements, which is frequently rooted in assumptions. Thus, assumptions analysis is crucial here. In this instance, it is particularly important to ensure that the assumptions associated with both functional and technical requirements are dissected to address their potential impact on project design.
- Because a large component of *source selection* is directly tied to assumptions on activities and performance, assumptions analysis heavily supports this area. For this application, however, it is especially prudent to assess the validity of assumptions based on the organization's knowledge of the sources under consideration and the volume of the information base available regarding those sources.
- *Budget submittal* also relies heavily on assumptions analysis. The vital questions for many of these assumptions are Where did the data come from?and How reliable are those sources?This information should be documented along with the budget so that the validity of the assumptions applied can be analyzed for future reference.

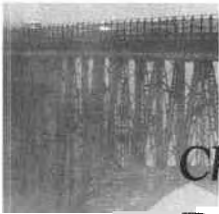
Outputs

Outputs from assumptions analysis are frequently in the form of one- or two-line statements regarding anticipated performance, activity, behavior, or environmental conditions. These statements are (ideally) linked to the source documents under evaluation (for example, if the assumption is about a budget element, it is documented with the budget).

- *Accuracy* of assumptions analysis is tied to the volume and the accuracy of the supporting data available. The more valid data that are available, the more accurate the analysis will be. Accuracy also ties to the skill of the evaluators. Skilled evaluators (or those with a history on the subject matter in question) will tend to generate more accurate assumptions assessments.
- The *level of detail* obtained through assumptions analysis ties to the level desired. If assumptions analysis is conducted at the work package level of the work breakdown structure, the level of detail will be exacting. If, however, the assumptions analysis is simply conducted on the project objective or the scope statement, the level of detail will not be as thorough.
- The *utility* of assumptions analysis is high because the analyses can be conducted at a variety of levels at different points during the project life cycle. It serves to refine requirements, cement understanding, and generate common interpretations of what may potentially be indistinct data.

Summary

Assumptions analyses take on a variety of forms within different projects and organizations. Although some assumptions analysis occurs almost unconsciously, the most effective assumptions analysis will be done with multiple parties and with extensive documentation. That documentation will ultimately be stored where those who can put the information to use can readily retrieve it. If assumptions analyses are done simply for their own sake and the documentation is not generated or retrieved regularly, the process has extremely limited utility.



Chapter 17

Decision Analysis–Expected Monetary Value

Decision analysis can be used to determine strategies when a decision maker is faced with several decision alternatives and an uncertain or risk-filled pattern of future events. Before selecting a specific decision analysis technique, the type of situation must be considered. Classifying decision-making situations is based on how much is known about those future events that are beyond the decision maker's control (known as states of nature). Thus, the two types of situations are as follows:

- Decision making under certainty (when states of nature are known)
- Decision making under uncertainty (when states of nature are unknown)

The decision analysis techniques appropriate for risk identification, quantification, and prioritization are those that consider decisions made under uncertainty.

In situations where good probability estimates can be developed for the states of nature, the expected monetary value (EMV) method is a popular technique for making decisions. In some situations of decision making under uncertainty, the decision maker may not have the ability to assess probabilities of the various states of nature with confidence.

Technique Description

In general, three steps are involved in formulating a decision theory problem using the EMV method:

- Define the problem
- Identify alternatives that the decision maker may consider (feasible alternatives may be denoted by d_i).

- Identify those relevant future events that might occur and are beyond the decision maker's control (may be denoted by s_j)

In decision theory terminology, an outcome that results from a specific decision and the occurrence of a particular state of nature is referred to as the payoff (denoted by V). The formula $V(d_i, s_j)$ denotes the payoff associated with decision alternative d_i and state of nature s_j.

By way of example, a project manager must decide which method to use for a business trip. A car trip would take 4 hours, with a 5 percent probability of delays of 1 hour or longer. A plane trip would take 3.5 hours (including travel time to and from the airport), with a 30 percent probability of delays of 2 hours or longer. In this scenario, d_i is the project manager's decision to drive. Based on expected values, the plane trip would have taken 4 hours 6 minutes [3.5 hours + (120 minutes (0.30)]. According to expected value, the car trip should take 4 hours 3 minutes [4 hours + (60 minutes (0.05)]. The alternative selected, s_j and how it turned out is the fact that the project manager had no delays and arrived in 4 hours. Note the characteristics. The decision alternative d_i could be determined at any point in time. The state of nature, s_j, remained unknown until the risk had come and gone. The payoff, $V(d_i, s_j)$, is the 4-hour trip, completed successfully.

When Applicable

The EMV method applies during any project phase, although it typically would be generated at the onset of the project to identify the probabilities and relative costs associated with particular courses of action. Because decision analysis models can be portrayed as decision trees, they can be applied to network analysis. Probability-based branching in a network is an example of using decision analysis in a network analysis framework.

Inputs and Outputs

The inputs to the EMV method consist of the decision alternatives to be considered (what options does the project manager have), the states of nature associated with the decision alternatives (what can happen), and the probability of occurrence for each state of nature (what are the chances that a given scenario will happen). The outputs of the EMV method are the expected payoff values for each decision alternative under consideration.

Major Steps in Applying the Technique

The EMV criterion requires that the analyst compute the expected value for each alternative in order to select the alternative that yields the best expected value. Because, ultimately, only one state of nature (or outcome) can occur (that is, only one given scenario can come to pass), the associated probabilities must satisfy the following condition:

$$P(s_j) \geq 0 \textit{ for all states of nature,}$$

$$\sum_{j=l}^{n} P(s_j) = P(s_1) + P(s_2) + P(s_3) + \ldots + P(s_n)$$

For this equation,

$$P(s_j) = \textit{ probability of occurrence for the state of nature } (s_j)$$

$$n = \textit{number of possible states of nature}$$

The expected monetary value of a decision alternative, d, is derived through the following equation:

$$EMV(d_i) = \sum_{j=1}^{n} P(s_j)V(d_i, s_1)$$

In other words, the EMV of a decision alternative is the product of the payoff and the probability that the payoff will occur. Put more simply, the EMV of a decision to buy a scratch-off lottery ticket is the sum of its probabilities and potential impact. Consider this example, where a single ticket has the following probabilities:

Winnings	Probability	Expected Value
$1	0.25	$0.25
$10	0.01	$0.10
$1,000	0.0001	$0.10
$1,000,000	0.0000001	$0.10
0	0.7398999	$0

EMV = $0.25 + 0.10 + 0.10 + 0.10 + 0.00 = 0.55

The sum of all the probabilities equals 1.0; all the states of nature are accounted for; and all the expected values sum to $0.55. Whereas there will never be a single ticket with a $0.55 winner, if enough tickets are purchased over time, their average value will ultimately be about $0.55.

The probability is expressed as the percentage for each potential state of nature (or outcome). The following is an example of a situation in which the EMV method can be used to make a decision.

Consider the decision of whether to purchase either Acme or Nadir water pumps for a fleet of 400 trucks based exclusively on the failure rates of the pumps, their relative maintenance cost in the first year of operation, and the purchase price. Historically, the organization has saved time, energy, and risk by replacing all water pumps in the fleet at the same time.

Acme water pumps cost $500 each and have a failure rate of 5 percent in the first year of operation. Reinstalling a failed (and then rebuilt) Acme pump costs $150. Maintenance on pumps that do not fail is $100 per year. Acme reimburses all maintenance costs on failed pumps.

Nadir water pumps cost only $485 but have a failure rate of 15 percent in the first year of operation. Reinstalling a failed (and then rebuilt) Nadir pump costs $200. Maintenance on pumps that do not fail is $100 per year. Nadir also reimburses all maintenance costs on failed pumps.

A decision table can be constructed that presents this problem with respect to two decision alternatives and the respective states of nature. Figure 16 depicts the decision table for this problem and the associated analysis.

Decision Alternatives	States of Nature: Fail	States of Nature: Maintain
Buy Acme d_1 = $200,000	$P(s_1) = 0.05$ 400 trucks (0.05 failure rate) ($150 per repair)	$P(s_2) = 0.95$ 400 trucks (0.95 maintenance rate) ($100 per maintenance event)
Buy Nadir d_2 = $194,000	$P(s_1) = 0.15$ 400 trucks (0.15 failure rate) ($200 per repair)	$P(s_2) = 0.85$ 400 trucks (0.85 maintainance rate) ($100 per maintainance event)

Analysis

EMV (Buy Acme)		*EMV* (Buy Nadir)	
$200,000	400 pumps ($500 each)	$194,000	400 trucks ($485 each)
3,000	400 trucks (0.05 failure rate) ($150 per repair)	12,000	400 trucks (0.15 failure rate) ($200 per repair)
38,000	400 trucks (0.95 maintenance rate) ($100 per truck)	34,000	400 trucks (0.85 maintenance rate) ($100 per truck)
$241,000		$240,000	

If objective is based on a 1-year time frame and cost alone, buy Nadir.

Figure 16. Decision Table

The analyst has the option of building a table or a decision tree or of doing both based on personal preference. The decision tree graphically represents the decision under consideration (Figure 17). Although the tree itself may never be drawn, all relevant events must be listed and analyzed to determine problems that can occur as the process reaches each decision point. Every outcome must be considered, and there must be a path through the tree to every possible outcome or payoff. Experts are consulted to identify each problem and possible outcome, as well as to assign probabilities to the various problems and outcomes. Any realistic number of sequential outcomes can be evaluated.

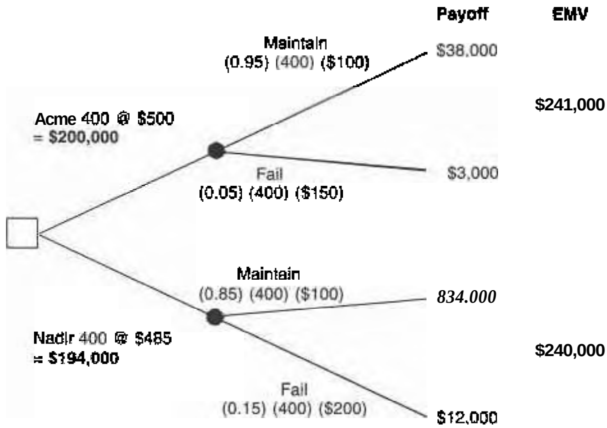


Figure 17. Decision Tree

Use of Results

Given the expected monetary values of the decision alternatives, the analyst's selection of the appropriate alternative is predicated on whether the objective is to maximize profit or to minimize cost. In the sample problem, because the objective was to minimize cost, the analyst would select the alternative with the lowest EMV. When the difference between decision alternatives is small, however, other programmatic factors may be considered when making the decision.

In the example provided, the apparent price gap between the two pumps has shrunk from $6,000 (the difference when only purchase price is considered) to $1,000 (the difference when expected value is factored in). It allows the decision maker to question whether the increased quality that an Acme pump affords is worth $1,000 to the organization.

Resource Requirements

With respect to resource requirements, the EMV technique is simplistic and can usually be calculated easily *after* obtaining the inputs to the model. Resource requirements for gathering those inputs may be more significant. As decision problems become more complex with an increasing number of decision alternatives and states of nature, the time required to create decision tables or decision trees will also increase.

Reliability

One of the most attractive features of the EMV method of decision analysis is that after obtaining the respective inputs to the model, no ambiguity exists regarding the analysis. The reliability of the results is based on the validity of the inputs to the model. If analysts can realistically define all relevant decision alternatives, states of nature, and respective probabilities, the model will reflect reality.

Another significant benefit of the EMV method is that it can readily be portrayed in a diagram, facilitating a conceptual understanding of the problem, the alternatives, and the analysis.

Selection Criteria

As with each chapter on techniques, decision analysis is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare decision analysis with other techniques, review Table 6.

Resource Requirements

- Decision analysis *cost* includes only the time to gather the data and to conduct the analysis. A skilled analyst requires only a limited amount of time to assess the data available and to review its validity.
- *Proper facilities and equipment* are limited to enough computers to support analysts in developing the information.
- The *time needed to implement* this approach is highly dependent on the level of depth required and the quality of outputs the organization mandates.
- *Ease of use* in decision analysis is based on the skill level of the analyst. When reviewed against the other techniques, this approach has a significantly shorter learning curve and thus does not require someone who has been conducting decision analyses over an extended period of time. It can be effectively taught, and because the results are quantitative, they are easier to review for flawed analyses.
- The project manager's *time commitment* to this particular technique is very limited. The project manager is normally responsible only for a final review of the outputs.

Applications

Decision analysis is frequently used as a tool to establish appropriate levels of contingency funding for projects. By applying EMV to the risks in the project and establishing the EMV for the project's major risks, it is possible to use decision analysis to ascertain the magnitude of an appropriate contingency budget. In the ideal, such a budget would incorporate from the EMV of any concurrent opportunities as well as risks in order to balance the project's potential windfalls against potential problems.

Decision analysis lends itself well to all the following applications:

- For *project status reporting,* decision analysis allows the project manager to provide quantitative information on future events. Because few techniques provide that information, decision analysis provides a valuable piece of information essential to quality risk management.
- *Major planning decisions* should hinge on the potential for success. Because decision analysis reviews the potential for success, it is invaluable. Since contingency funds sometimes become a determining factor in major planning decisions, the role of EMV in that regard comes to the fore as well.
- *Contract strategy selection* is keyed to the potential success of the buyer, vendor, contractor, or subcontractor(s) involved. Because monetary decisions often drive contracts, EMV and decision trees can help determine whether the contract strategy is appropriate to the value of the contract.
- As with contract strategy selection, *milestone preparation* is most often a step conducted at the beginning of the project. Here, decision analysis has limited utility unless it is applied to schedules to determine the potential for success in terms of the schedule. However, if the milestones are budget-driven, decision analysis becomes even more appropriate.
- *Design guidance* can stem directly from decision analysis because various designs will have different implications in terms of the potential for profits and the potential for technical success.
- In *source selection,* decision analysis applies if there is a history or data record for the vendors under consideration. If that information is available, decision analysis can be effectively applied. However, such evidence is often primarily anecdotal and, as such, does not work well with this technique.
- Decision analysis may directly affect *budget submittal* because some organizations use decision analysis as part of the consideration for budget allocations.

Outputs

Outputs from decision analysis can be extraordinarily helpful or utterly useless. The critical value in terms of outputs remains the quality of the inputs.

- *Accuracy* is highly analyst- and data-dependent. If the project can be modeled accurately, the outputs will be accurate. The inverse is also true. To generate effective, accurate information, the data must come from a valid, reliable source and must be analyzed by someone who clearly understands the implications of the technique.

- The ***level*** of ***detail*** is based on what the project manager deems necessary. Decision analysis is fully scalable. It can be conducted at broad scale or detailed level. As such, it offers an advantage over techniques that can be applied only at one end of the range.

- The ***utility*** of decision analysis is not as high as with many other techniques because it does not provide the same diversity of outputs or address the myriad questions that other techniques do. Instead, it works best when it provides intense focus on a single issue.

Summary

Decision analysis affords project managers a multiperspective analysis on a single issue. It does not answer broad, far-reaching project management questions. Instead, it draws on specifics to fill in the nuances of the larger picture. Decision analysis also gives the project manager some quantitative information to present in case of any significant conflict. If decision analysis is used to examine the appropriate questions using the proper inputs, it can become a powerful tool for the project manager. The keys to making decision analysis effective are to use the tools properly and to ensure that the information being analyzed is current, valid, and accurate.

Chapter 18
Estimating Relationships

The estimating relationship method enables project personnel to evaluate a project, and based on that evaluation, to apply an equation to determine an appropriate contingency or risk funds budget. When using this method, the contingency funds represent the amount of funding (above that determined by cost analysis alone) required for work associated with unanticipated risks. The contingency funds requirement computed is usually expressed as a percentage of the baseline cost estimate. The technique is called an estimating relationship method because it uses some of the same techniques associated with cost estimating relationships (CERs) used in parametric cost estimating.

Technique Description

The CER method is based on the observation that costs of systems seem to correlate with design or performance variables. The independent variables, often called explanatory variables, are analyzed using regression analysis to describe the underlying mechanism relating such variables to cost. This approach to cost estimating is widely accepted and easy to apply, even for complex functions.

This ease of application makes it natural to apply the same techniques to estimate costs that result from risks. The approach attempts to discover which project characteristics can be refined into discrete variables, which can then be correlated with the historically demonstrated need for contingency or risk funds. Regression analysis using actual contingency fund figures from past projects (as expressed as a percentage of total costs) is performed to develop an equation with which to estimate contingency fund requirements for a new project not in a database.

The application of this technique is described below. In an example describing this application, project personnel evaluate four project and subcontractor characteristics known to affect the level of uncertainty.

Each characteristic is assigned a value based on a scale provided for that characteristic. For this example, the four characteristics and their values are: engineering complexity (0 to 5); organizational proficiency and experience (0 to 3); degree of system definition (0 to 3); and multiple users (0 or 1). The sum of these numerics is entered as the value X in an estimating equation such as the following:[7]

$$y = (0.192 - 0.037X + 0.009X^2) \times 100$$

This formula determines the percentage contingency fund requirement, y. The model shown in this example is usable only for X values between 2 and 12. Lower values indicate essentially no need for contingency funds.

When Applicable

This method of estimating the additional funding needed to cover anticipated risks has limited application. It can be used only if the research has already been done to establish a valid historical relationship between the key project characteristics or contract characteristics of similar projects and contingency fund requirements. The method is most applicable in circumstances in which good historical project description and contingency fund requirements are available for several similar projects. If the required risk funding estimating relationship is available, this method has the advantage of being both quick and easy to apply.

Inputs and Outputs

The inputs for an estimating relationship model, such as the equation under the heading "Technique Description," consist of judgment values characterizing the four project or contract factors described in the example.

Regarding outputs, the estimating relationship method provides a percentage that is applied to the estimated baseline cost to determine the amount of total or contract contingency funds required. This percentage value is computed using an equation similar to that used in the example, with the X value being the sum of the four factor values project personnel have determined.

Major Steps in Applying the Technique

When an appropriate contingency estimating equation is not available, the first step in using this method is by far the most challenging: to develop an

[7] The figures in this equation were derived in the U.S. Department of Defense environment by the Defense Systems Management College. As such, they may or may not be appropriate within your organization. They are based on the collective experience of the organization and the implications of those specific characteristics within their project environments.

equation relating project characteristics to contingency fund requirements. The most difficult part of this step is finding valid historical characteristics and contingency fund data for enough similar projects to carry out regression analysis. Data from a minimum of 10 past projects should be used to develop an estimating relationship equation.

The second part of this step is to determine the project or contract characteristics that drive contingency fund requirements and for which historical data have been collected. After collecting the historical data, using regression analysis to identify these characteristics is relatively simple. The summing of judgment values for each of the four project characteristics, as done in the previous example, is only one way to develop one or more independent variables for an estimating relationship for contingency fund requirements. Geometric mean or weighted average techniques could also be used. Multiple regression analysis techniques frequently are used for parametric cost estimating.

The final step is to use the prediction equation derived through extensive analysis of past projects (coupled with the current project characteristic information) to compute a percentage for the contingency funds needed to cover anticipated additional costs associated with risk. It may be useful to vary the project description characteristic data somewhat and recompute the estimating equation to assess the impact of such changes on the computed contingency requirements. This sensitivity analysis is usually prudent because of the uncertainty associated with the predicted project or contract characteristics.

Use of Results

To cover funds needed for risk, a percentage of the estimated contract or project cost is added to the basic cost estimate. For example, if the contract cost estimate was $100 million and the prediction equation provided a result of 20 percent, $20 million would be added for risk, making the total estimated contract cost $120 million.

Resource Requirements

After a suitable contingency fund requirement prediction equation is available, only a few hours are required to apply this method. Most of the effort required involves interviewing project personnel to obtain their insights into the contract or project characteristic values to be used. If a prediction equation needs to be developed, it would require 1 to 3 months of a skilled analyst's time, depending on the difficulty in acquiring the needed data. However, if the required data are not available, it becomes impossible to produce a satisfactory prediction equation.

Reliability

This method provides results that significantly increase cost estimates[8] in order to allow for risk. Because the additional funds are based primarily on judgment values, they are subject to question. It would always be prudent for the project manager to have upper management review and approve the method (including the prediction equation to be used) before using it as the basis for a viable request for addition risk funding. The method can be used only where adequate historical data are available to develop a sound contingency fund requirement prediction equation.

Selection Criteria

As with each chapter on techniques, estimating relationships are assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare estimating relationships with other techniques, review Table 6.

Resource Requirements

- The *cost* of the estimating relationship technique depends largely on the availability of a parametric cost model specifically designed to estimate contingency reserve or risk funds as a function of one or more project parameters. If such a model is not available, 1 to 3 resource-months may be required to develop it. If the required historical data are not available, developing the required cost model may be impossible. On the other hand, if a satisfactory model is available, it generally takes only a few days at most to apply it.

- *Proper facilities and equipment* relate primarily to the databases with the appropriate information and the tools themselves. Otherwise, very little equipment is required. The model equations are usually so simple that a calculator is adequate to compute required contingency reserve fund requirements.

- The *time needed to implement* the technique can range from a matter of days to as long as 3 months depending on the maturity of the organization in terms of the technique. If the technique has been developed and exercised regularly, then only a few days will be required. Otherwise, a 1–3-month window is required to develop the appropriate information.

- Estimating relationships have high *ease of use* because after they are built, they require only the appropriate calculations to be developed.

[8] This is based on extrapolating historical data that may include costs for risks that have already been experienced.

Ease of use after the models are constructed becomes a function of ease in data gathering.

- The project manager's *time commitment* is extremely limited, but there are some responsibilities for the project manager. The project manager must support the technique's use so that key project personnel will provide the cost analyst with time judgments or information needed as inputs for the model.

Applications

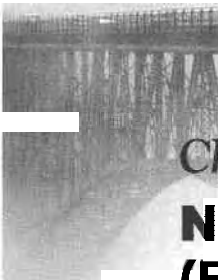
- This technique does not support *project status reporting* well. It is instead far more effective as a tool at project inception rather than at project midpoints.
- The only *major planning decision* that the technique supports is determining the extent of contingency reserve or risk funds to be included in the initial budget request or baseline budget.
- The *contract strategy selection* may hinge in small part on the level of risk funding required for the project. Otherwise, there is no relationship between the technique and this application.
- This technique does not support *milestone preparation* and *design guidance.*
- *Source selection* may be a critical input to the technique, but the estimating relationship outputs do not support it.
- *Budget submittal* is the primary application for this technique. By computing the level of contingency reserve or risk funds required, the project manager can develop a budget that incorporates and reflects risk issues and allows for the vagaries of real-world project management.

Outputs

- The *accuracy* of the technique is considered low, primarily because the historical databases on which such models are based are small. The accuracy also comes into question because accurately defining what funds were spent to address risk on past projects is often difficult.
- This method provides a *level of detail* that is unacceptable to the detail-oriented analyst. It provides little or no information with respect to which parts of the project are at greater risk and, therefore, more likely to require additional funding.
- Because so few models of this type are available and even their uses are subject to question, the overall *utility* of this method must be considered low.

Summary

Many project managers do not understand the estimating relationship method well. Some survey respondents indicated that they had used this technique when they had really used parametric cost estimating methods for some or all project cost estimates. Such analysis is more accurately described as all or part of a life-cycle cost analysis. The use of parametrics estimating methods defines the estimating relationship method to estimate risk or contingency reserve fund requirements. Currently, few parametric cost models are available with which to do this.



Chapter 19

Network Analysis (Excluding PERT)

A quality schedule, fundamentally a time-scaled and integrated structure of project objectives, is critical for effective project planning, implementation, and control. It includes activities and events that must be accomplished to achieve the desired objectives. Many project managers are familiar with the concept of network-based scheduling in project management. Network-based schedules formalize the project's internal functions and processes and result in graphics that depict the project's activities and their relationships (predecessors, successors, and parallel tasks). Network diagrams are valuable because they—

- Alert functional managers and team members to their dependency on other functions and teams
- Establish project completion dates based on performance rather than arbitrary deadlines
- Illustrate the scope of the project
- Provide a sense of resource requirements over time, particularly when multiple resources will be deployed on multiple tasks simultaneously
- Facilitate risk review scenarios
- Highlight activities that drive the end date of the project.

The following actions are essential to successful network development:

- Engage team members and their management (as appropriate) who will perform the work
- Determine appropriate level of detail (aggregate, intermediate, or work package)
- Identify relevant activities

- Define relationships among the activities
- Forecast activity duration

In many cases, project managers assume responsibility for planning, scheduling, and controlling projects that consist of numerous separate jobs or tasks that a variety of departments, project offices, and individuals perform. Often these projects are so complex or large that the project manager cannot possibly remember all the information pertaining to the plan, schedule, and progress of the project. In these situations, the Program Evaluation and Review Technique or PERT (see Chapter 20), critical path method (CPM), and precedence diagramming techniques have proven to be extremely valuable in helping project managers carry out their management responsibilities. The value of the tools is in their ability to depict relationships among activities and to provide a clear understanding of how the project will evolve as an integrated whole. Figure 18 represents an activity-on-arrow (either PERT or CPM) network. Figure 19 represents the same network as a precedence diagram.

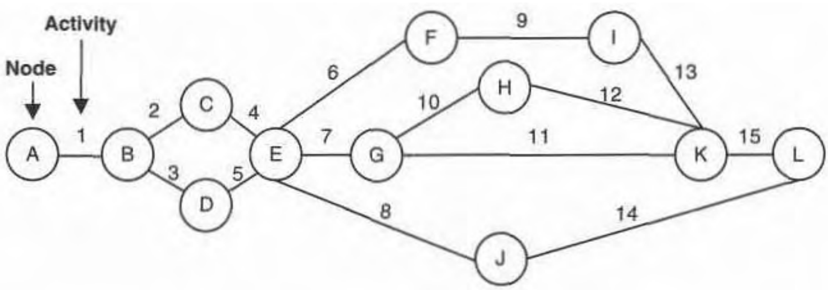


Figure 18. Project Represented as an Activity-on-Arrow Network

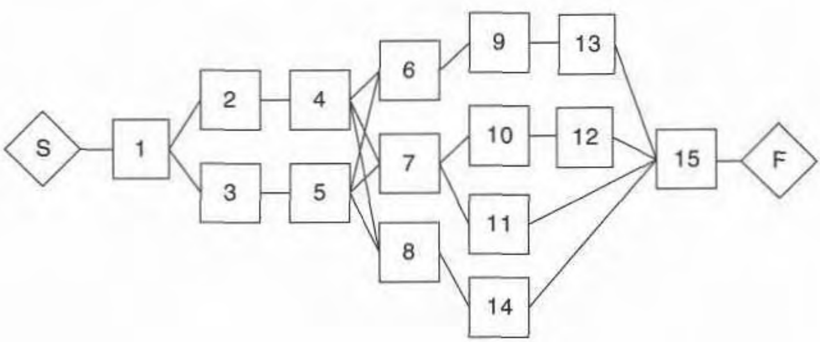


Figure 19. Project Represented as a Precedence Diagram

Significant outputs of a network analysis are identifying the critical path, which consist of those activities that must be finished on time or the project will be delayed. Activities in the critical path compose the longest single path through the network. Their total duration represents the project duration. Most modern project management software highlight critical path activities so that they can be recognized for their importance. While these tools help identify some potentially higher-risk activities, they also identify those activities with free time or slack. Activities not on the critical path can afford some modest schedule slippage without affecting the overall project schedule.

Technique Description

The original networking technique was based on the arrow diagramming method (ADM) or activity-on-arrow method of representing logical relationships between activities. ADM represents all predecessor and successor activities as finish-to-start relationships. Successor activities are not initiated until the predecessor is complete. However, because this form of relationship is not always true for predecessor-successor activities, other networking methodologies were developed to reflect more accurately the realities of those dependencies. Newer computer-based networking systems use the precedence diagramming method (PDM) or activity-on-node diagram to represent network logic. PDM allows greater flexibility than ADM in describing predecessor-successor relationships. With PDM, the following relationships can be described in addition to the finish-to-start relationship:

- Finish-to-finish: Successor activity cannot finish until after the predecessor has been completed
- Start-to-start: Successor activity cannot start until after the predecessor has started
- Start-to-finish: Successor activity cannot be completed until the predecessor has started

Newer network-based risk models also use PDM. The description that follows is based on the PDM networks because they have become more popular as both scheduling and risk tools.

To reflect the realities of risk-related issues more accurately, network diagrams have been enhanced over the years. Logic has been added to increase the functionality of network analysis as a risk analysis tool. In probability-based networks, uncertainty manifests itself in two ways. First, there may be uncertainty related to cost, schedule, or technical performance. Generally, technical performance is considered a fixed parameter, while time and cost vary. Second, initiating successors with a common predecessor may be predicable only against the probability of the predecessor's success (that is, if the predecessor fails, the successor may never begin). In some cases, the failure of a predecessor dictates an entirely different course of action. Some network models (like Scitor's Process) allow for iterative, probability-based cycles. It has become possible for the project manager to evaluate potential cost and time frames by ascribing percentage chances to the probability of achieving certain task outcomes. The project manager can then work through the model to determine the probability of achieving cost or schedule targets for the project as a whole.

A key issue in network development is selecting the appropriate level of detail. As with most project work, it is accepted practice to establish general process flows before working at the work package level. By their very nature, high-level networks embed significantly greater uncertainty. Detailed networks require a higher level of effort to generate but minimize the uncertainty associated with the relationships in the project. Realistically, as project requirements and information become more readily available, network models evolve to greater levels of detail.

When Applicable

Networks are formulated based on project activities, interrelationships among activities, and constraints, such as time, money, human resources, technology, and so on. Because all projects have these characteristics, network analysis applies universally. Using the technique is easier if network-based project schedules already exist because analysts can then make logic modifications so that network data can be incorporated into risk analysis software programs as appropriate. If a network does not already exist, one must be created to apply this technique. The time saved by transforming an existing network rather than creating one provides a strong argument for network-based project scheduling from the beginning of the project.

Inputs and Outputs

The inputs for the development of the network models may be as simple as inputting activities, relationships, and duration. Some network models are far more complex, using inputs including probability density functions. (Appendix D discusses some techniques available for quantifying expert judgment.) Initially, inputs to the network model may be qualitative judgment that must be transformed into quantitative information. Thus, it is imperative that all individuals who fill a relevant project role provide inputs during the development process. Their contributions affect the credibility of the resulting network. Standard outputs from network models include task start and finish dates as well as overall project duration. Models that incorporate risk factors and risk data often count probability curves, bar charts, histograms, and cumulative density functions as components of their outputs. These are discussed in greater depth in Chapter 24, Monte Carlo Simulations.

Even the most rudimentary of project scheduling tools provide valuable risk outputs. The clear definition of the early start and early finish of each activity, as well as its late start and late finish times, is frequently a risk indicator. Some activities that will have no free time (float) are low risk because the best and brightest individuals within the organization perform them. Other activities with nominal levels of float may pose far greater risks when less skilled personnel perform them. Networks highlight when an organization faces countless concurrent activities (and thus higher managerial risk). They clarify when a single activity has multiple successors (and thus higher dependency risks). And they draw out when multiple activities are being conducted serially, generating greater risk on an entire string of work to be done. The information derived from networks can be used to analyze and adjust labor, material, and time allocations.

Major Steps in Applying the Technique

The first step in this process is for the analyst to manually develop a rough-cut network. To develop a realistic model of the project, the analyst must identify all relevant parameters, such as activities, relationships, and probabilities associated with work or dependencies. As practicable, all relevant project personnel should participate in developing and validating the network.

The participants should work together to build the network diagrams in an open setting, first identifying the work to be performed and then following up with an analysis of the relationships among the activities. This should be "penciled in" on an erasable board or flip chart before being committed to a computer tool.

After the rough-cut network is developed, the analyst can enter the information into a computer for evaluation. Most project management software packages will conduct a rudimentary schedule analysis that provides the basic information needed for a high-level risk assessment. As more information becomes available, other computer modeling techniques, such as PERT and Monte Carlo simulations can be applied.

Use of Results

The outputs of network analysis are extremely useful to the project manager. The study of networks for their inherent risk generally provides a far greater understanding of the sources and degree of risks. Results of the risk analysis process provide the information required to execute the risk response control phase of risk management effectively.

Resource Requirements

Because the project team builds most network analyses, costs should be estimated from a human resource perspective. A comprehensive network analysis for a major project may require definition of between 200 and 1,000 activities, plus weeks of preparation, information gathering, and expert interviews to establish risks inherent in individual activities and to construct the network. Obtaining the information to build the network generally entails more time and rechecking than initially might seem necessary. This is because the project plan usually undergoes continual revision and definition and the support team may not fully understand relationships among project activities.

Although the difficulty and time required for network definition can pose a problem, the effort of constructing a consistent and acceptable network model forces the responsible participants to plan effectively and to understand how their own segments of the project fit into the whole. Project managers have indicated that this benefit alone can justify all the effort in accomplishing a formal network risk assessment.

Reliability

The reliability of network risk analysis is a function of multiple factors. Developing a network that accurately reflects activities and relationships among activities is crucial to the resulting network analysis. Thus, it is imperative that all relevant project personnel provide inputs to developing and modifying the network. Defining the relative levels of risk for the cost, schedule, and performance aspects of each task in the project can either be done here or later in a Monte Carlo analysis. The data are helpful here, even if they are not yet built into probability density functions (PDFs) because the more reliable the network, the more reliable the network analysis will be.

Selection Criteria

As with each chapter on techniques, network analysis is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare network analysis with other techniques, review Table 6.

Resource Requirements

- The cost of network analysis depends largely on whether the networks are already developed for the project. If so, or if only modest modifications are required, extensive labor can be saved since only the risks inherent in the relationships must be examined.

- *Proper facilities and equipment* should include computers loaded with current project management software and ideally, large-form printers or plotters. Without the printers, some network analyses bog down as massive cut-and-paste operations with team members developing giant networks by taping together dozens of small sheets of paper. Some teams use erasable boards and "stickie" notes to develop the initial draft of the network diagram. The key is to capture the outputs from such analyses before the information is damaged or destroyed. A digital camera set on high resolution may be used to retain those data for later inputs into a computer model.

- The *time needed to implement* the technique can be extensive depending upon the complexity of the network and the number of participants. A small network that three or four team members have developed may be completed in a couple of hours. A multilayered network of 1,000 activities that 10 or more team leaders have coordinated may take days to develop.

- Network analysis can be challenging and thus rates heavy *ease of use* because the processes of building the networks, capturing expert judgment, and understanding the software are not inherently easy to master. Ease of use increases significantly with greater process familiarity.

- Although the project manager's *time commitment* is slight to moderate, the project team must be educated on the process and the project manager must support changes to the networks over the long term. Networks that are changed frequently may increase the level of time required of the project manager.

Applications

As discussed earlier in this chapter, networks have a high degree of utility. Therefore, all applications listed are relevant.

- Network analysis clearly supports *project status reporting* because, as the project progresses, changes in the duration of activities may drive changes in the project critical path.

- *Major planning decisions* should include a review of the network diagrams and the network risks. Even modest changes in the network can have significant implications, so all major planning decisions should be reviewed in the context of a thorough network analysis.

- Network analysis supports *contract strategy selection* because the flexibility of the schedule may make certain types of clauses (especially liquidated damages) either more or less acceptable.

- Because milestones often become focal points in a network, network analysis becomes a critical input to *milestone preparation.*
- For *design guidance,* network analysis serves a role in clarifying schedule risks and the overall implications of switching from one design to another.
- Scheduling considerations may in part drive *source selection.* Thus, network analysis is important here as well.
- *Budget submittal* is probably the least applicable category for network analysis, although resource loading often drives budgets. If the resources are assigned across a longer period of time, budgets will inherently be higher. Thus, there is a modest relationship between budget submittals and network analyses.

Outputs

With respect to outputs, the accuracy of the analysis is a function of the validity of the network itself and the levels of effort generated for each activity.

- The *accuracy* of the analysis is a direct function of the validity of the network itself and the level of effort generated for each activity. If, however, there is a significant (perhaps disproportionate) level of effort in a single activity, the accuracy of the network can be diminished. If the work packages are developed in a relatively uniform fashion (similar sizes, similar costs, similar durations), there is a higher probability of accuracy.
- In many cases, management or the project manager determines the *level of detail,* which can be low, medium, or high. Because different project managers use network analysis to achieve different perspectives, the level of detail is a function of how much detail is desired.
- The *utility* of the networks generally is high if only because managers are forced to fuse detail into their plans before project implementation.

Summary

Network analyses are critical to risk management, given their role in ensuring that schedule objectives are met. These analyses focus attention on the relationships of activities and the interrelationships of risk among those activities. Although the network analysis models sometimes fail to give cost risk its due, they are invaluable early in the project when schedule risk is at its greatest. As with most tools, these are not the only tools required to evaluate or mitigate risk comprehensively. However, when used with other tools and techniques, network analyses are invaluable to the risk manager.

Chapter 20
PERT

The Program Evaluation and Review Technique (PERT) is considered a project management classic. Besides being one of the original scheduling techniques: PERT was the first significant project-oriented risk analysis tool. PERT's objectives included managing schedule risk by establishing the shortest development schedule, monitoring project progress, and funding or applying necessary resources to maintain the schedule. Despite its age (relative to other project risk techniques), PERT has worn the test of time well.

Technique Description

PERT is based on a set of mathematical equations known as Runge-Kutta. The best- and worst-case scenarios are established and weighted against the most likely set of occurrences. PERT mean and standard deviations and the project's PERT duration and standard deviations are established for each task in a project network, which allows the project manager to evaluate the likelihood of achieving specific schedule targets based on the network and PERT durations.

When Applicable

PERT is particularly applicable when historical schedule data are limited. In many projects, there is not sufficient information to ascertain precisely how long a given task might take; or sometimes team members are reticent about sharing planned duration for activities they have never performed. By allowing or encouraging each team member to provide a best-case duration, a worst-case duration, and a most probable duration for each activity, team members have the opportunity to share information they might not otherwise have considered (in a single data-point estimate).

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[9] PERT was originally developed during the Polaris submarine program in the late 1950s.

Consequently, PERT is normally applied early in a project when uncertainty is high.

Inputs and Outputs

Inputs for PERT include the multiple duration data points for each activity and the basic network of activities (Chapter 19). Gathering this information may require a significant level of effort, but it is normally tracked with the work packages in the project management software. Most mid- to high-range project management software packages incorporate PERT fields in their databases.

Outputs from PERT are mean durations for the project's critical path, as well as normal distribution curves to establish the likelihood of meeting various schedule targets. These outputs are normally more pessimistic than the duration derived from critical path method analysis because they take the best and worst cases into account (and worst-case scenarios tend to diverge further from the most likely duration than do best-case scenarios). Thus, PERT duration reflects more risks inherent in the network and the project as a whole.

Major Steps in Applying the Technique

PERT is applied in two general phases, first at the task level and again at the project level.

At the task level, there are three steps that must be conducted for each task:

- Gather the task duration *information*. As mentioned earlier, this will consist of establishing best-case, worst-case, and most likely durations for each task in the network. This information is normally extracted from individual team members performing the task.
- Calculate the PERT mean and standard *deviation* for each task. This is frequently done by using computer tools, although it can be calculated manually. For the PERT mean, the following formula is applied:

$$\frac{\textit{Optimistic} + (4 \times \textit{Most Likely}) + \textit{Pessimistic}}{6}$$

To establish the PERT standard deviation, some of the same information is used:

$$\frac{\textit{Pessimistic} - \textit{Optimistic}}{6}$$

- *Catalog the information.* Storing the information for easy retrieval is important because PERT data at the task level have limited utility. That may be helpful for establishing the basic duration of a task, but to apply the robust nature of the PERT process, the entire network must be considered.

At the project level, there are three steps that must be conducted once PERT information is available for each task:

- *Establish the PERT critical path.* The project manager must calculate the critical path based on PERT durations rather than the conventional, most probable durations. Because PERT durations frequently differ from their most likely counterparts, there is the distinct possibility that the PERT critical path will represent a different set of activities than the conventional critical path. The duration of this path becomes the PERT mean for the project.
- *Establish the standard deviation for the PERT critical path.* This tends to be one of the more confusing steps in the process since it involves calculation of the square root of the sum of the squares of the task-developed standard deviations. The process (once again, frequently performed by computers rather than people) is not as onerous as it might sound. First, square each of the individual task standard deviations. Then add those squares together. Finally, calculate the square root of their sum. The formula looks like this:

$$\sqrt{SD_1^{\,2} + SD_2^{\,2} + SD_3^{\,2} + SD_4^{\,2} + SD_5^{\,2} + \ldots}$$

  That number provides the standard deviation for the PERT duration of the project as a whole. It is noteworthy that this number is significantly smaller than the sum of the standard deviations for the project's PERT estimates. That is because it factors in the reality that not *all* activities will occur in their worst case on the same project. It also acknowledges that although some activities may be delayed, that will probably not be the case for the entire network.
- *Plot the PERT mean and standard deviation into a distribution.* There are two fundamental approaches to assessing the distribution of activities under a PERT mean. The first is the classic approach to normal distributions with a curve like the one in Figure 20.

  In this scenario, the assumption is that there is a 68.26 percent chance that the duration of the project will occur within one standard deviation of the PERT mean. There is a 95.4 percent chance the

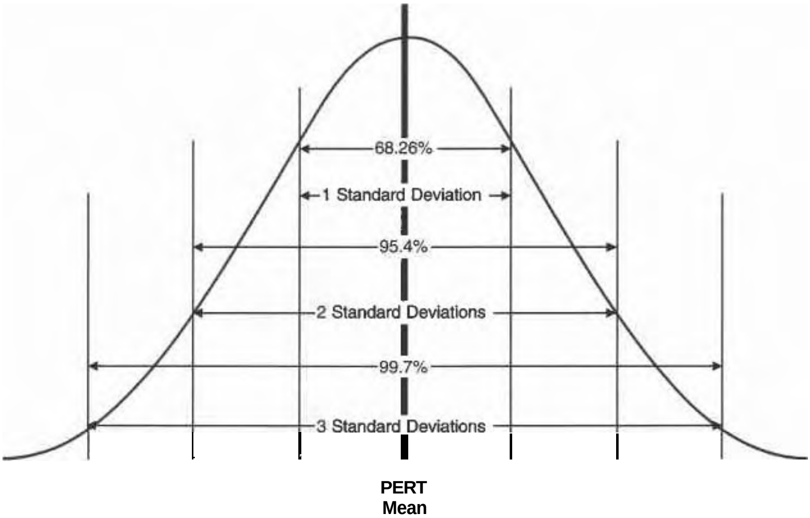


Figure 20. Normal Distribution

duration will be within two standard deviations. There is a 99.7 percent chance that the duration will be within three standard deviations. Normal distribution is discussed in greater depth in Appendix C, Basic Probability Concepts.

Another assumption set may be applied that actually works more in the project manager's favor. In many organizations, any performance to the left of the mean is wholly acceptable. In other words, there is no such thing as too early. Thus, all the points to the left of the mean (which account for 50 percent of the outcomes) are acceptable. In a single standard deviation assessment (68.26 percent), roughly half of the values (34 percent) are to the left of the mean and half are to the right. However, if *everything* left of the mean is acceptable, then the single standard deviation assessment encompasses 84 percent of the total population (50 percent, on the left, added to 34 percent, on the right), rather than 68 percent. The difference is substantial. In a diagram similar to the one above, the difference would be as displayed in Figure 21.

The second approach has a far more positive perspective on the project, as it does not penalize for early performance. The final outputs are normal distributions of the potential project duration, which afford the project manager the ability to objectively predict or declare confidence with a given duration.

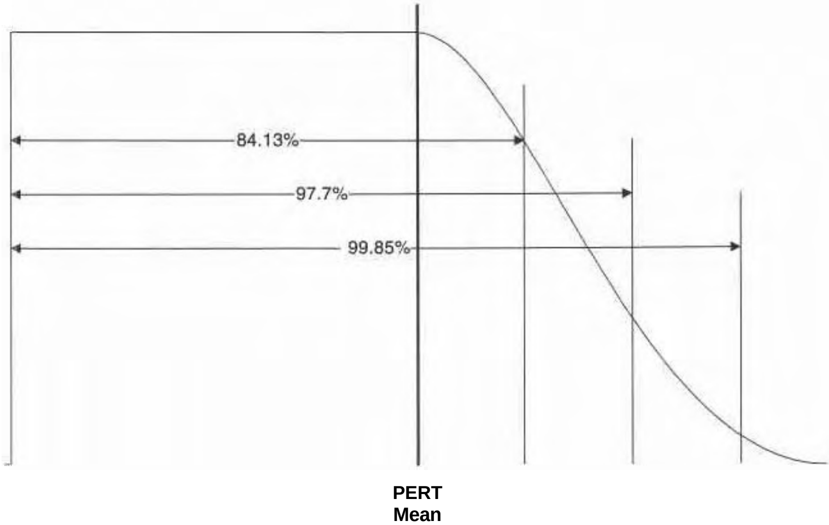


Figure 21. Normal Distribution Accounting Only for Late Outcomes

Use of Results

PERT outputs are normally used in discussions on the potential for achieving project schedule targets. By expressing a clear level of confidence, the project manager can indicate the potential for achieving any given project schedule target for the mean or higher. Using the assumptions associated with Figure 21, the PERT mean represents **50** percent confidence. That indicates that half the time this project is conducted that duration or less will be achieved. That is an important distinction. Many project managers believe the PERT mean duration to be a reasonable and realistic target to hit, when in fact it will be achieved only half the time. In most organizational cultures, 50 percent schedule confidence is not deemed acceptable. If the project manager includes one standard deviation later than the mean, however, the duration identified will be achieved 84 percent of the time. This 84 percent confidence is frequently considered sufficient to establish accurate estimates.

Resource Requirements

Someone skilled in drawing out the multiple duration data points is the best candidate to conduct the PERT process. That, in itself, is the most daunting single resource requirement for the practice. In addition, computer tools should support the process. Most current project management software packages will support PERT analysis and will facilitate both data entry and calculation.

Reliability

As projects have more work packages, PERT becomes more reliable. A project of 10 or 15 work packages will still have high levels of schedule variability even if PERT is applied. However, if a project has more work packages, including many occurring concurrently, PERT will balance out some of the natural incongruities and inaccuracy. PERT is also *perceived* as being more reliable when the standard deviations are calculated and then applied as schedule targets. A project manager is far more likely to achieve schedule duration of one or two standard deviations from the mean than he or she is to achieve a PERT mean as the project duration.

Selection Criteria

As with each chapter on techniques, PERT is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare PERT with other techniques, review Table 6.

Resource Requirements

- The *cost* of PERT is relatively low, as most of the information gathering processes that are associated with PERT will be conducted in one form or another with or without the tool. Because duration must be determined for each activity, it is not excessively time-consuming to gather additional data for optimistic and pessimistic duration. However, since PERT calculations are normally embedded in the project management software, investment in additional software is normally unnecessary.

- *Proper facilities and equipment* for PERT consist of a computer loaded with PERT-supporting project management software.

- The *time needed to implement* PERT is associated more with data gathering than with actual PERT calculations. Interviewing task leaders and team members to establish the optimistic, pessimistic, and most likely durations is the single most time-consuming effort and varies with the number of tasks associated with the project.

- PERT's *ease of use* is high if the project management software package being applied has built-in PERT capability. Since data fields for data entry and built-in calculators to perform the mean and standard deviation calculations already exist, most of the time and effort in the actual calculation of PERT is in validating the outputs.

- The project manager's *time commitment* ties directly to his or her role in gathering PERT data. Since that is the single most time-consuming effort associated with this technique, the project manager's role in that process is crucial in terms of establishing how much time is truly required.

Applications

Because many organizations live and die by their project schedules, accurate scheduling is a core competency that cannot be ignored. PERT affords more realistic schedules by taking more factors into account in establishing the duration for each project activity.

- PERT supports *project status reporting* because it can provide a sense of the likelihood of achieving schedule targets. Since many status reports include requests for information on the probability of schedule success and estimated time to complete, PERT has a high level of utility here.
- PERT also supports *major planning decisions* for many of the same reasons. Planning decisions and approaches are frequently resolved by opting for the approach that best meets customer requirements and schedule deadlines. Since PERT affords clarity on probability of meeting deadlines, it can plan a major role in planning decisions.
- PERT does not strongly support *contract strategy selection.* Even though scheduling considerations may play a role in contract options, the relationship here is weak. The only exception would be in determining the organization's exposure to late penalties or liquidated damage payments.
- PERT can be key in *milestone preparation* since milestones are a function of the schedule (or vice versa). PERT is easily applied to determine the likelihood of achieving certain milestones or to determine milestone realism.
- *Design guidance* is not normally a function of PERT. Whereas PERT supports the schedule, it does not facilitate understanding of given designs. In terms of the three sides of the triple constraint, PERT is somewhat one-sided with an emphasis on schedule.
- PERT does not support *source selection* unless external vendors will play a key role in determining the organization's success at achieving schedule targets. The only relationship between PERT and source selection stems from the potential schedule inputs vendors might have to support the process.
- *Budget submittal* is a cost issue; PERT is a scheduling tool. Although schedule and cost are inextricably wed, the link is not so great as to make PERT a viable support tool here.

Outputs

- The accuracy of PERT is high. Compared to conventional precedence diagramming or CPM analysis, PERT's accuracy is much higher because multiple data points are established for each of the project's activities. This additional consideration for each activity influences the level of accuracy by increasing both the time invested in considering project duration and by ensuring that the full range of potential task outcomes has been considered.
- PERT's *level of detail* is relatively low because it focuses on one issue and one issue alone: duration. It does not provide specificity on types of risks, risk issues, categories, or symptoms. Rather, it affords only information on the schedule and the potential schedule outcomes.
- The overall *utility* of PERT is high in that it provides the means to establish a fair, reasonable schedule with risk factored in and with a nominal level of additional effort.

Summary

PERT has been available to project managers for decades but still enjoys only limited use because of what has been perceived as the onerous level of effort associated with data gathering and calculation. Due to its incorporation into most project management software practices, coupled with executive management calling for more and more schedule accuracy, PERT currently is becoming more popular and better understood.

Chapter 21
Other Diagramming Techniques

In addition to PERT and network diagrams, there are a variety of other diagramming techniques that have broad application in a project risk environment. Flowcharts and probabilistic analysis tools, such as GERT (Graphical Evaluation and Review Technique) and VERT (Venture Evaluation and Review Technique), open the doors to other opportunities for risk examination and understanding. Similarly, Ishikawa's cause-and-effect diagrams and force field charts also have risk applications.

Technique Description

All the diagramming techniques have one element in common. They provide visual cues for risk issues that might go unnoticed or unattended in a text-based or mathematically derived tool—information that could be lost.

Flowcharts and GERT and VERT tools provide project analyses that depict project processes as flows, cycles, inputs, and outputs. Whereas flowcharts function without calculation, GERT and VERT analyses incorporate probabilities of occurrence for particular paths and may also incorporate the potential costs for each of these cycles.

Ishikawa's cause-and-effect diagrams (or fishbone diagrams) depict the general concern associated with a negative outcome and allow for exploration of that concern in the context of its numerous causes (and, in turn, the causes' causes). Such diagrams serve as idea generation tools and are particularly supportive in establishing multiple risk sources.

In contrast, force field charts are single-issue risk diagrams that highlight or illustrate potential pressures on a project or on a project issue.

Although these diagramming techniques vary widely in design, application, and use, they share the commonality of a visual display of risk information.

When Applicable

As visual tools, these techniques are most applicable when displayed well and when their display successfully provides the organization more risk information or team awareness and project understanding. They should not be perceived as tools for rigorous individual analysis but, instead, as opportunities to share information and gather the interpretations of others on a given set of data.

Inputs and Outputs

Flowcharts, GERT, and VERT. For these three tools, the key input is process. They all depict the project process in minute detail, including any potential reverse loops that might be required to work through the project as a whole. Inputs normally include a list of all process steps, together with an analysis of the relationships among those steps. Decision points, acknowledging when and where the project process may take different directions, are crucial as well. When using GERT and VERT, the only key supplemental inputs would be probabilities associated with each major junction in the workflow. GERT and VERT take into account the likelihood of repeated loops through the process and account for them in their analyses. These probabilistic flowcharts provide a sense of how the iterative cycles may have an impact on time and cost.

Outputs for these tools would be detailed process diagrams for the project, which provide greater clarity on the potential process flows the project may follow. VERT also provides extensive data based on simulations of the project.

Fishbone diagrams. With fishbone diagrams, the key input is the effect that will undergo scrutiny. Then, as the analysis is conducted, the inputs become the causes of that effect, and their causes and their causes. The effort continues until all root causes (including some that critics might deem minutiae) are developed.

Outputs are lists of causes linked to the resulting effects that they cause.

Force field charts. In a force field chart, single-influence issues are balanced pro and con against the project as a whole. The inputs are the key issues that, one at a time, may have either a positive or detrimental effect on the project as a whole.

Outputs from this process are diagrams that allow for at-a-glance analysis of the positive and negative pressures that may affect this project.

Major Steps in Applying these Techniques

Flowcharts

- *Determine the process relationships.* The first and most daunting step in any flowcharting process is to determine and map out the process relationships. This can be done either by using a computerized tool or by using traditional facilitation techniques on an erasable board or flip chart. The key is to identify all the steps in the project process and then to ascertain how they interrelate. Unlike precedence diagramming where all processes flow forward, flowcharts allow for iterative flows and cyclical processes, which, in some instances, may more accurately reflect the project environment.

- *Review the relationships for risk.* Any time a process step is completed and another begins, there is a modest amount of risk. In some processes, however, the risk is significantly greater than others. All risks identified should be documented and preserved for qualification and quantification, as well as the remaining steps in the risk management process. Because there are iterative cycles in flowcharts, some processes should be examined for their probability of recurrence. When using specialized flowchart-compatible tools like GERT and VERT, these probabilities are important and significant inputs. They represent the true risk associated with the process and the cycles thereof. If those tools are to be applied, then it will be important to establish cost targets for each of the iterations.

Fishbone Diagrams

- *Establish the pemise for analysis.* In Ishikawa diagrams, it is important to focus on a single issue to be addressed as the net effect of all causes in the cause-and-effect diagram. The broader the premise, the more likely there will be legion fishbones supporting it. Conversely, a narrower premise will yield a more directed analysis of the causes.

- *Build the basic diagram structure.* The basic structure is consistent in most cause-and-effect analyses, similar to the one in Figure 22.

  The basic structure includes causes related to personnel, equipment, methods, and materials. Although organizations may have broadly different risk issues and concerns, these remain the four classic elements of the structure.

- *ldentify the causes and their causes.* The key in this diagram is to identify root causes for significant concerns. As new causes are identified, the question is asked, "What caused that cause!" This continues until all causes associated with the effect have been exhausted.

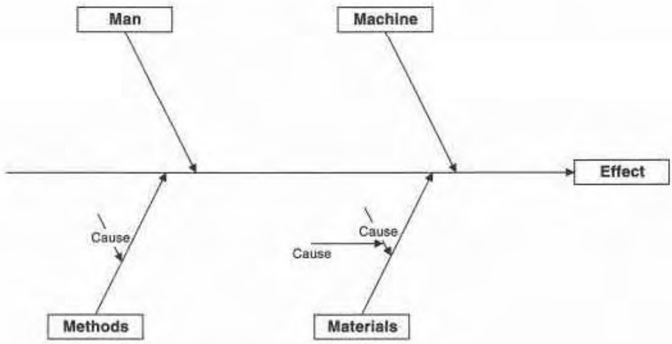


Figure 22. Ishikuwa (Fishbone) Diagram

Force Field Diagram

- *Establish the desired condition.* The key to successful force field diagramming is a clear definition of the desired condition for the project or issue at hand. The fundamental premise is that anything that will draw the organization closer to its ideal is good. On the other hand, anything that distracts from achieving that goal is bad. Thus, clearly establishing the desired state to be examined is important since all analysis will be conducted in that context.

- *Identify positive influences.* Project team members should conduct an environmental scan (analysis of the world around them) to determine what external forces could expedite arriving at the desired state, make the journey less expensive, or otherwise positively influence their ability to achieve or maintain the desired state. Every force—no matter how seemingly inconsequential—should be incorporated in the analysis.

- *Identify negative influences.* Similarly, the situation must be reviewed to ascertain the external forces that could have a negative impact on our ability to achieve the desired state. Those forces that would slow the journey to that state or that would make it more expensive or challenging to achieve should be documented.

- *Map the insights on a force field chart.* Outcomes of the discussions on positive and negative influences are ultimately documented on a force field chart. Positive influences are arrayed on top of the desired state and the negative influences are documented in Figure 23.

Use of Results

The results of these three diagramming techniques can vary widely yet follow a common theme. Data are used for alternative interpretations of

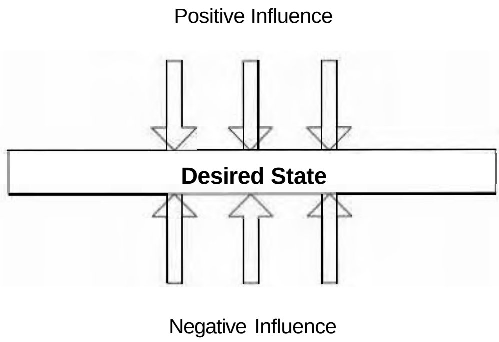


Figure 23. Force Field Analysis

risk information. However, all three techniques may point to the same issues. A risk identified along a process line in the flowchart may also be in evidence as a cause toward the negative effects in question on the Ishikawa diagram. That same risk may also be seen as a negative influence on the bottom half of the force field chart. Because people may interpret information in different ways, the solution is to ensure that everyone has the opportunity to review the information in a fashion in which they can put it to use.

Still, with all diagramming techniques, one key use is to post them both as a reminder and for future analysis of the information embedded therein.

Resource Requirements

Even though there are specific computer tools that will develop these diagrams, any good graphics application software package is normally sufficient to present the information effectively. In terms of resource effort, the requirements for flowcharts, GERT, and VERT will be significantly higher than those for the other applications here. Flowcharts require far more research and in-depth analysis since they must accurately depict the processes that myriad team members perform over an extended period of time. The resource requirements for force field analysis and cause-and-effect diagrams are extremely limited.

Reliability

Of all the diagramming techniques discussed here, flowcharts have the highest level of detail and therefore, generally have the highest perceived level of reliability. The issue, however, is that once again, outputs of the process must be measured against who develops inputs. The more qualified the individuals conducting the process flow reviews are, the more reliable the flowchart will be.

Although the other two diagramming techniques are broader in scope, they are not inherently less reliable. Rather, they are inherently less detailed.

Selection Criteria

As with each chapter on techniques, the diagramming techniques in this chapter are assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare these techniques with other techniques, review Table 6.

Resource Requirements

What resources a technique requires is often the dominant consideration in the selection process. Diagramming techniques require someone literate in the techniques themselves, as well as someone well versed in using the computer applications to capture and document the outputs.

- *Cost* for diagramming techniques depends upon the technique applied. Fishbone diagrams and force field analyses are relatively inexpensive, broad tools. They usually do not take long to develop (1 or 2 days) unless there are extraordinary project needs or an unusual level of depth is pursued. However, flowcharting a process and documenting sundry costs, issues, and risks associated with the iterations in the project can be a time-consuming endeavor. Whereas applying some of the more advanced approaches (such as GERT) should not span more than a few weeks, the analysis alone may take as much as a week to complete.

- *Proper facilities* and *equipment* for diagramming techniques include sufficient wall space or art space to allow them to grow to their natural size. Some flowcharts in development may require as much as twenty feet (approximately six meters) of open wall space. Although the information ultimately must be captured in a computer tool, the original diagram development is normally done in an open, facilitated setting, requiring adequate space to allow the charts to develop. Some advanced diagramming processes like GERT and VERT will require either custom software or software specific to the task, which most organizations do not possess.

- The time *needed to implement* the diagrams, as stated under "Cost," normally is nominal. If resources and facilities are available, the time should not be extensive.

- *Ease of use* is one of the more attractive elements of the diagramming techniques as they do not require any formal or extensive training to apply (unless using advanced techniques). Even though a flowchart may require a good facilitator, once the ground rules for processing information are established, most participants will not be concerned about any challenges associated with applying the tool. Moreover, although flowcharting and VERT and GERT are the most complex of the diagramming processes discussed here, the most challenging aspect is gathering the baseline data for tool inputs.

- The project manager's *time commitment* is sometimes based on the skill levels of the project manager. However, if the project manager is familiar with facilitating process discussions and knows how to ensure the best possible outcome in a reasonable period of time, the effort may go very quickly. Project managers who are not effective in marshalling insights from a variety of resources may find themselves taking more time than anticipated in developing both tool inputs and outputs.

Applications

The advantage to diagramming techniques is that, once built, their outputs are very easily interpreted. No training is required. Interpretation becomes a function of the individual's level of expertise and understanding of the organization and project together with their processes.

- Diagramming techniques generally do not support *project status reporting.* Although status reports normally reflect schedules (and, to a lesser degree, processes), the diagramming techniques described here are not designed to address these concerns in a reporting format.

- *Major planning decisions* may rely in some measure on how these techniques are deployed. Whereas the diagrams do not drive major planning decisions, they do present information that can be perceived as valuable in such settings. The connection here is moderate.

- *Contract strategy selection* is not normally a function of diagrams or their outputs.

- Although some of the other diagramming techniques from other chapters may support *milestone preparation,* the connection here is extremely indirect. As such, diagrams play only a minor supporting role in developing milestones.

- Flowcharts can strongly support *design guidance.* Because many service projects (or even product-oriented projects) require a service element and extensive customer interface, some of these diagramming techniques can be invaluable in establishing how the relationships should ultimately be designed and defined.

- *Source selection* is not *a* prime application for these diagramming techniques. Inasmuch as the techniques can illustrate the concerns associated with particular vendors or highlight the vendors' role in the overall process, the connection is largely tangential.

- Even though these diagrams may indirectly support *budget submittal,* the relationship is extremely indirect. Although project managers may use the diagrams to defend a particular budget position, they provide no true budgetary information.

The diagrams described herein serve other applications as well. They provide insight on potential approaches to projects. They focus attention on particular issues and causes. They encourage open discussion on environmental pressures. And most importantly, they provide visual cues on how to interpret what is frequently vague information.

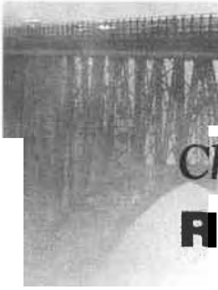
Outputs

Outputs of the diagramming techniques are in the form of their respective diagrams, which are normally used for display purposes to highlight and illustrate issues and concerns.

- The *accuracy* of diagramming techniques relies on their inputs, but the accuracy is generally perceived as high. Because the diagrams depict processes, causes, or environmental conditions, there is not a high probability of significant error, unless those processes, causes, and conditions are broadly misunderstood.
- The *level of detail* associated with diagrams can be extremely high since process diagrams (like GERT and flowcharts) generally dissect processes to a very fine level of granularity. Although some organizations may apply top-down flowcharts or keep their analyses at a high level, flowcharting is respected as a tool that leads to a rather exhaustive level of detail.
- *Utility* of diagrams is dependent on the particular diagram and the audience. If the audience can take advantage of the information being presented, then the utility is high. If, on the other hand, the diagrams are generated only for their own sake and have no specific or intended audience, their utility may be reduced. For the most part, however, the outputs have a relatively high level of utility.

Summary

Diagramming techniques are valuable tools for sharing information in a group setting that otherwise may be somewhat challenging to share. Process flows, environmental forces, and cause-and-effect linkages can be difficult to explain and even more difficult to document without clean, clear diagrams. Diagrams also afford opportunities to build the project team by encouraging open discussion of issues and concerns in a group setting.



Chapter 22
Rating Schemes

Every risk event has both probability and impact. In most organizations, those values are established qualitatively rather than quantitatively. That creates problems because perceptions frequently differ as to what constitutes a "high" probability or a "moderate" impact. Driving those differences in perception is, in part, the lack of organizational standards or schemes to determine those values.

Technique Description

Rating schemes are standardized and are applied on either a projectwide or (ideally) an organizationwide basis to clarify the relative magnitude in terms of impact and probability for a given risk. They define terms like "high," "medium," and "low" for those risk considerations. Clear definitions and the means to test individual risks for their compliance with those definitions support the terms.

When Applicable

Rating schemes are applicable any time a qualitative analysis will be conducted. Because qualitative analysis prompts a review of the probability and impact of risk, schemes should be applied any time the risks are undergoing qualitative review. The schemes are applicable only after they have been developed and after there is general concurrence among team members or the project organization that they are truly applicable in the environment in question.

Inputs and Outputs

Inputs to *develop* rating schemes will be evaluations from the organization's most veteran project managers on the relative values for both probability and impact. However, inputs to *apply* rating schemes will be the actual schemes themselves, along with support and evaluation of the team members' project risks in question.

Outputs from *developing* rating schemes will be clear definitions of terms and values for high, medium, low, and extreme probabilities, as well as clear definitions of impact values for such issues as cost, schedule, performance, and other issues of importance within the organization. Outputs from *applying* rating schemes will be probability and impact assignments for each project risk.

Major Steps in Applying the Technique

Unlike the other techniques, there are actually two major areas of focus here. The first is in developing the schemes; the second is in applying them.

Scheme Development

- *Identify basic probability values.* Using a numeric scale and/or value statements, a core group of project office, senior management, or project team members should establish the basic probability values to be applied across the project (or ideally, across all projects). These values should be designed to minimize confusion or misinterpretation of probability assignments, which risk impact often inappropriately sways. The values should be set to reflect the organization's tolerance for frequency of risk occurrence. Thus, organizations with a high tolerance for risk in general (such as research and development operations) may classify the *low* value using terms like "won't normally happen" or may set it numerically at 30 to 40 percent. On the contrary, organizations with a low tolerance for risk (such as medical product developers) may classify their *high* value using terms like "could reasonably happen" or may set it numerically at 15 to 20 percent. Difference in organizational concerns will influence what constitutes a low, a medium, or a high probability.

- *Publish probability values.* Probability values should be documented and distributed to all team members so that they are aware of perceptions on the potential frequency of occurrence and the organizational culture for probability. Such publication may simply be a memorandum including guidance on probability application. The guidance need not be minutely detailed, but it should provide a sense of the application of terms and the interpretation of frequency versus probability within the organization or on the project team, as is depicted in the following example.

EXAMPLE

To: Project Team

From: Project Manager

Re: Probability Guidance

In all project reviews and risk analyses, please use the following standard to establish values for probability of occurrence and for communicating probability:

- High (80 percent)–This risk has occurred in past projects, and the current project has environmental conditions that make it likely to recur.
- Medium (50 percent)–Even though this risk may not have occurred in the past, environmental conditions make it a very real possibility. Or: this risk has occurred in the past, and although environmental conditions are different, it is still a very real possibility.
- Low (10 percent)–This risk may not have occurred in the past, but it cannot be dismissed, even though environmental conditions make it somewhat less likely. It remains a distinct possibility.
- Extreme (<1 percent)–This risk will likely not come to pass, but its occurrence is not completely outside the realm of possibility.

Please apply these values in all discussions of probability in project correspondence.

Figure 24. Sample Probability Guidance

Note that the probability values are assigned as fixed numbers rather than ranges. This affords the project team consistency if other practices (such as expected monetary value) are applied using the probability values. While probabilities cannot be predicted with accuracy (and probably are more accurately reflected in a range), establishing a single data point to represent high, medium, and low probability opens the door to more consistent interpretation of risk and risk values.

- Identify impact areas. There should be basic areas of concern when it comes to risk impact. Although they will not cover the breadth of possible project risk, they should encompass as many different areas as possible. The classic, basic areas are schedule, cost, and performance (or requirements). Other impact areas may include organizational politics, public relations, shareholder value, team member retention, and so on. The most significant impact areas will be those that the organization prizes most highly on its projects and those that cover the greatest range of organizational concerns.

- *Establish impact values.* This is frequently done on a project basis as well as organizationally. The effort establishes what constitutes low, medium, and high impact within each impact area identified in the previous step. This process tends to be somewhat more complex than establishing probability values since impact values can vary widely from project to project as well as from organization to organization. As such, careful consideration must be made to ensure that either the impact values are set to apply to all projects or guidance is provided to support project managers as they modify them for project application.

  Impact values may be established by setting the high value as the point when the full time and attention of the project team (or senior management or a task force) would be mobilized to deal with the impact of the risk. High values often represent an organization's "threshold of pain." Low values can be defined as those times when the risk is still of some note (if only for documentation or historic purposes) but will not impede project completion or the organization's stated objectives. Medium impact risks are those that fall between those two thresholds. Different impact statements will be established to clarify the range of cost impacts, schedule impacts, quality impacts, and impacts for other risk areas.

- *Publish impact values.* Impact values should be documented and distributed to all team members so that they are aware of the perceptions on the potential magnitude of risk impact. Such a document may simply be a memorandum including guidance on impact value application. The guidance need not be excessive in its detail, but it should provide a sense of the application of terms and the interpretation of risk impact, as in the following partial example:

EXAMPLE

To: Project Team

From: Project Manager

Re: *Impact* Guidance

In all project reviews and risk analyses, please use the following standards to establish values for potential impact of risks if they come to pass and for communicating risk impact:

Cost

- High–more than 25 percent of total contingency budget
- Medium–5 percent to 25 percent of total contingency budget
- Low–less than 5 percent of total contingency budget

Schedule

- High–more than 20 percent of total schedule contingency
- Medium–5 percent to 20 percent of total schedule contingency
- Low–less than 5 percent of total schedule contingency

Requirements

- High–Would cause deviation from the requirement or specification, which the customer and end user would clearly discern
- Medium–Would cause deviation from the requirement or specification, which would not be visible to the customer or end user but would still constitute a clear deviation from specifications/requirements
- Low–Would modify the existing approach to requirements but would not constitute deviation from specifications/requirements

Politics

- High–Would prompt issue escalation to senior management
- Medium–Would prompt issue escalation to functional manager
- Low–Would prompt issue escalation to project manager

Please apply these values in all discussions of impact in project correspondence.

Figure 25. Sample *Impact* Guidance

The impact values above are samples only and should not be construed as true and actual. Each organization (or in some cases, project) will have a clear set of risk impact values, which should reflect their culture and project management approach.

When publishing impact values, stress the importance of consistent application. It is also important to emphasize that a risk should be considered high-impact whenever *any* of the impact values are high. A risk with a high requirements impact but a low impact value for all the other scales would still be considered a high-impact risk.

Scheme Application

- *Review identified risks for probability.* For each risk identified, the expected likelihood of risk occurrence is based on the metrics developed for probability under the rating scheme. Catalog or mark the risk as high, medium, or low probability. Ideally, multiple team members should participate in the ranking process to ensure that a single individual's personal experiences do not bias the value. Remember, for each risk the question is the same: "What is the likelihood that the risk event will come to pass!"
- *Review the risks for impact.* For each risk event, the team members should now use the rating scheme to establish a high, medium, or low impact. Because there will be impact values for multiple areas (such as cost, schedule, frustration level), it is important that those risks marked as low impact in one area are reviewed for their potential impact in other areas. The highest value becomes the risk event's impact value. A risk that has a low cost and schedule impact but a high impact in terms of organizational politics is a high-impact risk.

Use of Results

Risk rating schemes can be used in various ways to support qualitative analysis. They provide support for organizations attempting to establish a common risk language for probability and impact. They afford team members the ability to share information consistently on a given project and to conduct comparative risk analyses among multiple projects by virtue of their consistency.

They also provide support in terms of how the risk can be quantitatively evaluated for both expected value and risk models. Because ratings schemes may establish congruous probability or impact values, they can facilitate consistent prioritization of risk, as well as concordant assessment of risk prior to response strategy development.

The values that risk rating schemes establish are used in lieu of quantitative values when quantitative analysis is either unavailable or excessively expensive to apply.

Resource Requirements

The resource requirements essential to developing a rating scheme are much more significant than those used to apply it. Rating scheme development generally requires the participation of senior-level project management (or organizational management). This may take the form of representation from the project office or the participation of program managers with extensive organizational experience. Management participation is essential if the rating scheme is to be applied and accepted universally.

To apply a rating scheme, however, the resource requirements are minimal. Once the scheme is in place, its application on a project-by-project basis becomes an issue of basic project understanding. Anyone with a clear understanding of the project's nature and environment can apply a well-crafted scheme.

Reliability

Reliability is a function of use. Over time, rating schemes are adjusted to accommodate changing environments and changing needs. As a rating scheme is tested and proven, it becomes progressively more reliable. Moreover, since rating schemes ultimately reflect the organization's posture on risk impact and probability, absolute values are not nearly as important as the ability of the organization to assess the relative risks of one project over another. Over time, reliability becomes high.

Selection Criteria

As with each chapter on techniques, rating schemes are assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare rating schemes with other techniques, review Table 6.

Resource Requirements

- The cost of rating schemes is low as it actually reduces cost in the risk qualification process by minimizing the need for data gathering. By providing common metrics and terms, the cost associated with risk assessment is actually reduced.
- Proper facilities and equipment for rating schemes consist of the schemes themselves and a conference room sufficient to conduct a review of

risk based on those schemes. The information should then be ultimately stored in an organizational database.

- The *time needed to implement* rating schemes is low. As with cost, this approach actually reduces the time commitment required to conduct a thorough risk assessment. With the schemes in place, any risk assessment becomes a relatively cursory review of the nature of each risk and the application of the scheme.
- The *ease of use* associated with rating schemes is high. If the scheme is well written, virtually any team member with project familiarity can apply the scheme.
- The project manager's *time commitment* is actually a function of scheme development rather than application. During scheme development, the project manager's time commitment is significant since time and effort must be committed to building organizational and executive buy-in. Once the scheme is actually constructed, the project manager's time commitment is minimal as the responsibility to apply the scheme can readily be delegated.

Applications

The primary application of the rating schemes is to provide a consistent understanding of the probability and impact of each risk in the project. Because those terms are somewhat imprecise, the development of metrics to generate consistency allows organizations to build contingency policies, management strategies, or organizational dicta on how risk should be managed. The metrics also allow for the simple ranking of project risk, a critical endeavor for any project.

- Rating schemes support *project status reporting* only if risk status is an element of such reports. If the reports include notification of major project risks together with the status of those risks, the rating schemes are invaluable because they provide common terminology and understanding of the criticality of a given risk.
- For the same reasons, rating schemes also support *major planning decisions*. Because major planning decisions depend on an understanding of risk in the organizational context, the common terminology that the schemes afford engenders a clearer understanding of the nature of any concerns associated with the decisions.
- The schemes could support *contract strategy selection* if the selection process was directly tied to the volume and nature of the project risks. However, since very few contract organizations are structured to consider these issues, the relationship here is generally weak.

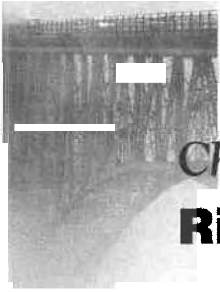
- Rating schemes serve no useful function in *milestone preparation* because milestones are a function of the schedule, and the schemes themselves have no direct effect on the schedule.
- *Design guidance* is not a strength of rating schemes, save for the comparative analysis of one design versus another in a consistent fashion.
- The schemes could support *source selection* in the case where risk is a critical deciding factor in the process. Otherwise, they do not provide extensive support.
- *Budget submittal* may or may not incorporate contingencies. If the budget in question does not incorporate contingency funding, then rating schemes serve no useful function. However, if the budget will include contingency funds, then the rating schemes play a pivotal role in ensuring that the funding levels are appropriate and are in keeping with the organization's perspective on probability and impact.

Outputs

- The *accuracy* of rating schemes is moderate. Because they are qualitative tools, they lack the precision that is sometimes desirable in a thorough risk analysis. But precision is not the same as accuracy. Accuracy is a reflection of how well the tools actually establish the probability and impact of given risks. Since different team members may have diverse perceptions on the severity of risk, the schemes lend a degree of accuracy that would be unattainable without them.
- The *level of detail* is relatively high as rating schemes provide a means to conduct a risk-by-risk analysis of probability and impact. Rating schemes raise risk analysis to a very detailed level and make it a type of analysis that some would abandon if a means did not exist to facilitate the effort. In essence, that is the role of the schemes.
- The overall *utility* of rating schemes is high in that they provide metrics where metrics would otherwise not exist. They facilitate a thorough, consistent assessment of probability and impact, yet without the significant investment associated with many of the more quantitative approaches.

Summary

Rating schemes require an up-front investment of time and management energy to establish consistent measures for probability and impact, which is enough to dissuade some organizations from the investment. However, once in place, the measures make risk qualification simple, consistent, and clear from team to team and from project to project. Even though they do not generate hard numbers with which to work, they do generate a clear sense of risk relative to other projects and other organizational risks. Furthermore, they encourage a common risk vocabulary within the organization so that all parties involved know how high "high" is.



Chapter 23
Risk Modeling

Risk models are developed so that project managers will be able to better identify high-risk or high-opportunity projects consistently. That drive for consistency is actually closely aligned with the discussion on rating schemes (Chapter 22). The problem that many organizations encounter is their own inability to measure projects for risk. Although they will have predictive tools for cost and schedule, there are very few tools specific to the notion of risk. The risk model seeks to fill that void by encouraging the consistent evaluation of projects for issues that put the organization at risk, as well as issues that afford the organization the highest probability of success.

Technique Description

The technique consists of constructing a set of questions that, when answered candidly, will provide a metric value as to the overall risk and opportunity associated with a project. The questions should span the organization's experiences and concerns and should reflect the organization's risk tolerances. Because this involves a clear understanding of what risk tolerances exist within an organization, it is prudent to develop the rating schemes prior to attempting to build an organizational risk model.

When Applicable

Project risk models are normally built only after an organization encounters a series of significant project risks or failures and then wants to ascertain how they can avoid these concerns in the future. Once built, the models should be applied in much the same fashion as any major evaluation. They should be applied during the go/no go decision process and again at any major evaluation and decision points.

Inputs and Outputs

Model Development

Inputs into model development include a list of critical risk issues and tolerances for the organization, as well as a list of what the organization perceives as its strengths and opportunity generators. Those inputs will be crucial in constructing the model, as they will provide the baseline against which all projects are judged. The other inputs will be concurrence among senior management staff as to the relative weights of the individual risk and opportunity issues and the objective metrics by which the likelihood of occurrence can be measured.

The outputs of model development are the models themselves. This is most effectively built into a spreadsheet or database program that allows the information to be plotted against a chart, graph, or other display to illustrate the relative level of risk on the project under consideration.

Model Application

The inputs for applying risk models are information germane to the questions asked within the model. Project managers and team members are charged with answering the questions objectively and applying the measures identified in the model.

The outputs from the risk model are normally a grid, graph, or display that highlight the position of the project (from a risk perspective) relative to other risks within the organization. ESI International, for example, plots risk using a graph like the one shown in Figure 26.

A straight line across the top is indicative of a low-risk, high-opportunity project. An oblique line from lower left to top right highlights a high-opportunity, high-risk project.

Major Steps in Applying the Technique

As with rating schemes, there are really two major applications here. The first is in building the model; the second is in applying it.

Model Development

Building a risk model requires time and energy on the part of senior management or senior project management to clearly establish the metrics by which all projects will be judged (from a risk perspective). They should be parties to all of the steps in this process.

- *Identify critical risk and opportunity areas.* The identification of risks and opportunities within an organization is normally not a challenging effort; however, the identification of *critical* risks and opportunities is.

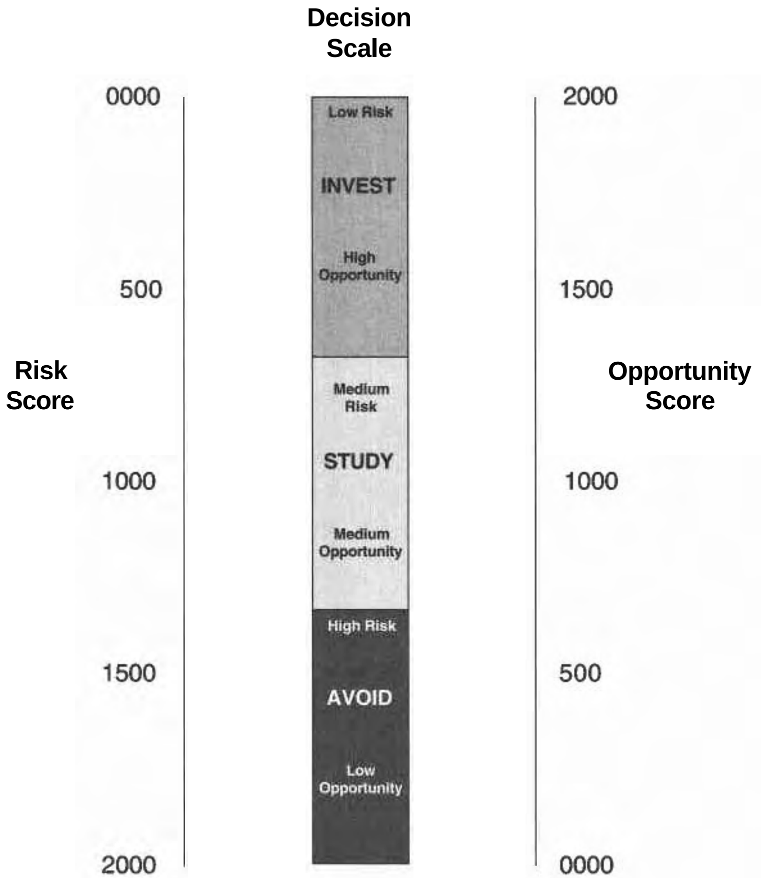


Figure 26. Risk-Opportunity Decision Scale

Senior managers participating in this process will frequently have many years or even decades of experience within the organization. As such, their insight is invaluable. It is also possible that as a result they will have somewhat skewed perspectives as to what issues are likely to be critical to the organization. Thus, this approach is more effective when the senior managers involved first share their perspectives on all risk and opportunity areas they can identify rather than simply identifying those that are critical. Once all the risk and opportunity areas are identified, then a sorting or filtering process can begin.

Note that these are opportunity and risk areas rather than simply opportunities and risks. Areas can be synonymous with categories or terms like "repeat offenders." These risk areas are the areas of concern that strike the organization with sufficient regularity to warrant attention and redress. In contrast, the opportunity areas are the areas that the organization most consistently acknowledges as positive or rewards.

These risk and opportunity areas should be sufficiently well defined that developers can build metrics to characterize the probability of their occurrence later in the model building effort:

EXAMPLE

Risk area: Technological novelty

"In our organization, projects that apply new technology inherently promote greater risk."

Opportunity area: Trade press

"The trade press is generally *very* favorably disposed to us. Projects that attract trade press increase opportunity for us."

- *Assign impact weights or values to the risk and opportunity areas.* Weights are numerically assigned and should be established on a scale with the highest values being assigned to the risk areas of the greatest concern and to the opportunities of the greatest value. If some risk areas pose dramatically greater concern, then they should be assigned a significantly higher value than those of lesser concern. If, however, the differences are marginal, then the differences in values should be marginal as well. Thus, because of the need for fine-tuning on such models, scales frequently range from 1 to 5 or 1 to 10 to allow for modest adjustments. A model with a range of 1 to *3* does not allow for fine adjustments.

EXAMPLE

Risk area: Technological novelty

"This issue is not as important as multivendor integration (5 on our scale) but is more important than potential employee loss (3 on our scale). We will weigh technological novelty as a 4."

Opportunity area: Trade press

"This issue presents an opportunity for us but not to the degree of potential profit (a 5) or shareholder value (a 4). We will weigh trade press as a 3."

- *Establish the probability scale.* Probability scales in risk models are not the same as probability rating schemes as defined in Chapter 22. In risk models, the probability scale is a ranking (normally set at 1 to 3 or 1 to 4) of the likelihood that the conditions will be ripe for a risk or opportunity area to become a significant issue in the project. Scales of probability for each area will be mapped to metrics to allow for consistent evaluation of their probability of occurrence.

> EXAMPLE
>
> "For all risks, we will assess probability as low, medium, or high, and rank them as 1, 2, and 3 respectively."

- *Develop metrics to assess probability of occurrence.* This, in many ways, is the single most arduous step in the process. For each risk and opportunity area, clear, objective measures need to be established to identify when the conditions for the risk area are likely to exist and when they are highly unlikely to exist. For each area, the first question to consider is "How does one know when conditions are ripe for this area?"

> EXAMPLE
>
> *Risk area:* Technological novelty
>
> 1) The technology is well established and familiar
>
> 2) The technology is new to our organization but well established in the marketplace.
>
> 3) The technology is new, but we participated in developing it.
>
> 4) The technology is new and was developed outside our organization.
>
> *Opportunity area:* Trade Press
>
> 1) The project is internal and does not involve any new approaches or technology to interest the trade media.
>
> 2) The project is external and does not involve any new approaches or technology to interest. the trade media.
>
> 3) The project involves new approaches to existing technology and may have modest interest for the trade press.
>
> 4) The project is a breakthrough effort that will draw the attention of clients, media, and competitors.

Afterwards, objective statements must be established to clarify whether they fit on the scale established in the previous step. This process takes time since each risk area must be examined and analyzed to ensure that the objective measures accurately reflect the risk or opportunity area in question.

- *Determine the range of scores for the outputs.* Each impact value should be multiplied by the lowest probability value to establish the lowest possible score for each risk and opportunity area. All low risk scores should be summed to establish the lowest possible risk score. All low probability scores should be summed to establish the lowest possible opportunity score. Thereafter, each impact value should be multiplied by its highest probability value to establish the highest possible score for each risk and opportunity area. All high risk scores should be summed to establish the highest possible risk score. All high probability scores should be summed to establish the highest possible opportunity score.

EXAMPLE

Risk area: Technological novelty	*Opportunity area:* Trade press
Impact weight: 4	Impact weight: 3
Low score: 1	Low score: 1
Risk score (Low): 4 × 1 = 4	Opportunity score (low): 3 × 1 = 3
High score: 4	High score: 4
Risk score (high): 4 × 4 = 16	Opportunity score (high): 3 × 4 = 12

- *Create a graphic display for the outputs.* The model can be mapped to a variety of graphic displays, ranging from the ESI model (page 207) to a simple grid to a scatter diagram (Figure 27). (A scatter diagram is appropriate if *all* individual risk and opportunity answers are to be displayed on the grid rather than merely the summed score.)

- *Test the model.* Once all impact values and probability metrics are established, the model can best be tested on old projects perceived as high risk–high opportunity, high risk–low opportunity, low risk–high opportunity, and low risk–low opportunity. The model's questions should be completed based on the perceptions for the project *when it began* rather than after completion. If built properly, the model should accurately reflect the levels of opportunity and risk as established *after* the project was completed.

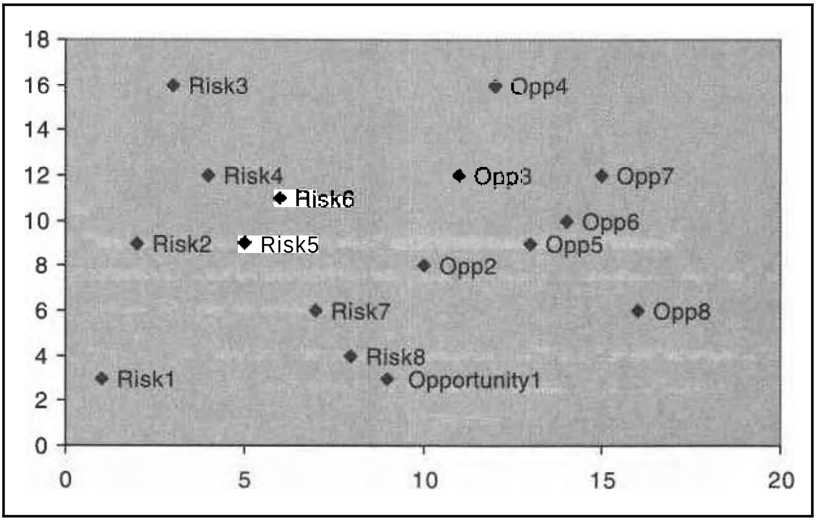


Figure 27. Scatter Diagram Example

Model Application

- *Apply the tested model to new projects.* When a project is conceived, project team members should host a meeting to evaluate the new project in the context of the questions in the model. They should mark each of the correct objective statements and score the project in the model accordingly.
- *Score the project.* Based on the scoring practices created for the model, the new project should be scored for total risk and total opportunity scores. The scores should then be mapped into the model's graphic.
- *Communicate the score.* As risk models are frequently a component of go/no go decisions, the information developed should be sent to the key decision makers on the project to facilitate their efforts in deciding whether the project is viable. The entire score sheet should be retained for historic purposes in determining long-term model accuracy and the need for adjustment.

Use of Results

Risk models can be used to—

- Communicate relative levels of risk to senior management and project decision makers
- Establish or defend the need for contingency funding on a given project based on its overall risk and opportunity scores

- Challenge assumptions as to relative levels of risk and opportunity that marketing or technical personnel may make
- Present an argument for certain levels of support or reward based on project complexity, opportunity, and risk

The models' applications are as varied as the organizations that use them, but their primary use is simply to create a situation where risks can be consistently evaluated within a given organizational climate. In the nascent days of a project, risk is all too frequently assessed according to the individual perception of the most effective negotiator. The model is designed to mitigate some of the personality issues associated with risk and to encourage a significantly higher level of consistency.

Resource Requirements

The resource requirements to develop the model are significantly greater than those required merely to apply the model. Although model development requires inputs from senior project personnel and senior management personnel, model application generally requires inputs only from those individuals who understand the nature of the project in question. Apart from personnel needs, the only other needs for both applications are database capabilities to store and maintain outputs from the model.

Reliability

Risk models have reliability only when applied consistently within the organization. The challenge in many organizations is that individuals attempt to modify the metrics to color the perspective on their individual project. That defeats the purpose of the model as well as its ability to interpret the information accurately. However, when applied properly and consistently over an extended period of time for multiple projects, the model has increasing reliability.

Selection Criteria

As with each chapter on techniques, risk modeling is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare risk models with other techniques, review Table 6.

Resource Requirements

- The cost associated with implementing risk models is extremely limited. The resource time commitment consists of the time required to review the project in the context of the risk model.

- There are no special equipment needs for this technique because it is primarily a small administrative burden. For *proper facilities and equipment*, the only requirement is to find the files, databases, or shelves housing the information to support the model and store its outputs.
- The *time needed to implement* risk models is very short. Very little time is involved beyond ensuring that the information required to assess the project against the objective metrics is available.
- Risk models have extremely high *ease of use*. The intent is to provide a quick snapshot of the project in terms of both risk and opportunity.
- The project manager's *time commitment* to the models is extremely low because developing the responses to the objective statements is generally quick, easy, and readily completed.

Applications

Project risk models can be used in some application categories in Table 6. In some of the applications, risk models are effective only if they are applied on a regular basis in project reviews and midterm assessments, as well as at the beginning of the project.

- For *project status reporting*, project managers may find risk models very effective in determining the relative status of a project's risks and opportunities when compared to earlier assessments.
- *Major planning decisions* can definitely hinge on outputs from risk models. Risk models can be applied to establish go/no go decisions, set up contingency funds, or determine appropriate courses of action to improve relative risk and opportunity scores.
- *Contract strategy selection* may also be tied to the risk model. Firm-fixed-price contracts can be used with those projects that have lower risk and higher opportunity, whereas cost-plus contracts may be more appropriate for those where the organization would have to assume higher risks and less opportunity. The model can provide early indicators of which tendencies the project may display.
- Risk models do not support *milestone preparation*.
- In terms of *design guidance*, risk models have very limited utility, unless multiple risk and opportunity questions are directly focused on design.
- Risk models do not directly support *source selection*.

- Risk models may support *budget submittal.* If the risk model is used to establish levels of a contingency fund by percentage or score, then the risk model can be crucial to proper budget submittal.

outputs

Outputs from a risk model are the completed model questionnaire and the graphical outputs thereof. Some organizations maintain risk questionnaire responses as a means to discern what areas of risk exist in a project (rather than simply relying on the overall score).

- *Accuracy* of the risk model is high if the model is well established and has historically been applied to a variety of projects.
- The *level of detail* obtained through risk models is low. Although the risk model analyzes a variety of categories, it does not explore the detail associated with a particular project. Instead, it consistently examines risk areas across projects. And although that focus has value and can be highly indicative of relative risk levels, the level of detail is slight.
- The *utility* of risk models rests in their consistent application. If they are used consistently across the organization and are used to evaluate relative levels of risk or capability, then the utility is high.

Summary

The keys to project risk models are consistent application and a clear understanding of the tool's role. The risk model will not develop detailed lists of highly project-specific risks. Instead, the risk model will provide a scoring system and a metric that can be applied effectively to make go/no go decisions, establish appropriate contingency reserves, and ascertain areas of heightened concern or interest. Consequently, it is a general evaluation tool and should be treated as such.

Chapter 24
Monte Carlo Simulations

This technique takes cost and schedule risk into account not just for individual activities but also for the entire project. In many cases, there is the temptation to assume that all project risks must be accounted for in the worst case. This technique, however, takes a more holistic approach. The total project cost risk and the total project schedule risk are usually expressed as a cumulative probability distribution of total project cost and total project schedule, respectively. Such distribution information can be used to reflect project risk by computing the probability that the project will be achieved within particular cost or schedule targets. It can also be used to assess what level of funding or schedule would be required to virtually guarantee success.

A computer is necessary to use this technique because the analysis requires many repeated computations. Most of the software packages (for example, **Risk+** and **@Risk)** conduct both cost and network analysis simultaneously, whereas some tools **(@Risk** for Excel, for example) can perform just cost analysis. Input data requirements for such models are significantly less than cost/schedule analyses.

Technique Description

The technique uses simulation analysis to establish relative levels of risk. In Monte Carlo analysis, uniform, normal, triangular, and beta distributions are used to assign risk values to cost and schedule targets for each work package within the WBS. The type of distribution applied depends on the nature of the work as well as the nature of the understanding of that work. However, different distributions require different levels of understanding. A uniform distribution, for example, requires only that one know what the highest and lowest possible costs and durations are. A beta distribution, on the other hand, requires a far greater depth of data and understanding.

Monte Carlo analysis uses a random-number generator to simulate the uncertainty for individual WBS elements. After costs and schedules are simulated for each WBS element, they are aggregated to establish a critical path, a total project duration, and a total project cost estimate. This process is repeated many times. Each time a new set of WBS element costs and durations are developed is referred to as an experiment. The results of many such experiments provide a frequency distribution of total costs, reflecting the aggregate of the cost risks associated with all individual WBS elements.

When Applicable

This technique applies when the project manager needs to know the probability that a project can be completed successfully at a given funding level or within a given time frame. It also applies when there is a need to know what funding level is required to achieve a specified probability of completing a project. To ensure that this technique can be applied, the project manager must obtain sound estimates of the cost uncertainty plus the schedule uncertainty associated with each WBS element. After cost and schedule estimates are already in place at the work package level, this becomes a relatively quick analytical procedure.

Inputs and Outputs

With Monte Carlo simulations, inputs and outputs vary depending on the models used. As an example of inputs and outputs information, **Risk+** and **@Risk** (as well as Primavera's Monte *Carlo*) can apply various types of cost uncertainty against each individual WBS element and then generate a variety of information types.

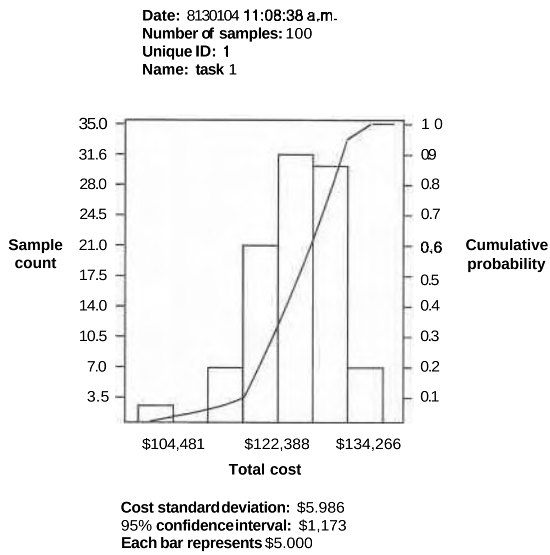
For each model run, three elements of data are required:

- Project name
- Monte Carlo sample size (number of iterations)
- Decision to compute either a partial analysis or complete analysis

For each work package, the data required become more extensive. Depending upon the type of distribution requested or required, data needs will vary widely. For instance, uniform distributions will require only the range of best- and worst-case information for cost and schedule. Triangular distributions will include the best- and worst-case as well as the most likely targets for both cost and schedule. Normal distributions may call for the mean duration as well as the standard deviations from the mean. In addition, beta distribution data will require information on the shape of the curve as well as the mean.

Some tools allow broader inputs for the work packages, thus requiring simple confidence levels (expressed as percentages) for cost and schedule. In these cases, either a uniform or normal distribution is generally applied, with the single-point cost or single-point schedule estimate as the median or the mean.

The outputs from the tools are similar to those in Figure 28. These outputs show that roughly 53 of the samples fall into the range near $122,388 (the mean). That type of information is used to develop the probability curve and the histogram. Each bar on the histogram represents a range of roughly $5,000. As you can tell by examining the histogram, the odds of project costs coming in at less than $115,000 are extremely low (about 10 percent).

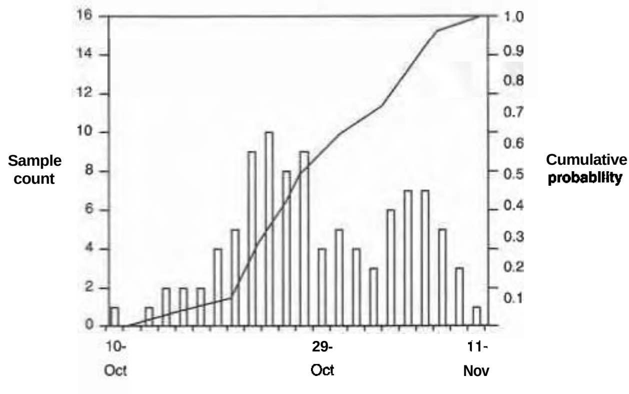


Cost Probability Table

Probability	Cost ($)	Probability	Cost ($)
0.05	111,542	0 55	123,953
0.10	114,121	0.60	124,510
0.15	115,638	0.65	125,158
0.20	117,606	0.70	126,421
0.25	118,802	0.75	126,773
0.30	119,438	0.80	127,602
0.35	120,204	0.85	128,476
0.40	120,870	0.90	129,682
0.45	121,520	0.95	130,803
0.50	122,568	1.00	134,266

Figure 28. Cost *Risk/WBS* Simulation Model

Similarly, schedule curves can be plotted to establish ranges of probability and risk associated with given schedule targets. Figure 29 illustrates how schedule values can be presented in the tool.



Date: 8/30
Number of Samples 100

Completion Probability Table

Probability	Date	probability'	Date
0.05	*10117*	*0.55*	10/28
0.10	10/21	0.60	10/30
0.15	10/22	0.65	10/31
0.20	10/23	0.70	11/01
0.25	10/23	0.75	11/04
0.30	10/24	0.80	11/05
0.35	10/24	0.85	11/06
0.40	10/25	0.90	11/06
0.45	10/25	0.95	11/07
0.50	10/26	1.00	11/11

Figure 29. Risk *Support*

These data can now be used to establish reasonable levels of funding and acceptable schedule targets. Based on the information in Figures 28 and 29, project funding would have to be set at more than $130,000 to achieve 95 percent confidence that the project would be funded adequately. To be 95 percent confident that schedule targets were achieved, the deliverable due date would have to be moved to November 7. That does *not* mean that the project will cost $130,000 or be done on November 7. It means, rather, that based on the simulation, there is a 95 percent probability the project can be completed within those targets.

Major Steps in Applying the Technique

The Monte Carlo simulation process assumes some baseline understanding of project computer simulation tools. Such tools are commercially available but have a significant learning curve associated with them. Although macros can be established in some project management software to achieve the same goals as a quality Monte Carlo program, the level of effort is rarely worth the investment.

- *Identify model input requirements.* Depending on the choice of tools, the inputs required can vary widely. Some tools can take extremely simple inputs (confidence ranges or high, medium, low risk values) and use those data to generate an analysis based on predetermined values for those inputs. *Risk+* and some other tools have this capability. Other tools, like *@Risk*, require more detailed data inputs, including type of distribution being applied to each task and data ranges. The input requirements are important as they will significantly affect the data gathering processes.
- *Gather data.* Those two words capture the single most onerous element of applying the Monte Carlo technique for cost and schedule simulations. Data gathering and organization in Monte Carlo are significant and time-consuming. Even if only limited data are being applied, each task must be examined for its relative range of risk and in most cases, the distribution of that range.
- *Input the data into the tool.* As tool utilization increases, facility with these processes should increase accordingly. Even so, first-time data entry effort can be significant. If all appropriate data are in hand, this step is generally a function of following any step-by-step instructions that the tools provide.
- *Establish simulation parameters.* Each simulation can take on characteristics all its own. A simulation may include as few as two iterations (which would have limited utility) or 10,000 or more iterations (which borders on statistical overkill). The parameters may also change how the information is examined, whether by classic Monte Carlo techniques or more current statistical trends (like the Latin Hypercube, a technique that supposedly takes fewer iterations to achieve statistical validity).
- *Run the simulation.* For most simulations of any size, running the simulation can be a surprisingly time-consuming effort. A 1,000-iteration simulation running on a fast computer for a several-hundred-task

project may take as long as an hour or more to churn through all the data. This often comes as a surprise to novice users accustomed to computer analyses that run in the blink of an eye.

- *Analyze the data.* The curves that the tool develops should be examined for the insights they afford. This should include identification of the mean duration, the best- and worst-case scenarios, and anomalous information provided. Any trends, spikes, or outlying data elements should be reviewed to determine if they represent anomalies or information of value.
- *Communicate and archive.* Communicate the outputs to those who have a vested interest in or some decision-making authority on the project. Archive the results for later comparisons with project outcomes.
- *Review from a historical perspective.* Upon project completion or at ongoing major decision points, retrieve archived outputs for comparison to project outcomes. Take note of the cumulative probability assigned to the outcome(s) achieved and document them.

Use of Results

The outputs from a Monte Carlo simulation can be used to establish reasonable cost and schedule targets or to identify appropriate contingency levels. The information is used to define reasonable cost levels or to defend specific project approaches. Monte Carlo outputs from multiple simulations with modified variables can also illustrate the influence of those variables on the project as a whole.

Resource Requirements

The resource requirements for Monte Carlo are significant in that the requisite tools tend to be more expensive than conventional project management application software and because users must have specialized expertise to gather data and operate the tools.

Reliability

The mathematics and logic of the Monte Carlo simulation technique are basically sound. However, the tool is only as reliable as the inputs and the interpretation of the outputs also influences the tool's efficacy. The technique is highly reliable at establishing cumulative probabilities of schedule and cost targets but is completely unreliable at establishing the probability of a single cost or data point. The value of the tool rests in its ability to set a range. On the other hand, Monte Carlo's greatest limitations rest in the challenges associated with obtaining sound and supportable data.

Selection Criteria

As with each chapter on techniques, the Monte Carlo simulation model is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare Monte Carlo with other techniques, review Table 6.

Resource Requirements

- The *cost* associated with this technique includes both the one-time cost of software acquisition (which can range from several hundred to several thousand dollars) and the cost for a resource to gather the data and develop the appropriate scenario to run through the computer. This resource is normally a highly skilled analyst.
- As to whether the *proper facilities and equipment* are available, the answer in many organizations is no. Although the investment is a one-time experience, some organizations feel that the information delivered through the tool represents data overkill.
- The *time needed to implement* after the tools and skills are in place is, much as with estimating relationships (Chapter 18), in proportion to the time required to gather the necessary data.
- The *ease of use* associated with this analysis method is high after a few hours of hands-on experience if the user has a basic understanding of distributions, probabilities, and the range of risk. Although available programs come with instructions, the real challenge is associated with obtaining and substantiating sound values for all cost element uncertainty information. Ideally, the best source for such information would be past experience on similar projects, but that type of information is rarely available.
- The project manager's *time commitment* is slight (assuming that the project manager is not also the analyst) but necessary to ensure that team members provide the information to the analyst in a timely manner.

Applications

- *Project status reporting* represents only a small fraction of the overall use of the technique. Only one respondent to a major survey that the Defense Systems Management College conducted identified using this technique for this purpose. Even so, as the tools become less expensive and more user-friendly, the application here could readily increase.

- The Monte Carlo model is best applied when *major planning decisions* are made. The model provides insight into the range of possibilities associated with any given modification to the plan.
- *Contract strategy selection* and *milestone preparation* are not applications that can effectively use the Monte Carlo model.
- This technique can be applied in *design guidance* if the ranges of cost and schedule implications are required for a variety of different potential designs.
- *Source selection* is not a common application, but Monte Carlo has been applied to examine the cost and schedule ranges for different potential vendors based on their submitted costs, schedules, and WBSs.
- *Budget submittal* is also a rare use for this technique, although the Monte Carlo models will provide management with clear insight into the best-case, worst-case, and most likely cost and schedule parameters for the project.

Outputs

- The subjective nature of most input data used to conduct the analysis determines the *accuracy* of output results. The more accurate the inputs, the more accurate the outputs.
- The analysis does nothing to increase risk visibility at a lower *level of detail.* Values are computed by aggregating detailed information into overall project cost and schedule risk information.
- The overall *utility* of this type of analysis for actually identifying risk, controlling risk, or planning risk responses is limited. However, this type of analysis can be used to display cost and schedule risks known to exist at the cost account level in an aggregate manner (the way some management executives will want to see it).

Summary

This type of analysis aggregates cost and schedule uncertainty due to risk for any number of work packages into a distribution of the cost and schedule uncertainty for the entire project. It provides the project manager with the information necessary to answer the following questions:

- What is the probability that the project will be complete for X dollars or less?
- What is the probability that the project will be complete on or before X date?

- How much budget should we assign to this project based on the risk and our desire for X percent confidence?
- How much time should we allot for the project based on the risk and our desire for X percent confidence?

These are not inconsequential questions. They are classics of project management. They represent the body of knowledge that many managers want to have at the outset of their projects.

The challenge in applying Monte Carlo is not understanding the outputs or even understanding the tools. The challenge stems from attempting to gather information on likely distributions of time and cost for individual work elements. There is also risk with Monte Carlo that derives from the innate complexity and detail in the data outputs. That detail generates an aura of certainty, which may or may not be deserved (based on the quality of rhe inputs).

Chapter 25
Risk Factors

This method is simple to implement. It consists of applying risk consideration to the individual work package budgets within the WBS. If the risk input values for the work packages are in hand, then the effort moves rather quickly. However, in many cases obtaining sound and dependable risk input values can be a challenge. Often, the input values are based on quick judgments project personnel make. The method does not include procedures for systematic and scientific development of the needed input data. Nevertheless, the primary use of the method is to estimate the total added project costs that might be expected due to risks associated with the individual work packages.

Technique Description

The basic concept of the risk factor method is to determine factors, or multipliers, with which to increase cost estimates of individual baseline WBS work packages to cover anticipated risk-associated cost growth. A reasonable budget above that resulting from the baseline cost estimate is the objective. The method uses a WBS based on a technical (deliverable) breakdown like that shown in Figure 30.

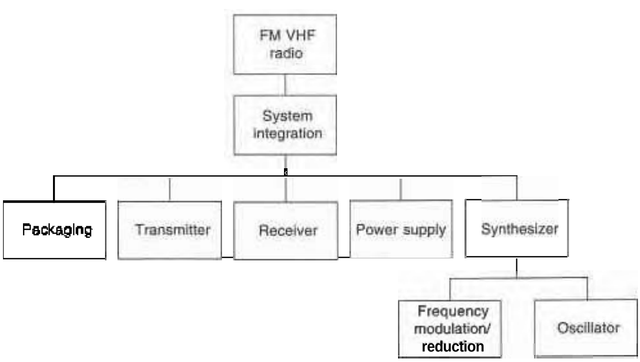


Figure 30. Sample Technical Breakdown

First, the baseline estimate must be developed for each cost element. Applying whatever considerations are appropriate, a risk factor is established between 1.0 (indicating no risk) and 2.0 (indicating so much risk that expected costs could be twice the baseline cost estimate values). Each baseline estimate is then multiplied by its corresponding risk factor to obtain new WBS element cost estimates. These new estimates are then finally summed to derive a budget that will account for technical or other risks.

Obtaining sound WBS element risk factors is the critical aspect of this method and may be difficult. Data analysts have scant documentation to use in substantiating such factors. Because these factors significantly affect analysis results, the inputs must be obtained from highly experienced technical experts. (In other words, the apparent simplicity of the method has not relaxed the requirement that the most experienced project personnel should take key roles in the analysis.) After preparing a baseline cost estimate using cost estimating methods, an analyst should be able to formulate a new cost estimate expeditiously by using the risk factor. The effort will depend on the difficulty an analyst has in obtaining the assistance of technical experts and on how detailed the WBS or cost breakdown is.

When Applicable

Of the 57 project management offices responding to a survey on past and current risk analysis utilization that the Defense Systems Management College conducted (as part of the original draft of this text), only 6 had used this technique. Personnel in these six offices found the technique useful primarily for developing project requirements documentation and for project planning. The technique is more applicable early in the life of a project when information is not available to apply some of the more sophisticated risk analysis techniques. This technique is applicable only when single data-point estimates, broken out by the work package, are available. The method's simplicity makes it applicable to even small, low-cost projects

Inputs and Outputs

One of the primary inputs of a risk factor assessment is a baseline cost estimate broken out to the work package level. The second primary input is a set of risk factors for each work package. These factors usually will be the subjective judgments of experienced personnel who know the project, its current status, and potential problem areas. Using checklists or watch lists and the number of items on the lists that apply to each work package is one way of helping to judge the level of risk associated with each element of work.

Outputs of a risk factor application consist of a budget or cost estimate that is increased over the baseline budget (or estimate) by an amount required to cover risk-induced costs.

Major Steps in Applying the Technique

- Obtain project cost estimates. These should be broken down to the work package level and should include sufficient detail to resolve any questions or issues about their content. Such estimates should be available from project planners. Their actual preparation is not considered to be part of applying this method.
- *Identify* work package risk factors. Each work package should be assessed to determine the level of additional risk associated with it. That level of additional cost risk should be expressed as a percentage of the original estimate and should be added to the task costs to accommodate additional work resulting from risk. Knowledgeable technical and project management personnel should offer their opinions on these factors. Analysts should also review lessons learned for similar systems to gain insight on how much risk might be involved. If similar tasks have been performed heretofore and by the same people assigned to the current project, risk should be lower. It is important to remember that past projects were also risky; therefore, any parametric cost estimates based thereon already may include some cost to cover risk.
- Recalculate project costs. Sum the work packages and their risk factor budgets to derive a new project cost estimate.

Use of Results

According to the survey of project offices, those offices using risk factor results found them helpful, particularly in the early development of cost estimates during requirements development.

Resource Requirements

Resource requirements for this method can vary greatly. Frequently, the same cost estimator responsible for preparing the baseline cost estimate can also develop the risk factor-adjusted estimates quickly if the appropriate experts provide the work package factors in a timely manner. However, applying the method can become more involved as more technical and other experts are used to derive the individual work package risk factors.

Reliability

The reliability of this technique can vary widely, both in fact and in the opinion of those reviewing results. Because use of the technique generally requires judgments based on limited information, the knowledge and skill of those making judgments will greatly affect the reliability of the results. However, providing documented justification for all factor values used increases reliability. A single cost analyst assigned risk-level factors for all WBS elements without inputs from technical and other experts would likely produce relatively low-reliability results.

Selection Criteria

As with each chapter on techniques, the risk factors technique are assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare risk factors with other techniques, review Table 6.

Resource Requirements

- The time required to develop activity-by-activity breakdowns of the cost estimates, coupled with the time spent in obtaining WBS activity risk factors from qualified experts, generally drives the *cost* of the technique.
- The *proper facilities and equipment* for the technique consist of a personal computer loaded with project management and spreadsheet software applications.
- The resource time spent in gathering data and assessing risk factors from experts drives the *time needed to implement* the technique much as it does the cost.
- After data are developed, the technique has relatively high *ease of use*. The project manager must review the computations and apply them.
- The project manager's *time commitment* normally consists of tracking down the correct experts to provide risk factors for each activity.

Applications

The method applies to product and service projects of virtually any size but can be used only when a cost estimate broken out by work package is already available. It can quickly provide a systematically derived estimate of required funds to cover risk-related project costs. However, the method is best applied when project personnel with experience on other projects are available to provide judgments regarding the level of risk involved with each work package.

- *Project status reporting* is a reasonable use for this approach because it provides an estimate of the total funds required to complete the project. That figure, along with actuals to date, provide the project manager with the baseline status, current status, and potential status of the project at completion.

- The results of the analysis of the technique, as described in the previous paragraph, may also drive *major planning decisions.*
- *Contract strategy selection* and *milestone preparation* are not typically applications for this technique.
- This technique can support *design guidance* only from the perspective of the cost implications of different design recommendations.
- *Source selection* is not a prime application for risk factors because this technique requires a fully developed, comprehensive WBS. Normally at this preliminary stage, such information is not readily available.
- The technique can support *budget submittal* only if the budget is being developed comprehensively from the bottom up in the WBS. If an exhaustive WBS is not developed for the budget, then the technique will not apply.

outputs

- The *accuracy* of this technique is a direct function of the expertise of the experts providing data for inputs. This model is the classic example of a "garbage in/garbage out" scenario. If the information provided is less than sound, the outputs will have a low accuracy level. To the contrary, if the experts have extensive experience on similar efforts, the accuracy of the method increases significantly.
- The *level of detail* is low for risk factors because the technique focuses on a projectwide, rather than a task-by-task, perspective.
- The *utility* of the technique is high as long as the correct goals are sought. If the project manager is looking for project-wide information and a perspective on the overall costs associated with remaining risks, the technique is ideal. For other goals, though, it would be somewhat inappropriate.

Summary

This analysis method has been used widely to develop an estimate of the funds required to cover added costs resulting from the individual risks associated with specific work packages. It is designed not to analyze potential task-by-task overruns but rather to analyze the aggregate overruns for the project, as some of the risks identified will come to pass and others will not. In the long term, however, the method balances out those risks that do become problems and those that do not in establishing a reasonable, whole-project estimate.

Chapter 26
Risk Response Matrix

In risk response development, one of the key challenges is finding strategies that will not take longer to implement than the project itself. The risk response matrix addresses that concern by affording individuals and team members the opportunity to analyze and generate strategies that deal with multiple risks and cause the fewest problems in terms of other project risk.

Technique Description

The risk response matrix is a grid the team creates that lists risks on one axis and strategies on another. The grid is then populated by plus and minus signs to reflect positive and negative influence on other risks. Ideally, the grid should include the standard risks of cost and schedule. The risks and strategies are juxtaposed as shown in Figure 31 on the following page. For more in-depth analyses, an additional set of grids can be placed across the top of the grid to encourage evaluation of the risk strategies in the context of other strategies, thus creating a diagram not dissimilar from the famed "house of quality" used in quality function deployment (QFD). This expanded type of diagram is shown in Figure 32 on page 233.

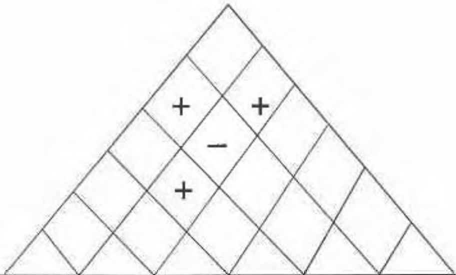
In the matrix example, it is possible to see that only one strategy has been developed for the "no viable names" risk, and it is the same strategy that helps mitigate at least one copyright issue. It is also evident that writing the site in HTML code will mitigate a host of risks and may actually save time and money. Some Web designers, however, would argue that the site will tend to be unimaginative as a result (which illustrates how the matrix can help in identifying new risks based on risk strategies).

The addition of the roof to the matrix illustrates how the diagram can highlight potential relationships among the strategies. In this instance, a browser at the 7.0 level can apparently handle HTML code with ease and the two should work together favorably. But the 7.0 requirement could be a hindrance for beta tests because some beta testers are apparently operating on old 5.0 or 6.0 version browsers. The roof highlights potential support or conflict.

The grid is used with a limited number of risks to keep the information manageable. Ideally, these should be the top priority risks as identified during risk qualification or quantification.

Risk strategies / Risks associated with starting a commercial Web site	Write the entire Web site in very simple HTML code	Beta test the system, along with a major "stress test," using dozens of representatives from our biggest corporate clients	Make up a nonsense word and conduct a Web search for it to ensure no previous use	Mount the system on redundant servers around the world	Establish minimum entry criteria for the site (e.g., "Browser must be version 7.0 or later")	Meet with corporate client network staff to include them in the design
No viable names will be available, so traffic will be significantly reduced			+			
Legal challenges on copyright issues could occur, tying up the site in court			+			
Web site could generate too much traffic, causing serious downtime and server errors	+	+		+	+	
The code behind the site could be too ornate, and upgrades may not be possible	+					+
A programming language could be included that does not work well through corporate firewalls, causing a loss of business	+	+				+
Project will be overbudget	+	–	+	–	+	
Project will be late	+	–		–		–

Figure 31. Risk Response Matrix



Risk strategies / Risks associated with starting a commercial Web site	Write the entire Web site in very simple HTML code	Beta test the system, along with a major "stress test," using dozens of representatives from our biggest corporate clients	Make up a nonsense word and conduct a Web search for it to ensure no previous use	Mount the system on redundant servers around the world	Establish minimum entry criteria for the site (e.g., "Browser must be version 7.0 or later")	Meet with corporate client network staff to include them in the design
No viable names will be available, so traffic will be significantly reduced			+			
Legal challenges on copyright issues could occur, tying up the site in court			+			
Web site could generate too much traffic, causing serious downtime and server errors	+	+		+	+	
The code behind the site could be too ornate, and upgrades may not be possible	+					+
A programming language could be included that does not work well through corporate firewalls, causing a loss of business	+	+				+
Project will be overbudget	+	−	+	−	+	
Project will be late	+	−		−		−

Figure 32. Expanded Risk Response Matrix

When Applicable

The grid is applied after the project team has identified and quantified risks to establish those that are the greatest concerns. It is best applied when the skills and insights of the entire team can be exercised since team members may have widely different perceptions as to what constitutes a corresponding strategy or a conflicting risk approach.

The grid should be applied whenever risk strategies are being evaluated and should be a part of any strategy assessment or major risk reassessment.

Inputs and Outputs

The inputs for the tool include the prioritized risk listing that has been whittled down to the top 5 to 10 risks. The inputs will also consist of multiple strategies for those risks, allowing team members to review them in the greater context of the project, its other risks, and other strategies. In addition, the inputs incorporate the team members' evaluations of the implications of the risks and risk strategies in the context of the other risks and other risk strategies.

The outputs are completed grids, which can then be interpreted to determine which risk strategies address the greatest number of concerns with the least impact to cost and schedule.

Major Steps in Applying the Technique

- *Construct the grid.* Before beginning the data gathering, it is reasonable to generate a grid in which all the appropriate risk control information will be placed. The grids (like those used in Figures 31 and 32) should list both "Project will be overbudget" and "Project will be late" as risk events. These standard elements are recommended for each grid since risk strategies should always be assessed for their potential role in generating schedule delays or cost overruns.

- *Gather the prioritized risks.* Actual prioritization of the risk events should have been completed using another technique, such as expected value or a simple "high-high" sort. The top 5 or 10 risks should be listed on the left side of the grid (as depicted in Figure 31).

- *Identify multiple strategies.* Ideally, multiple strategies should be developed for each risk in the list. This can be accomplished by reviewing the basic options of avoidance, acceptance, mitigation, and deflection for each risk event. The key is to expand the list of available options and establish the broadest possible range for risk control opportunities. As the strategies are identified, they should be arranged in the boxes along the top of the grid (as depicted in Figure 31).

- *Assess the strategies' impact on the risks.* Even though a strategy may have been created primarily to resolve or deal with a single risk, each strategy should be evaluated for its own potential impact on the other risk events listed. Risk strategies frequently have unforeseen consequences (both favorable and unfavorable) when considered against the project's other risk events. To document the influence of the risks, a plus sign (+) can indicate when a risk strategy will have a positive influence on a risk event (for instance, a plus sign next to budget overrun would indicate that the strategy would likely reduce overall cost or minimize the possibility of budget overruns). A minus sign (–) can indicate when a risk strategy might have a negative influence on the risk event (for example, a minus sign next to schedule delay would indicate that the strategy will likely add to the schedule or increase the probability of delays). Some users put zeros in sectors where the risk event has neither a negative nor positive influence. Other use circles to indicate the risk strategies deemed to be optimal for the situation.
- *(Optional) Assess the strategies' impact on other strategies.* This step is often undertaken as a matter of course rather than as a formal step in the process. However, to formalize it, some users will put the roof on the diagram to illustrate possible connections among risk strategies. The process is much the same as the previous step with the difference being that the evaluation is designed to determine whether the risk strategy will make it easier or more challenging to implement other risk strategies.
- *Select the strategies with the greatest overall positive influence.* Although this is a subjective decision, it is tempered by virtue of the tool's indications that some risk strategies have a broader span of influence than others. Thus, by determining which risk strategies in general are the most beneficial and have the least negative influence, it is possible to review options in the context of the project's overall risk environment.
- *Select secondary options.* The obvious advantages of one set of risk management options developed using the tool may render this step moot. However, since management and team members frequently prefer to decide which are the best available options, a set of options should be identified as the logical alternatives to the primary selections.
- *Select optimal risk management actions.* With the options and information in hand, either the project manager or the team should determine which strategies have the greatest overall positive influence and should

therefore be deployed on the project. Implementation should be expressed as work packages and should be incorporated into the WBS or the project plan.

Use of Results

Outputs from the matrix can be used in basic decision making or to present information to upper-level or executive management to facilitate *their* decision making. However, the information ultimately needs to be captured, reviewed, and presented to build organizational support and acceptance for the risk management options selected.

Resource Requirements

The resource requirements for the technique are somewhat limited, although those individuals with a history of creative risk intervention should be welcomed in this process. The primary resources required for this approach are participants who are willing to provide inputs and offer insight on the optimal risk approaches and options. One key physical resource requirement is a large wall on which to post the flip chart pads that depict the grid to encourage a comprehensive perspective on which options will work in this environment and which will not.

Reliability

The approach is surprisingly reliable as it forces a level of assessment on risk response development that frequently does not occur at all. Because it adds a layer of checks on the process, the risk response matrix creates a more reliable process. Still, there is never an assurance that all possible risk responses have been reviewed since the responses are as diverse as the participants themselves. This technique ensures that considerations have been made for the bulk of the available options.

Selection Criteria

As with each chapter on techniques, the risk response matrix technique is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare using a risk response matrix with other techniques, review Table 6.

Resource Requirements

- The *cost* of the technique is a function of the time commitment of the participants in the process. Although the effort is occasionally tedious, it does not consume an excessive amount of time. Thus, the cost is relatively low.

- The *proper facilities and equipment* for the technique consist of flip charts or erasable boards sufficient to create the grid and input the data. Some project managers may opt to capture the information after the session using a digital camera as supplemental equipment.
- The resource time expended in gathering data and cataloging the information on the grid drives the *time needed to implement* the technique, much as it does the cost.
- The tool has high *ease of use* as its application is primarily intuitive. However, the tedium of completing the grid sometimes disguises the minimal effort required for its application.
- The project manager's *time commitment* normally consists of seeking the correct experts to provide inputs and evaluate the strategies across multiple risk events.

Applications

This approach can be applied to virtually any type of project but will work only on a relatively small number of activities. One key to success is to ensure it is applied to a limited number of activities simultaneously. Thus, the tool is best applied after the top 5 to 10 risk events have been established.

- The risk response matrix does not support *project status reporting.* The matrix is an ideation and decision-making tool rather than a tool for gathering data on past performance.
- The matrix may drive *major planning decisions.* Because such decisions rely on a breadth of background and information, the insights generated using the matrix can provide a distinct tactical advantage in determining which decisions are the right ones.
- *Contract strategy selection* can get modest support from the matrix because different contract strategies can be seen as different risk management approaches and thus be loaded into the matrix. In that regard, the matrix can be most effective in helping to determine which risk responses represent the most viable options in terms of contract strategy.
- The matrix does not support *milestone preparation.*
- As with contract strategy selection above, the matrix supports *design guidance* if and when the different designs are integrated as potential risk responses into the matrix itself.

- *Source selection* is well supported by the tool. That support comes when sources are identified as potential risk response strategies and are integrated into the matrix. From that perspective, risk responses can be assessed as more or less viable in terms of overall project risk mitigation.

- The technique can support *budget submittal* only by virtue of the costs of individual risk responses. Because the tool helps ascertain the optimal responses, those responses can then be evaluated for potential budget impact. That can be expressed either as budget line items (for the risk responses that are incorporated into the WBS) or as a contingency (for the risk responses that *may* be deployed at some later date if the project conditions change or meet certain criteria).

Outputs

- The *accuracy* of this technique is largely a function of the expertise of the experts providing the data for inputs. If the experts are creative and experienced in developing risk strategies, the opportunities here are virtually boundless. As the risk responses are spelled out in greater detail, the tool becomes more accurate. The more detail written into each risk response, the more accurate the tool becomes. However, the tool becomes highly inaccurate if the risk responses applied here are only one or two words. In such instances, there is a distinct tendency to make the responses more inclusive (that is, to claim that the responses will solve more risks than they actually will).

- The *level of detail* is high as numerous specific risks are addressed at the work package level.

- The *utility* of the technique is high. The tool can be applied at virtually any point in the project as long as the risk events have been identified and prioritized. The technique can be used both to discern new strategies and to present those strategies to the team or management. And the tool, if used as presented in Figure 32, affords the ability to review risk responses in the context of the other responses.

Summary

This technique is the model of practicality in risk response development. It affords clear understanding of project risks, the options available to respond to those risks, and the most viable and practical of the options. That breadth of capability is rare. And because the tool is relatively intuitive, that breadth of capability is something that can readily be applied at a variety of levels within the organization.

Chapter 27
Performance Tracking and Technical Performance Measurement

A U.S. government report on technical risk devoted much discussion to examining the importance of managing the technical aspects of a project. However, measuring technical risk on any effort that involves furthering the state of the art is difficult and can involve significant risk itself. Performance tracking is conducted by establishing exacting performance criteria for all aspects of the project and assessing them against the acceptable ranges around those criteria. Some concrete measurements that are available can be useful in measuring technical progress against preset goals of projects.

Technique Description

The performance tracking technique advocates using a technical risk assessment report, which is updated periodically. The report is based on working-level data but is intended to provide an overview of current trends and status. The technique uses a set of standard technical indicators proven to be effective measures of technical performance. In addition to the standard measures, the analyst also develops project-unique technical indicators. Each indicator has clearly defined performance projections and preset alert criteria. Standard indicators are shown in Table 11 on page 240; a sample indicator is shown in Figure *33* on page 241.

When Applicable

This technique is most effective when objective and quantifiable criteria are established. The technique is best used to manage near-term requirements, but with minor modifications, it can be implemented on any type of project. It can also be used in conjunction with more elaborate probability-driven risk models to examine corresponding cost-and-schedule effects of current technical performance.

Technical Risk Indicator (typical unit of measure)	Applies To				Source					
	System	Subsystem A	Subsystem B	Subsystem C	Subsystem D	Subsystem E	Statement of Work	Contract specifications	Contractor plans	Previous experience
Design										
Wait time (seconds)	X	X	X	X	X	X		X		
Size	X	X	X	X	X	X		X		
Database access	X	X	X	X	X	X		X		
Throughput	X							X		
Memory utilization (percentage of capacity)	X							X	X	
Design-to-cost (dollars)	X	X	X	X	X	X	X			
Design maturity (number of design deficiencies)	X	X	X	X	X	X	X		X	X
Failure activity (number of failure reports submitted)	X	X	X	X	X	X	X		X	X
Engineering changes (number of engineering change orders)	X	X	X	X	X				X	X
Drawing releases (number of drawings)	X	X	X	X	X				X	X
Engineering resource-hours	X	X	X	X	X				X	X
Test										
Critical test network (scheduled dates for critical test events)	X	X	X	X	X				X	X
Reliability growth (mean time between failures)	X	X	X	X	X		X	X	X	X
Production										
Transition plan (scheduled dates for critical production events)	X	X	X	X	X				X	X
Delinquent requisitions (number of delinquencies)	X	X	X	X	X				X	X
Production cost (dollars)	X	X	X	X	X		X			
Labor and material requirements (resource-hours unit and material-cost unit)	X	X	X	X	X				X	
Cost										
Cost and schedule performance index (ratio of budgeted and actual costs)	X	X	X	X	X		X			
Estimate at completion (dollars)	X	X	X	X	X				X	
Contingency reserve funds (percentage remaining)	X	X	X	X	X				X	
Management										
Specification verification (number of specification items)	X	X	X	X	X			X		
Major project risk (ranked listing)	X	X	X	X	X					X

Table 11. Standard Indicators

Inputs and Outputs

The technique requires that performance be tracked on a periodic basis for each technical indicator selected. This requires full cooperation with the various stakeholders in the project, including the customer and any

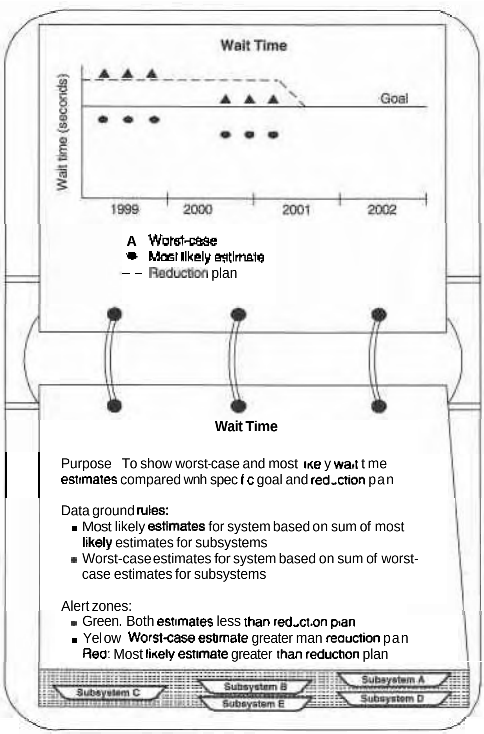


Figure 33. Sample Indicators

subcontractors. It also requires that subcontractors participate in managing risk (a good benefit). The outputs can be in the form of risk management reports or briefings. The contents should include an analysis of each indicator's current performance and longer-term trends.

Major Steps in Applying the Technique

One of the first steps in adapting the technical risk assessment method to track risk performance is to choose indicators that can be applied to the development project. If the project were aircraft construction, weight and size would always be significant indicators. On the other hand, weight and size may not be regarded as important factors on a system to be installed in a building. Many standard indicators (Table 11) can be used on development projects, and the utility of certain indicators will vary as the project progresses.

The selection should include indicators for the entire project, as well as indicators especially for the subsystems. The unusual aspects of a developmental project frequently require the use of special technical indicators. In the case of space systems, certain indicators are appropriate, such as the production of gasses from the material in the product when exposed to a space environment. Examples of special indicators are listed in Table 12.

Derived from Specification Requirements	**Derived from Program Requirements**
Performance characteristics: Speed, capacity, accuracy	Schedule: Feasibility and probability of timely accomplishment
Physical characteristics: Memory utilization, support requirements	Resources: Adequacy, distribution
Effectiveness characteristics: Reliability, safety, logistics support	Test plan: Sufficiency of planned testing
Environmental conditions: Platform, workstations	Procurement factors: Availability of multiple sources
Design and construction: Technology, packaging, materials	

Table 12. Sample Special *Indicators*

Each indicator, whether standard or special, must have ground rules established for data collection and assessment. These can be in the form of a dictionary and can describe the objective of the indicator, the reason it was chosen, the use of the indicator, and the procedure when a signal is generated that indicates a problem is developing. The dictionary should have sufficient detail to inform the system operator of the meaning of the indicator and the relationship of the measurement to risk.

It is advisable to explain the trends that might be expected during the life of the indicator. Expected values may take many different forms or curve functions but should include traceability to the project goals (cost, schedule, performance, or various combinations thereof). Evaluation criteria must be set so that they will highlight situations that signal problems. Color coding (such as red, yellow, and green for high, medium, and low risk, respectively) can be used as can percentage bands for the same type of message. These bands may vary as time progresses: that is, getting tighter as completion is nearing or getting more tolerant as time passes to indicate that a risk is disappearing. In any case, the project manager and any contractors should agree and understand the evaluation criteria chosen and their significance in order to facilitate rapid corrective action.

All this planning would be useless without a formal reporting system. This will vary in form from organization to organization and from manager to manager. It may be produced in report form for presentations to customers and management or stored as raw numerical data points. In any case, it must be in a form that both the contractor and project manager can immediately use in making critical project decisions. As in any system that requires the coordinated efforts of a matrix organization, someone must ensure that the job is done accurately and in a timely fashion and that proper decision makers are informed of risk situations.

In summary, the major steps in applying risk measurement techniques are as follows:

- Select standard indicators
- Select special indicators
- Establish data definitions
- Project expected trends
- Set the evaluation criteria
- Plan the reporting system
- Assign responsibilities
- Ensure that the job is done accurately and meets deadlines

Use of Results

Technical risk assessment reports furnish information needed to start any action to correct potential problems. Each indicator should be first examined separately and then again in related groups of indicators. In using the results, analysts must simultaneously consider the factors of cost, schedule, and technical risks.

Resource Requirements

This technique requires personnel with knowledge and skills in highly specialized technical areas. The data received are derived from many functional groups and must be analyzed by people who have skills within the various functional areas. This does not mean that each functional risk assessment area requires a full-time person. It does mean, however, that each functional area may have to contribute expertise.

Reliability

To have a reliable technical risk assessment, all major participants must understand the importance of the assessment and must be actively involved in establishing and implementing the system. Each team member should participate in the initial assessment of the project's technical risk and help select indicators to be used in tracking the risk. These same people should provide updates for each reporting period. Raising problems early allows the manager to take action, precluding failure or at least tempering risk.

Supplemental Information

Performance tracking is not new. It has existed in one form or another for many years but has recently surged in popularity and use. Many variations on the theme are presented in this discussion. Control is one of the most critical elements in risk management, and performance tracking is one of the most effective control techniques. Another variation of the method is fully integrated performance measurement. This is a capability being developed to integrate technical, schedule, and cost performance. It also provides earned value performance measurement capability to project managers who are not getting formal performance data from their contractors or team. The major steps are described in the following sections.

Technical Performance

- Identify specific technical parameters (based on the project's objectives, plans, and specifications) and their value for performance, producibility, quality assurance, reliability, maintainability, supportability, and so on. A few examples (for an aircraft) are shown in Table 13.

- Relate each technical parameter to specific WBS elements whenever practical. Many will relate only to the total system level, but quite a few will come from the specifications, which should match the WBS. In Table 13, for example, the topic of facility square footage under producibility could be aligned with either an existing WBS activity (such as "Lease construction hangar") or under a separate analysis activity designed exclusively for performance tracking (such as "Evaluate hangar size"). A typical parameter might be "Hangar size is not to exceed 45,000 square feet."

- Define specific methods for calculating, measuring, or observing the value of each technical parameter. For example, it is important to clarify the parameters of how calculations will be derived: "Hangar size evaluations shall include all building square footage used in the actual construction of the aircraft, including all storage areas and housing facilities that are adjacent to the facility."

- Assign a specific individual or organization the responsibility for managing each technical parameter and the progress toward achieving the goal value. Returning to the example of the hangar, a single team member from the maintenance team might be assigned ongoing responsibility to account for any space utilization modifications that occur as the project progresses.

Performance	Producibility
Speed (kn)	Capital ($)
Weight (lb)	Human resources (number of people)
Range (NM)	Facilities (sq ft)
Power (kW)	Material ($)
Turn rate (deg/sec)	Equipment (machinery required)
Takeoff distance (ft)	Schedule (time)
Climb rate (ft/sec)	Risk (1.0-2.0)
Accuracy (ft)	
Radar cross section (sq ft)	
Quality Assurance	**Reliability**
Scrap, rework, and repair (% of labor)	Mean time between failures (MTBF) (hrldays)
Yield (% of first-time inspection successes)	Mean time to repair (MTTR) (hrldays)
Supplier rating (%)	Probability of component/assembly failure (0–1.0)
Quality costs ($)	Life-cycle analysis ($)
Customer satisfaction (0–1.0)	Design-to-cost ($)
Software lines of code (LOC) in violation per 1,000 LOC	
Supportability	**Maintainability**
Parts inventory ($)	Standardization (%)
Costs ($)	Modularity (%)
Resources (human, equipment, facilities)	Update ability (0–1.0)
Modularity (%)	Special equipment ($)
Operational availability (%)	Frequency (how often, how long)
MTBF (hddays)	Costs ($)
MTTR (hrldays)	

Table 13. Fully Integrated Performance Measurement—Typical Technical Parameters

Schedule Performance

- Identify or create specific schedule events where the calculation or observation is to be made.
- Determine values or conditions to be achieved at each milestone. In addition, set a tolerance or alarm value to represent a threshold for corrective action.
- Identify or create a specific schedule event where the goal is to be achieved.
- Identify whether calculation or observation will be used to assess the event at various points in time.

Plotting the technical performance parameter value against time creates a visual portrayal of the relationship between technical performance and schedule (see Figure 34 and Table 14).

Cost Performance

- Assign budgets to each technical performance parameter. These budgets may be real and add up to contractual values, or they may be hypothetical units created just to determine relative weights. These budgets can be assigned in many different ways; the only requirements are rationality, traceability, and consistency.

Category: Quality assurance

Factor: Scrap, rework and repair

Goal: 1%

Method of Calculation

Method of Observation

Measurement Milestones

Milestone	Desired Value	Method	Rationale
____(#3)	6%	CALC	____
____(#4)	5%	CALC	____
____(#6)	3%	CALC	____
____(#7)	3%	OBS	____
____(#8)	2%	OBS	____
____(#9)	1%	OBS	____

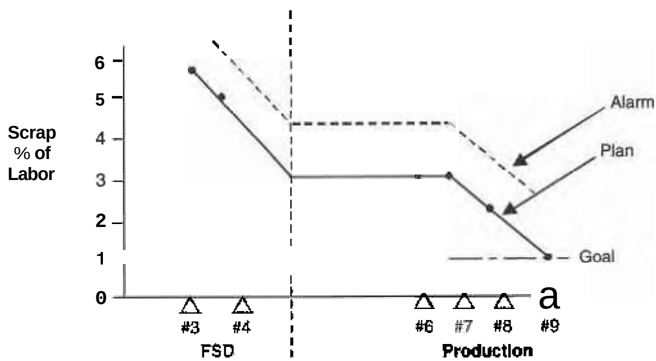


Figure 34. Technical Performance Management

- Distribute the assigned budgets to each of the measurement milestones based on the engineering judgment of the percentage of the total value associated with each milestone.
- Use conventional earned value techniques to measure accomplishment (such as 50-50 milestones).
- Apply the schedule performance index to appropriate activities in the resource-loaded network to determine the cost impact of the technical and schedule performance.

Parameter	Spec or Goal	Development Project Specific Milestones 1	2	3	4	5	Production Project Specific Milestones 6	7	8	9	10	Ops
Performance												
Parameter 1	V_{GOAL}	V_{CALC}		V_{OBS}	V_{OBS}	V_{GOAL}						
Parameter 2	V_{GOAL}		V_{CALC}	V_{OBS}	V_{GOAL}							
Parameter 3	V_{GOAL}			V_{CALC}		V_{OBS}		V_{OBS}	V_{GOAL}			
•												
•												
Quality Assurance												
SCRAP	1_{GOAL}			6_{CALC}	5_{CALC}		3_{CALC}	3_{OBS}	2_{OBS}	1_{OBS}		
Factor 2	V_{GOAL}					V_{CALC}			V_{OBS}		V_{GOAL}	
Factor 3	V_{GOAL}		V_{CALC}		V_{CALC}		V_{OBS}	V_{GOAL}				
•												
•												
Reliability												
Parameter 1	V_{GOAL}	V_{CALC}	V_{CALC}	V_{CALC}	V_{OBS}	V_{OBS}	V_{OBS}	V_{GOAL}				
Parameter 2	V_{GOAL}											
•												
•												
Maintainability												
Condition 1	C_{GOAL}		C_1		C_2			C_3		C_{GOAL}		
Condition 2	C_{GOAL}	C_1	C_2			C_3			C_{GOAL}			
•												
•												
Supportability												
Condition 1	C_{GOAL}			C_1		C_2			C_3			C_{GOAL}
•												
•												
Producibility												
Parameter 1	V_{GOAL}	V_{CALC}		V_{OBS}	V_{OBS}		V_{GOAL}					
Parameter 2	V_{GOAL}		V_{CALC}	V_{OBS}		V_{GOAL}						

Table 14. Technical Performance Schedule Milestones

A quick example may help clarify the technique. As shown in Table 14, Performance Parameter 1 has a numeric goal. A method for calculating progress against the goal has been derived. At Specific Milestone 1, progress against the goal is calculated (CALC). By Specific Milestone **3,** progress against the goal can be observed (OBS); and by Specific Milestone 5, the goal should be attained (GOAL).

Selection Criteria

As with each chapter on techniques, performance tracking is assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare performance tracking with other techniques, review Table 6.

Resource Requirements

- The *cost* of the performance tracking technique is limited if the systems are already in place and it is maintained on an ongoing basis. Setting up the initial indicators is somewhat time-consuming and should be done with exacting care.
- The *proper facilities and equipment* are limited because little more than a spreadsheet is required to track the data and maintain accurate project records.
- If the entire team and the project manager commit to performance tracking from the beginning of the project, their *time needed to implement* will be minimal on an individual basis. Collectively, however, the time appears more significant. If the project manager decides to implement performance tracking at midproject, significant initiative with extensive time commitments will be required.
- The *ease of use* of the technique is a function of the clarity of the instruction the project manager provides for the effort. Although performance tracking is not overly complex, it does require clear direction for the uninitiated.
- The project manager's *time commitment* for the effort primarily stems from ensuring total involvement (including all team members and contractors) in the process.

Applications

This technique can be used in most categories in Table 6. Because the technique focuses on monitoring progress after an item is assigned, using it in the resource allocation process is of little value.

- *Project status reporting* is a key asset of this technique. Although there are schedule tracking tools (like earned value) and cost tracking tools (like budgets and interim reports), performance tracking affords the project manager a means to quantify and report on quality and requirements achieved. No other tools go to quite this level of depth in establishing specific values for the activities as they relate to the requirements.
- The results of performance tracking can drive *major planning decisions* because the information derived from the technique points to areas of organizational expertise and weakness. Since most organizations strive to find projects and approaches that take advantage of their strengths, performance tracking is an excellent technique for identifying what those strengths may be.
- *Contract strategy selection* both supports and is supported by performance tracking. The strategy to support performance tracking will incorporate the vendor's or subcontractor's detailed reporting to mirror the systems the host organization deploys. Performance tracking supports contract strategy selection by building, over time, a historic database that includes information on how the organization has performed against specific types of activities and, therefore, in relation to specific types of subcontractors and vendors.
- In *milestone preparation,* performance tracking allows for a completely different type of milestone. Rather than identifying milestones for a percentage of schedule achieved or a percentage of costs spent, performance tracking allows for milestones developed against degrees of anticipated customer satisfaction achieved, based on performance to date. It can be used to establish triggers and thresholds for risk, which can then be converted into project milestones.
- *Design guidance* is supported in much the same fashion as major planning decisions. Performance tracking identifies strengths, allowing the project manager to endorse designs that work with the organization's high-skill areas.
- Performance tracking may drive *source selection,* particularly if there is an established database of performance tracking numbers. Performance tracking identifies responsibility for tasks that are at a designated level of quality, as well as for those that are not high quality. This affords the project manager a quantitative measure to apply in assessing past performance of vendors.
- Performance tracking supports *budget submittal* primarily as an element of the budget's cost. Project managers need to account for the costs

associated with performance tracking. But the development of performance tracking data gives the project manager a much more detailed analysis of each work package and what it will take to achieve quality with it. As such, a budget submitted after an initial performance tracking review may be far more accurate than one developed without using the technique.

Outputs

In general, the outputs of the technique are very good. If appropriate indicators are selected, a quantified measure for each potential problem area is graphically presented. This information is extremely useful for project management as well as management communication.

- The indicators selected, the measures used to assess those indicators, and the personnel responsible for tracking the performance in the context of those indicators primarily drive the *accuracy* of the technique.
- Most project managers would consider the *level* of *detail* associated with performance tracking to be extensive. Because the technique requires a thoughtful, painstaking review of each work package to determine its contributions to quality outputs, the level of detail is often much higher than is normally developed in a project without performance tracking.
- The main *utility* of the technique is in tracking project quality and providing management communication both internally and to the customer. By tracking all the various aspects of the project and the deliverables, the project manager can, on short notice, develop comprehensive analyses of the organization's ability to provide the deliverables as promised to the customer.

Summary

The performance tracking technique challenges the project team to meet preordained success criteria for each element of the project. No single significant component is overlooked, and team members clearly understand what is expected of them. In many organizations, that is a significant shift from an attitude that pushes team members toward an overall satisfactory deliverable to the customer. Performance tracking propels the organization toward higher levels of quality.

Chapter 28
Risk Reviews and Audits

Risk reviews and audits can adopt a variety of forms and formats, but there are sufficient common elements to discuss them as a whole. The key for any quality risk review is to acknowledge that it is a comprehensive review rather than a review of a single risk event in isolation. The objective of a risk review is to reevaluate the risk environment, the risk events, and their relative probability and impact. A risk audit is a more exhaustive review that involves a task-by-task, risk-by-risk analysis.

Technique Description

For both risk reviews and risk audits, the technique most often involves conducting a meeting with team members and any external risk owners (such as vendors and subcontractors). The meeting is focused exclusively on the risks, with an emphasis on the elements and perspectives that have changed.

When Applicable

Risk reviews are conducted at regular intervals, when change is planned, and when change occurs. The changes need not be dramatic but rather only sufficient to change the climate in which the risks occur. As for the regular intervals, they should be appropriate to the project's schedule and scope. A project of several years in duration may be host to quarterly risk reviews, whereas a project of two months may have a single midterm review or weekly reviews, depending upon the organization's investment in the project and the complexity of the project. The audit entails a more exhaustive review, normally conducted either at a predetermined milestone or when a major problem prompts a dramatic shift in the potential for project success. The audit frequently focuses on the success or failure of the risk response strategies.

Inputs and Outputs

Inputs and outputs are largely the same as for the risk process as a whole. The inputs include the risk management plan, the WBS, the risk event listing, and earlier assessments of the events for probability and impact. Outputs are updates to risk documentation, including any changes to the events, probabilities, impacts, response strategies, or environment.

Major Steps in Applying the Technique

The steps in applying risk reviews and audits are largely the risk management process in miniature. A good risk review will include risk reidentification, requalification, requantification, and a reassessment of responses.

- Identify the risks. In a risk review or audit, risk identification includes both the basic practice of identifying risks using the WBS or idea generation techniques, as well as the identification of risks based on project documentation and experience to date.
- Qualify the risks. Establish the probability and impact for each risk event identified, based on any organizational rating scheme (see Chapter 22). This should include both new risks identified as well as those risks identified in previous reviews or during the original risk identification process.
- Quantify the risks. To establish contingency funds for any newly identified serious risks, the risks identified as the most significant (during risk requalification) should be evaluated for their potential financial impact and their relative probability of occurrence.
- Reassess responses. This is the most comprehensive step in a risk audit. It involves examining each risk response identified to date and establishing the level of success, the potential for future success, and any repercussions associated with implementing the strategy. In Chapter 3, The Risk Management Structure, the discussion on watch lists points to how project management software tools can be applied to store data on basic risk analyses and approaches. If those tables are expanded, they can be applied here as well, using additional text columns to record response strategies, outcomes, and follow-up requirements:

WBS #	Task Name	Text 12	Text 13	Text 14	Text 15	Text 16

Renamed, the fields take on a different look and now support the risk audit:

WBS #	Task Name	Risk Event	Risk Response	Response Owner	Outcome	Follow-up Required

On the other hand, in a risk review, the reassessment may be little more than an examination of the risk responses applied to date and an update on implementation plans for the near term for remaining strategies.

- *Communicate updates.* No risk review or audit is complete until the findings have been communicated across the organization to those who need the information and can apply it in the project context. Without communicating newly identified risks, shifting priorities, and changed strategies, the risk audit becomes nothing more than an administrative exercise. It takes on life only when those responsible for implementation are aware of what has been planned.

Use of Results

The results are used in the day-to-day management of risks on the project. They are also used to establish any newly needed contingency funding and to clarify strategy for handling risk in the near term.

Resource Requirements

A proper risk audit should involve those who have been responsible for risk management on the project to date, as well as the project manager and any team members who will be taking on new responsibilities in the near term. The last group is important since they frequently have the lowest awareness of project risk, and because of their new roles in the project, may be facing the most significant (and yet invisible) risks. When team members do not know what to look for, it frequently remains hidden.

Reliability

The reliability of these practices relates directly to the reliability of risk management as a process. Because this is little more than a microcosm of the risk process, it reflects on the reliability of risk management as a course of action. The reliability of the audits and reviews will be high if—and only if—they are applied consistently. As with any effective process, consistency is essential. If the reviews and audits are conducted at regular intervals and carried out consistently as change occurs or is planned, then their reliability will be high. If they are conducted on an ad hoc basis, then there will be a far lower level of reliability.

Selection Criteria

As with each chapter on techniques, risk reviews and audits are assessed using selection criteria relating to resource requirements, applications, and outputs for the technique. To compare risk reviews and audits with other techniques, review Table 6.

Resource Requirements

- The *cost* of risk reviews and audits ties to the levels of risk associated with the project and with the thoroughness of the initial work done in establishing risk events, their priority, and the responses. The more documentation and history generated in the first cycle through the process, the more costly the review. Even so, the most exhaustive risk reviews and audits will rarely take more than a couple of days' time, except for those projects spanning multiple years.

- Proper *facilities and equipment* for a risk review generally include a location where large volumes of documentation can be spread out for analysis and/or where there is a personal computer projection display to allow for group data sharing. Otherwise, very little equipment is required.

- As described for cost, the *time needed to implement* the technique is a function of the magnitude of the risk assessment and response effort. Generally, a matter of days, at most, should be required for a risk review or audit.

- Risk reviews have relatively high *ease of use*, but because they follow a consistent practice, they are sometimes perceived as administratively onerous. That perception is ill-founded, particularly in organizations where data are well maintained and where processes are pursued consistently.

- The project manager's *time commitment* for the risk review is the time required to assemble relevant project data and conduct the audit itself. As stated before, the time commitment should be minimal.

Applications

- Risk reviews and audits provide strong support for project status reporting as the reviews serve primarily a status function. Audits (because of their comprehensive analyses of risk strategies and their applications to date) provide even more valuable insight into project work to date, changes in the environment, and efficacy of the overall risk approach.

- *Major planning decisions* get support during risk reviews because the reviews provide guidance on which planning decisions in the project have been effective and which risk strategies are bearing fruit. A reassessment of the strategies will facilitate any decision making required at midproject.

- Since risk reviews and audits are generally conducted at midproject, their support of *contract strategy selection* is extremely low. However, audits serve a valuable role in helping to identify strategies that may be more appropriate for future projects of a similar nature.

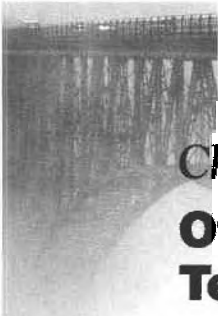
- Risk reviews do not support *milestone preparation.*
- Risk audits and reviews can support design *guidance*, particularly as they apply to shifts in approach at midproject. Since risk reviews are intended to highlight new areas of risk and new strategies, a thorough risk review may support any changes in design.
- Although *source selection* relies heavily on risk analysis, risk reviews offer support only on those midterm decisions for sources or vendors that may be brought in to address a need not considered at project inception.
- As a project progresses, budgets often need to be reconsidered; consequently, risk reviews provide strong support for *budget submittal.* By establishing any new needs for contingency funding or to finance new risk strategies, there is a strong correlation between risk reviews and any midterm budget assessment.

Outputs

- The *accuracy* of the technique is high as it is built on a much greater data foundation than the original risk assessments and because the process is more familiar to participants at midproject than it normally is early in the project.
- The *level of detail* associated with the technique is directly related to the level of detail originally generated for the risk analysis. The more detailed the original risk analysis is, the more extensive the risk review will ultimately be.
- *Utility* on this method is high since it is a brief reiteration of the risk management process in toto.

Summary

Risk reviews and audits serve a valuable function in forcing organizations to look at risk in light of new information, changes in the environment, and the passage of time. Believing that project risk will remain static throughout the project life cycle is a foolhardy assumption. Risk changes are virtually constant. Vigilance is essential. Consistency affords the project manager and the team the ability to justify the reviews. To conduct only a single risk analysis at the beginning of the project is analogous to putting oil in a car once, only when the vehicle is purchased. Conditions change and risks change. A fresh perspective is sometimes essential.



Chapter 29
Other Common Techniques

Cost Performance Reports Analysis

Cost performance reports (CPRs) have become useful in uncovering areas in which technical problems are causing variances. In these reports, team members explain cost and schedule variances using narrative to indicate the specific problem causing the variance. Many of the variances reported can signal risk situations as they are developing, such as late vendor or subcontractor deliveries. Continuing these types of schedule slips can put an entire project schedule at risk. Normally, project managers are limited in what they can do to alleviate these situations except when the sponsoring organization is causing the delays. In such cases, high-level coordination with the sponsoring organization can sometimes alleviate problems. However, this does not always work. For example, tight control over a highly specialized, highly technical subcontractor may not be very effective and the risk of inaccurate specialty work may add risk to risks in other areas of the project.

Just as cost variance may drive risk, risk can also drive cost variances. Cost growth must be considered a significant risk item. The CPR is designed to display cost growth as a variance and then to discuss that variance in terms of cause, effect, and corrective actions that might alleviate the situation.

If the project is using the CPR as a cost reporting tool, it should also be used for risk assessment and analysis. The discussion of variances in that report can contain data vital to risk identification, qualification, quantification, and response development. The report may also present new and previously undiscovered risks. These risks should then be investigated to ascertain their effects on the project.

Independent Technical Assessment

An independent technical assessment is nothing more than a formal technical review that an expert (or experts) in the field conducts to determine the project's potential for achieving specific objectives. An independent technical assessment requires personnel other than those subordinate to the project manager and, therefore, will always require the approval of some higher level of authority. The timing of these reviews is critical. If problems are found, there must be time to correct them before any critical milestone reviews. This technique has been cited for substantially reducing project risk, especially risk associated with multi-organizational involvement.

Technique Description

A team of experts from outside the project office reviews a number of specified aspects of the project. The team usually consists of senior personnel who can make timely evaluations of project activities and progress based on their extensive experience. Team size can vary with the size of the project and the number of issues the team is tasked to review. The entire process is usually limited to several weeks of near-full-time effort on a multiyear project. On a smaller effort or a short-term project, however, the assessment may last only a day or two. The final product is a briefing to the sponsor or manager authorizing the review, as well as a written report.

When Applicable

This technique can be used to support design reviews. It can also be used to address perceptions of a troubled project. A good time for an independent technical assessment is when a project is (or is perceived to be) in trouble. If the trouble is real, this technique will give the project manager added credibility and will quiet critics. When possible, such reviews should be scheduled to cause minimum disruption of milestone activities. An independent technical assessment is usually more appropriate during system development than during actual implementation or production.

Inputs and Outputs

Inputs will vary widely depending on the issues to be addressed and the team members' expertise. Team members will obtain necessary information through project team briefings, reviews of project documentation, interviews, and visits to project facilities. The expertise and experience team members bring with them are important inputs. The most common outputs are briefings to the sponsor or manager. As appropriate, other stakeholders may also be brought into the briefing. The briefing must address each of several criteria or issues defined at the outset of the review. It should also include recommendations for follow-up action.

Major Steps in Applying the Technique

The following procedure is common to most independent technical assessments:

- Upper management (with control over the expert resources required) calls for the review.
- The project manager and upper management specify issues to be addressed.
- The project manager and upper management form the review team.
- The team gathers the required information about project objectives, status, resources, and activities.
- The team analyzes the information gathered.
- The team and the project manager present their results to the authority requesting the review and to other appropriate stakeholders.

Use of Results

Independent technical assessments are useful for design, contracting, strategy, planning, and implementation coordination. When review results are favorable, project risk is reduced immediately. An associated benefit is the ability to meet pending milestone reviews.

Resource Requirements

Two types of resources are required to carry out an independent technical assessment. First, as many as 10 experts may be needed to form the review team. (Team size will depend largely on the expertise required and the magnitude of the project.) The team should include experienced personnel from the middle-management level or higher. These people should anticipate having to commit roughly half their time for the duration of the assessment.

In addition to team resource requirements, the project manager must arrange a number of informational briefings and interviews to provide the review team with the required information quickly. If review team members are from off-site locations, the project manager may have substantial administrative tasks in dealing with the needs of out-of-town guests.

Reliability

Whereas the reliability of an independent technical assessment is usually high, it depends somewhat on the quality of team members in terms of their recognized level of expertise. Although team independence is essential, cooperation between the team and the project manager is also a requisite trait. The project manager must provide all required information, and the review team must present a balanced picture rather than focusing on the most negative areas. The major disadvantage of an independent technical assessment is that it can disrupt other project activities. This is especially true if it uncovers deficiencies and there is not enough time for corrective actions before an important milestone. Therefore, the review schedule is an important consideration.

Selection Criteria

The selection criteria for this technique are all rather positive. Although independent technical assessments do not place great demands on any single resource during the project, they do require some of the project manager's time to support the individual or team. Many organizations require project managers to submit periodic jeopardy reports that mirror much of the information that independent technical assessments generate. The technique has applications across the project life cycle and provides other key pieces of data that can readily be incorporated into the historic project database every organization should maintain. Outputs may be marginally less accurate than other techniques because they reflect an individual or group perspective. But the level of detail and utility of the technique is without peer: it is easy to understand, requires little training, and provides valuable real-time information.

Independent Cost Estimates

Independent cost estimates must be developed one or more times for many projects, depending on the level of control that the sponsoring organization demands. Historically, it has been the perception that project managers drive these estimates because they naturally tend to be optimistic regarding the risks and costs of the project (particularly in the early stages) due to their commitment to achieving project goals. As a result, independent cost estimates have become popular in an effort to provide decision makers with data reflecting an independent viewpoint. The premise is that since cost estimators are outside the influence of the project, they should develop estimates that more accurately portray the challenges, risks, and costs associated with developing and implementing projects.

An independent cost estimate basically entails the same procedures, methodologies, and techniques that would be used to develop any major project cost estimate. Ideally, the independent estimate should select methodologies and techniques different from those that underlie the original cost estimate. In addition, the independent cost estimate should incorporate a detailed comparison of the two approaches and explain the differences.

The key aspect of the independent cost estimate is that it is developed in organizational channels separate from the project. This helps it serve as an analytical tool to validate or cross-check estimates the project manager develops. This second opinion helps avoid the risk that some significant costs have been overlooked or that the project manager's sense of advocacy has resulted in low estimates that could jeopardize the success of the project.

To the extent that a technical staff independent of the project team advise and support those preparing independent cost estimates, some independent assessment of technical risks may also be accomplished while preparing the cost estimate.

The selection criterion for independent cost estimates is that it is resource-intensive; thus, management may not approve it for any but the most significant projects. The applications for the technique are almost exclusive to the beginning of the project or major design decision points. Outputs from the technique vary widely in value because the organization may or may not be equipped to handle the information this technique provides.

Appendix A Contractor Risk Management

Organizational Responsibilities

In putting work out for bid, the purchasing agency must accept the fact that risk management is a key part of a procurement strategy. Thus, it is best for the organization to establish a formal plan of risk assessment and response very early in each major project or program. This plan considers the contractor risks and intemal organizational risks. Assessment and analysis of each significant element of project risk should continue throughout the purchasing or procurement cycle. The procurement strategy ought to be designed to lower risks to acceptable levels. The intemal purchasing or contracting agency should include requirements in the requests for proposals (RFPs) for risk management on the part of the contractors. If the process is followed well, contractors will have to stipulate their approach to identifying and managing risks inherent in the project.

Good procurement strategies incorporate demands that the contractors will provide their own risk management plans and risk assessment reports to bolster intemal efforts. Similarly, in an ideal world, all RFPs would include a clear request for identifying project risks and trade-offs and an understanding of who bears those risks.

Sample statements (DSMC 1986) that could be used in RFPs follow.

Engineering/Design

The offeror shall describe the engineering/technical tasks to be accomplished during the project that contribute to risk reduction. The discussion shall contain the following item:

A discussion of major technical risk items associated with the offeror's proposed concept, including payoffs that will potentially result from the proposed approach, as well as problem areas. The approach to determining the technical risks involved in your project and your approach to reducing such risks to acceptable levels shall be described. Key development issues and the proposed solution approach shall be identified. The discussion shall present the criteria to be used to evaluate critical decision points and information requirements, and the process to be used to develop, evaluate, and implement fallback positions as required.

Reliability and Maintainability (Quality)

Describe your approach to determining the technical risk involved in your reliability and maintainability (quality) programs and your approach to reducing such risks to acceptable levels. This discussion shall present the criteria you plan to use in determining the criticality of technologies; the techniques used to evaluate critical decision points and information requirements; and the process used to develop, evaluate, and implement fallback positions as required.

Quality in Design

Identify quality in design risks, and factor these risks into design trade-off studies.

Producibility

Describe the approach to determining the technical risk involved with your capacity to produce and the approach to reducing such risks to acceptable levels. This discussion shall present the criteria you plan to use in determining the criticality of technologies; the techniques used to evaluate critical decision points and information requirements; and the process used to develop, evaluate, and implement fallback positions as required.

Manufacturing Research/Technology

Provide an assessment of the likelihood that the design concept can be produced using existing technology while meeting quality, cost, and schedule requirements. Include an evaluation of the capability to follow through on the design concept, including requirements for critical process capabilities and special facilities development. Also include tests and demonstrations required for new materials and alternative approaches, anticipating implementation risks, potential cost and schedule impacts, and surge capabilities.

Project Control System

Describe your risk management approach. Discuss how information from functional areas will be integrated into the risk management process.

Planning

Describe the initial planning accomplished in the following areas: risk identification, risk resolution, risk control implementation, fallback position identification, resource requirements, critical materials, and critical processes. Also identify risks associated with any long lead-time requirements, management systems, organizational requirements, staffing, and scheduling.

Quality Assurance

Describe any quality assurance risks you foresee for this project and the actions planned to reduce those risks.

Evaluation Summary

The overall evaluation of each proposal may include on-site inspections and results of preaward surveys to provide information to the contracting authority. This information may include offeror's current and future capability to perform all aspects of the project. Risk assessment associated with the major areas of the project will be accomplished. In assessing risk, an independent judgment of the probability of success, the impact of failure, and the alternatives available to meet the requirements will be considered.

Contractor Responsibilities

The contractor must be made aware through the language in the contract that the information contained in its response will be used for risk analysis. The contractor should be responsible for making a thorough assessment of risks in its proposal. The contractor should include sufficient information to convince the purchasing authority that the contractor recognizes and has quantified the risk inherent in the project. The proposal should identify areas in which actions by the organization can support risk reduction. These areas can include items such as long lead-time funding and the need for approval of priority status for materials.

In proposing a risk management system, the contractor should highlight how it can use existing internal systems to provide information on risk. The contractor should also focus on how it can include risk management in its normal management practices and in its regular communication with the organization.

Appendix B
An Abbreviated List of Risk Sources

An exhaustive list of risk sources would be as long as the dictionary (or longer). The sources listed in Table B-1 represent only a small percentage of the possible sources. However, this list of risk sources includes risks that are most common and prevalent in the community that created it. This list was generated for a bureaucratic organization focusing on field deployment of large-scale hardware and software systems and engaged in intense activity on short notice. This may or may not describe your organizational environment. However, this background information should provide some perspective on why these sources were selected above all others.

Risk sources are where risks originate. Risk sources are not categories, although treating them as categories could help identify and define other risks. Categories sort risks to aid in identification. Sources generate risks.

Risk	Cost	Project	Schedule	Technical	Comments
Capacity				x	The lack of facilities and tools to produce at the desired rate (rate tooling) could prevent production flow from reaching the desired level.
Concept, failure to apply logistics support analysis (LSA) during concept exploration				x	Failure to participate in the definition of system concepts could produce a system design in follow-on phases that does not meet supportability objectives and requires excessive or unattainable operation and support (O&S) costs, as well as labor, to meet the readiness objectives.
Concurrency	x		x		Concurrent development or preparation for production could cause deviations. Concurrency often results in discovery of problems at a time when a cost premium must be paid to resolve problems and keep the project on or near the original schedule.
Configuration control of vendor products				x	Organizations do not control the configuration of items procured from the marketplace, which presents potential risks in both initial design and availability of spares.
Contracting, inadequate provision for support	x				In terms of impact and the probability of its occurrence, the major risk area in integrated logistics support (ILS) contracting is the failure to contract properly for data, materials, and services.
Contractor, communication by		x			Failure of the subcontractors' and contractors' personnel to keep prime contractor and project management organization informed of problems and potential problems in a timely manner. Communication problems may also occur if management fails to fully communicate direction to all involved in the project in a timely manner.
Contractor, lack of financial strength of	x		x		If any contractors have not been able to adequately finance project requirements, the required work may be delayed or curtailed.
Contractor, production readiness of			x		A contractor may fail to be adequately prepared for production.
Contractor, subcontractors and control of		x			A prime contractor may not maintain adequate control of subcontractor quantity, schedule, and cost performance.
Contractor, underbidding by	x		x		A contractor may underbid or buy in to get contracts and may fail to provide the desired products and services on schedule and within budget.
Coordination, inadequate	x	x			Organizations often fail to coordinate purchases with other departments or divisions, which minimizes available logistics support and the economies of scale that would otherwise be available.

Table B-1. Possible Risk Sources

Risk	Cost	Project	Scadu ile	Tehni cal	Comments
Data, inadequate planning for utilization of				x	Collecting data without detailed planning for its use may lead to a mismatch of data collection information requirements and failure to accomplish the intended purpose of the assessment.
Data, incomplete or inaccessible			x	x	Without sufficient data available from each test and used properly for planning subsequent tests, it is not possible to evaluate the adequacy of the system to meet all readiness requirements. Without accurate failure rates, system and component reliability cannot be determined. Lacking the necessary data, system design and ILS progress cannot be established, problems cannot be identified, and additional testing may be required.
Design, delayed definition of logistics criteria			x		Delayed decisions on reliability and supportability requirements could result in suboptimum support. After the design is committed, the options become limited.
Design, impact of engineering changes	x				A high number of design changes made during development could overwhelm ILS planning and create an inability to reflect ILS and O&S cost considerations fully in engineering change decisions.
Design, invalid application of component reliability and maintainability (R&M) data		x			Design and manufacture determines the mean life and failure rate of components when viewed in isolation. The consequences of improperly computed material replacement rates are invalid labor requirements, incorrect supply support stockage lists, and invalid repair level analyses.
Design, lack of life-cycle cost (LCC) impact on design and logistics support process	x			x	LCC is most effective when it is integrated into the engineering and management process that makes design and logistics engineering choices. This integration must start at project initiation. Failure to implement LCC throughout may result in costly reworking, test failures, contract termination costs, and increased O&S costs.
Design, unrealistic R&M requirements	x		x		Unrealistic R&M requirements could lead to increased design and development costs incurred as a result of excessive design iterations.
Design stability	x		x		There may be lack of design stability during the production phase.
Engineering, late establishment of readiness and supportability objectives	x		x	x	The system engineering process is a key factor in identiiing and attaining realistic readiness and supportability objectives. If a well-organized process is not started at the project inception and continued throughout the development phases, then the project risks are increased design, development, and O&S costs; schedule delays; and degraded readiness factors.
Engineering, site survey results		x	x		Historical or archaeological site survey findings could delay site construction and cause significant deployment problems.

Table B-1. Possible Risk Sources (continued)

Risk	Cost	Project	Schedule	Technical	Comments
Environmental impact	x		x		Natural disasters (such as fires, floods, storms, earthquakes) may occur.
Equipment, common support	x		x		Common support equipment may not be available to operate and maintain the system.
Failure to structure or tailor LSA requirements	x		x	x	Failure to establish an LSA plan specifically designed to meet the needs of the material system could result in excessive costs, the performance of unwanted analysis while failing to complete needed studies, and the development of excessive documentation while overlooking critical information needs.
Familiarization		x			Contractor personnel may be unfamiliar with the systems or equipment or may lack experience producing similar systems or equipment.
Familiarization, tolerance levels		x			Difficulties in achieving closer than usual tolerance levels may occur.
Fault detection				x	A failure to obtain designed performance may be detected.
Funding, advanced buy authorization limitations	x				Long lead-time requirements may create problems if there is insufficient advanced-buy funding to meet the needs of the project.
Funding, constraints on	x				Lack of timely receipt of project funds may cause delays.
Funding, long-term	x		x		The requirement to execute a project over a period of time with funds provided through a fiscal-year-to-fiscal-year agreement may result in constraints.
Inflation	x				Levels of inflation significantly higher than originally forecast may increase costs.
Integration/ interface		x			New and unique requirements (such as adaptability, compatibility, interface standard, and interpretability) may delay the project.
Joint partner project decision			x		Problems and delays resulting from reduced joint partner participation or other user decisions could disrupt the project.
Labor disputes	x		x		Labor difficulties (such as strikes, lockouts, slowdowns) could increase costs and delay schedules.
Legal disputes	x		x		Award and performance disputes and related legal actions could delay a project.
Legislation	x				Higher taxes, new labor laws affecting pay and benefits, social security increases, and so on, could increase costs.
Maintainability				x	Failure to achieve maintainability using a design that is compatible with established maintenance procedures may force changes in the maintenance approach.
Material properties	x				Material property requirements beyond those usually expected may increase costs.

Table B-1. Possible Risk Sources (continued)

Risk	Cost	Project	Schedule	Technical	Comments
Modeling validity		x			Inaccuracies in models used to develop mathematical and physical predictions may disrupt the project.
Objectives and strategies		x			Changes in objectives and strategies may disrupt the project.
Operating environment				x	Performing in an unusually harsh environment could increase technical difficulties.
Operating policies		x			Changes in operating policies may affect system or system support requirements.
Personnel, available skills of		x			The shortage of personnel with technical, management, and other skills needed to carry out internal and contractor activities may disrupt the project.
Personnel, downsizing and streamlining of	x			x	Initiatives on downsizing and streamlining could impose restrictions on the project manager as well as the designer early in the definition of requirements. Although intended to decrease cost and improve efficiency, casual application of such guidance could result in a loss of standardization, attendant cost increases, and loss of documented lessons-learned experience.
Personnel, forced placement of		x			If the project has several inadequate personnel and managers, either internally or under key contractors, seriously counterproductive events could occur.
Personnel, security clearances of			x		Any delays in obtaining required personnel security clearances could delay the schedule.
Physical properties	x				Different-than-expected dynamics, stress, thermal, or vibration requirements could increase costs.
Planning, delayed facilities			x		Failure to perform timely facility planning could result in substantial deployment delays.
Planning, delayed postproduction support				x	Continued support of the material system by the industrial base existing in the post-production time frame might not be economically feasible.
Planning, updating deployment		x		x	Unreported and uncorrected deployment problems could generate a serious flaw in an updated deployment plan.
Policies, new		x			Added workload or time requirements brought about by new direction or policy may disrupt the project.
Priority			x		Problems resulting from changing the priority assigned to the project and thereby timely access to testing facilities, funds, materials, and so on, could delay the schedule.
Project stretchout			x		Direction to slip the project schedule from the original plan may disrupt the project.
Radiation properties				x	Increased radiation stress resistance requirements could cause technical difficulties.

Table B-1. Possible Risk Sources (continued)

Risk	Cost	Project	Schedule	Technical	Comments
Reliability	x		x		Failure to forecast system reliability properly may affect predicted reliability growth.
Scarce resources	x		x		Shortages of critical materials, components, or parts may disrupt the project.
Scheduling, accelerated acquisition	x				Lead times for delivery of nondevelopmental items could be extremely short, particularly for in-stock items. This poses a substantial risk of deployment with incomplete or inadequate logistic support and attendant degraded readiness.
Scheduling, accelerated projects	x		x		An accelerated system development project may be required to overcome a critical deficiency in an existing capability. This "streamlining" could pose the risk of delaying design maturation with frequent configuration changes occurring in late development.
Scheduling, accelerated projects	x				Compressed schedules increase the demand for critical assets during the time of normal asset shortages, which could create unrecoverable delays.
Scheduling, decision delay			x		Disruption of the project schedule may result from delays in obtaining higher-level approval to award contracts, proceed to the next phase, and so on.
Scheduling, excessive lead times			x		Lead times for critical components or services that are longer than expected may delay the schedule.
Scheduling, slippage			x		Failure to understand how slippage in one functional element affects other elements and milestone events could ultimately delay the entire project.
Service roles and mission changes	x		x		Problems may cause deviations from the project resulting from changing service roles and missions that significantly alter the planned use of the system.
Software design			x		Unique software test requirements and unsatisfactory software test results could result in changes in the basic project.
Software language			x		A new computer language or one unfamiliar to those responsible for planning and writing software could cause schedule delays.
State-of-the-art advances, lack of supporting		x			Advances from other projects that might not be as expected could significantly affect the current project.
State-of-the-art advances, major		x		x	Problems resulting from greater-than-anticipated advances in techniques and development (such as complexity/difficulty in meeting requirements, percent proven technology, lack of work on similar projects, special resources required, operating environment, theoretical analysis required, and degree of difference from existing technology) could disrupt the project.

Table B-1. Possible Risk Sources (continued)

Risk	Cost	Project	Schedule	Technical	Comments
State-of-the-art advances, slow progress in		x			Slower progress than expected in making advances could disrupt the project.
State-of-the-art field failures				x	Field failures of state-of-the-art equipment types that were assumed to be ready for incorporation into the project could cause technical difficulties.
Survivability		x			New requirements for nuclear hardening, chemical survivability, and so on, might require revised planning to meet original or new goals.
Testing, extrapolation requirements				x	The need for extensive extrapolation using field test results could hamper the assessment of the project under actual deployment conditions.
Testing, facility compatibility			x		Not having suitable test facilities available during the required time frame could cause schedule delays.
Testing, incomplete or delayed support package for			x		Without an adequate test support package on-site and ready to support the scheduled test, it might be possible to start testing, but the chances of continuing on schedule would be low.
Testing, inconsistencies				x	Inconsistent field test results could cause increased technical risk and require retesting.
Testing, safety				x	Problems could result from requirements that testing be nondestructive or that it not interfere with other activities.
Testing, security requirements			x		The testing of classified equipment could cause scheduling concerns associated with clearances, data transfer, and public interest.
Testing, unrealistic scenarios for		x			A subtle risk, particularly during development testing, and one that can have a lasting effect on the viability of a project, is testing to an unrealistic scenario. A realistic approach does not necessarily mean that stresses put on the system under test must duplicate those of actual service, because in most cases this is impractical. It does mean, however, that the test is planned to simulate conditions as closely as possible, with differences carefully documented.
Testing, weather	x		x		Weather-related occurrences could cause testing delays.
Threat changes	x		x		Possible changes could require alterations in schedule and performance objectives.
Uniquely harsh requirement				x	Existing design technology that differs significantly from that required for success of the new system could cause technical difficulties.
Vendor base	x	x	x		A shortage of qualified vendors can affect adequate price competition and a satisfactory supply quantity base.

Table B-1. Possible Risk Sources (continued)

Appendix C
Basic Probability Concepts

This appendix serves as a very basic introduction to probability and statistical concepts that may be useful for risk analysis. It is by no means all-inclusive but rather may be thought of as a primer. The appendix contains three sections. The first section is an introduction to probability, centering on definitions and simple examples. The second section provides a summary of descriptive statistics, including a look at statistical confidence and confidence intervals, and explains probability density functions (PDFs) and cumulative density functions (CDFs) defining distributions that are relevant to risk analysis, such as the normal, uniform, and triangular. The third section discusses statistical independence, which is the prerequisite for the concept of expected value. Decision tree analysis is illustrated to show the merit of the expected value approach.

Probability

Probability is a concept used by many people every day. As an example, the weather forecaster predicts a 30 percent probability of rain. This means that, in the long run, rain is expected 30 days out of 100 when conditions are the same as they are at the time the forecast is made. For risk analysis, a statement might be made to the effect that the developmental stage of weapons system A has a 10 percent probability of a schedule (time) overrun. This is equivalent to saying that 10 percent of all developmental stages of weapons systems similar to A have had a schedule overrun in the past.

More formal definitions of probability follow.

1. The quality or condition of being probable; likelihood.
2. A probable situation, condition, or event.
    a. The likelihood that a given event will occur: *little probability of rain tonight.*

b. *Statistics*. A number expressing the likelihood that a specific event will occur, expressed as the ratio of the number of actual occurrences to the number of possible occurrences. (*The American Heritage Dictionary of the English Language* 2000)

In practical situations, probability is used as a vehicle in drawing inferences about unknown population characteristics. Additionally, . . . probability concepts can be used to give us an indication of how good these inferences are." (Pfaffenberger and Patterson 1977)

Many individuals think of probability in relation to gambling and games of chance, such as card playing and dice throwing. They measure the probability of an event in terms of the odds against the event's happening. For example, throwing a pair of dice (illustrating the inverse relationship between probability and the odds against an event) results in 1 of 36 possible outcomes, which are illustrated in Figure C-1.

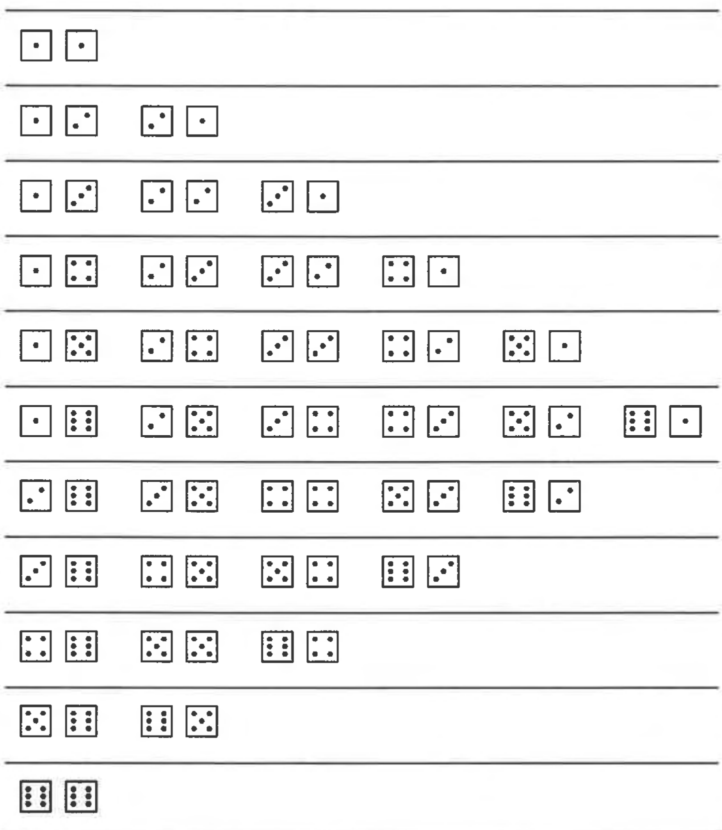


Figure C-1. Results of Variance in Throwing Dice

The probability of throwing a 10 is 3/36 or 0.083. That is, 3 out of the 36 possible outcomes result in a 10. The odds of not throwing a 10 are 33/36 or 0.917.

Probability is a key quantitative measure associated with many risk assessment techniques. The above examples are simplistic but show how easy it is to comprehend probability concepts.

Descriptive Statistics, Confidence, and Distributions

Any group of numbers, such as a sample composed of quantitative evaluations, may be described with the following basic statistical parameters:

- Mean
- Median
- Range
- Mode
- Variance and standard deviation

These parameters enable the statistician to determine what level of confidence (or assurance) may be accorded to predictive statements about the entire population of numbers. The parameters also help determine where the sample lies in a possible statistical distribution. Conversely, a statistical distribution may be described by such parameters. A statistical distribution is basically just a way to describe which numbers will appear more often (or with a high probability) and which numbers will appear less often (or with a low probability). The following paragraphs define the parameters in some detail and then discuss confidence levels, PDFs and CDFs, and the other relevant distributions applied in risk analysis.

For illustrative purposes, let the following numbers represent exam scores for an introductory statistics course:

75	60	100	65	80	45
25	45	60	90	60	40
50	70	55	10	95	70
85	20	70	65	90	90
65	80	70	55	70	

Let X_i represent these numbers, where *i* is indexed from 1 to 29. So X_1 = 75, X_2 = 25, X_3 = 50, ..., X_{28} = 70, X_{29} = 90. The mean of these numbers is nothing more than the arithmetic average. The mean is computed as follows, where *n* is the number of exam scores:

$$Mean = \frac{\sum_{i=1}^{n} X_i}{n} = \frac{1{,}855}{29} = 63.96$$

The *mode*, the score that occurs more often than any other score, is 70. The mode occurred five times (more often than any other score).

The *median* is the middle score if the scores are ranked top to bottom. Because there are 29 scores altogether, the median is the fifteenth score, which is a 65. The *variance* and *standard deviation* of a group of numbers are attempts to describe the dispersion or scattering of the numbers around the mean. The variance is computed using the following formula:

$$Variance = \frac{\sum_{i=1}^{n} X_i^2 - \frac{\left(\sum_{i=1}^{n} X_i\right)^2}{n}}{n-1}$$

For this example, the variance is as follows:

$$\frac{132{,}275 - \frac{1{,}855^2}{29}}{28} = 486.4$$

The *standard deviation* is the square root of the variance. The standard deviation has a more intuitive appeal than does the variance because the standard deviation is the mathematical average variation of a value from the mean. For this example, the standard deviation is:

$$\sqrt{486.4} = 22.05$$

The *range* is the high score minus the low score. For this example, the range is 100 – 10 = 90.

Many times when examining data, a *level of confidence* or *confidence interval* is used to indicate what certainty or faith is to be put in the sample being taken as representative of the entire population. Far and away, the most common measure is the confidence interval for the mean.

A statement such as the following can be made about a particular sample mean:

The 95 percent confidence interval for the mean is 56 to 72.

Statistically, this statement means that of all the possible samples of this size taken from this population, 95 percent of the samples will have a mean between 56 and 72. It does not mean that 95 percent of all possible values that are sampled will fall between 56 and 72, which is the common, though faulty, interpretation of the statement.

Confidence intervals are determined by adding and subtracting some calculated value from the mean of the sample. Usually, but not always, this value is based on the standard deviation of the sample. As an example, if the population from which a sample is taken is determined to be normally distributed, and this was assumed in previous statements (this determination may be made based on the relative values of the mean, variance and standard deviation, mode, median, range, and other factors), then a 95 percent confidence interval for the population is calculated in this manner where $\overline{X}$ is the sample mean and σ is the standard deviation:

$$\overline{X} \pm 1.96\sigma$$

A 95 percent confidence interval for the mean is calculated in this manner:

$$\overline{X} \pm \mathbf{1.96} \frac{\sigma}{\sqrt{n}}$$

where $\frac{\sigma}{\sqrt{n}}$ is commonly referred to as the standard error.

How is the population determined to be normal (or normally distributed) in the first place?Similar groups of numbers have similar relationships between their respective parameters. These similarities help determine which distribution describes the entire population. Typical distributions for problems associated with risk are normal, uniform, triangular, and beta. (Discussion of the beta distribution is beyond the scope of this appendix. If further information on the beta distribution is needed, any of several statistics and operations research books can supply the information.)

For the normal distribution, 68.3 percent of all possible values lie within one standard deviation of the mean, 95.4 percent lie within two standard deviations, and 99.7 percent lie within three standard deviations. This is shown in the probability density function. The PDF gives the probability

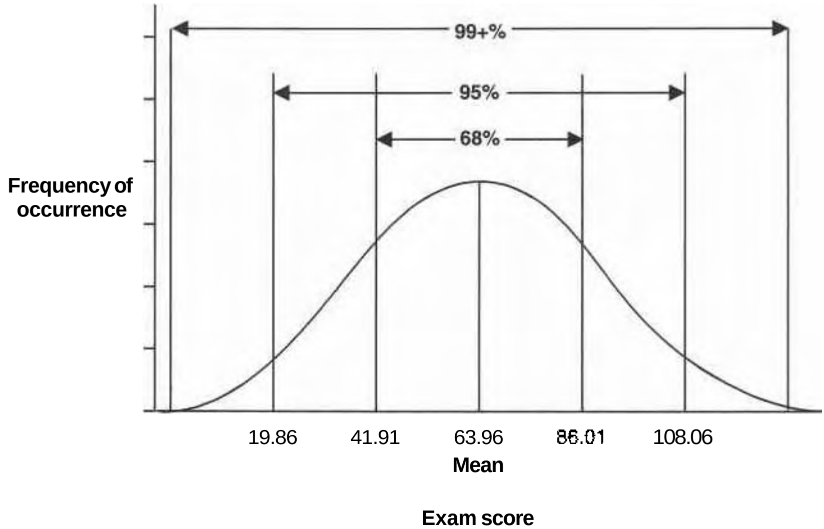


Figure C-2. *PDF of a Normal Distribution*

that certain values will occur. Figure C-2 illustrates a PDF for the exam scores example, assuming that the scores are from a normal distribution.

The normal distribution is, by strict definition, a continuous distribution. However, it is implied in Figure C-2 that fractional exam scores are possible—and of course it is not realistic in this example. A discussion of the differences between discrete and continuous distribution is beyond the scope of this appendix, and because the example is meant to be used only for illustrative purposes, this finer point of statistics will be ignored. It is also implied in Figure C-2 that extra credit is given because scores exceeding 100 are possible, and this could certainly be within the realm of the example. The most important distinction of the normal distribution PDF is the bell shape of the curve. This shape is the most definitive characteristic of any PDE

The cumulative density function is the arithmetic summation of the PDE In other words, the CDF gives the probability value (or any value less than the value) that will occur. The shape of the various distribution CDFs are distinctive, and the CDF is merely another way of illustrating the distribution. Figure C-3 illustrates a typical CDF for normally distributed values, in this case the exam scores example.

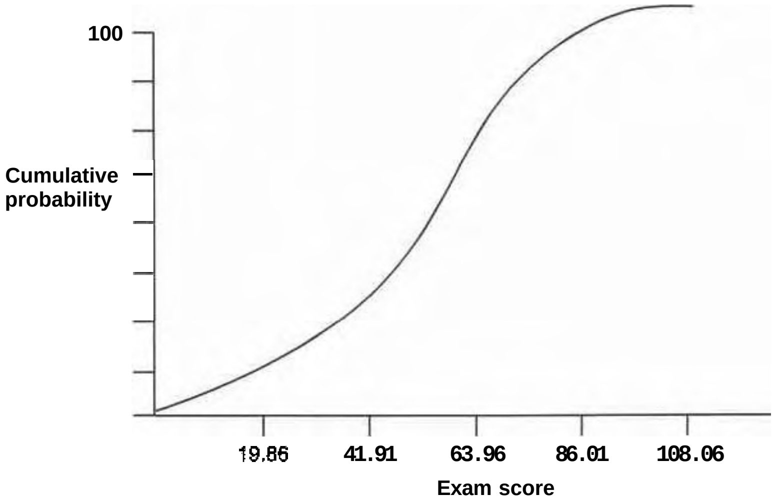


Figure C-3. CDF of a Normal Distribution

The uniform distribution is used to describe a set of values where every value has an equal probability of occurrence. Returning once again to the exam scores example, one might hypothesize that all possible scores (1 through 100+) have an equal probability of occurrence: 0.01. The *PDF* for this is illustrated in Figure C-4. Figure C-5 illustrates the uniform *CDE*

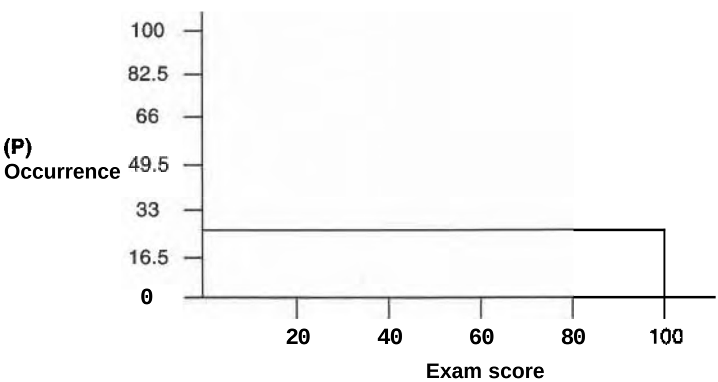


Figure C-4. PDF of a Uniform Distribution

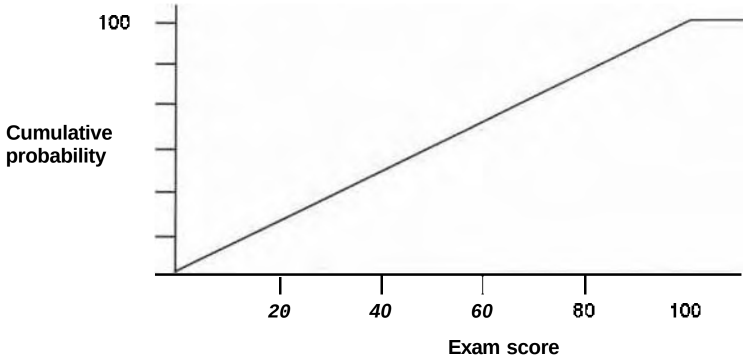


Figure C-5. *CDF of* a *Uniform Distribution*

The triangular distribution is used often in risk analysis situations to describe the most optimistic, most likely, and most pessimistic durations of some event or activity. The PDF of the triangular distribution, illustrated in Figure C-6, is not necessarily symmetric. Indeed, often the triangular distribution is purposely asymmetric or skewed to the right to reflect the possibility of very long time durations. These long durations are less likely to occur but do happen occasionally. Figure C-6 shows that the most likely production time for a widget wing is 8 days. Clearly, the average is skewed to the right and is very close to 9.3 days. Hence, the triangular distribution, when skewed, has a mode and mean that are clearly different. Contrast this to the normal distribution, where the mode and mean are the same (as is the median).

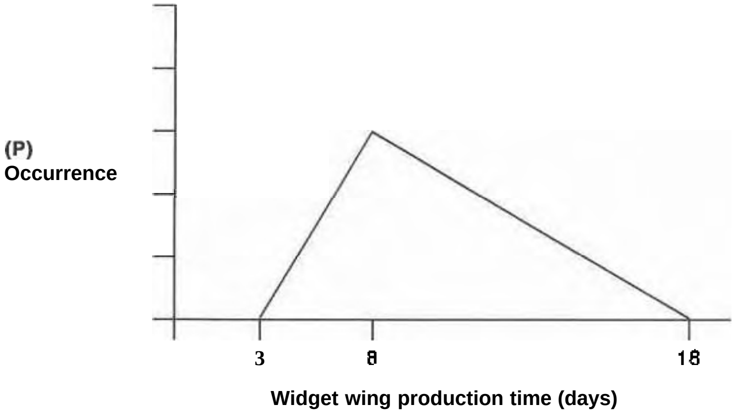


Figure C-6. *PDF of a Triangular Distribution*

Independence, Expected Value, and Decision Tree Analysis

Statistical independence is an important concept on which a good deal of methodologies are based. Most discussions of statistical independence begin with a tutorial on conditional probability, sample space, and event relationships. Rather than discuss these concepts, a more practical definition of statistical independence is presented: Two events are said to be independent if the occurrence of one is not related to the occurrence of the other. If events are occurring at random, they are independent; if events are not occurring at random, they are not independent. A set or group of possible events are said to be mutually exclusive and collectively exhaustive if they are all independent and the sum of their probabilities of occurrence is 1.0. This is the basic notion behind value.

To illustrate expected value, suppose that a simple game of chance can be played for $1. The bettor pays $1 and has a chance to win $50 or $2 or no money at all. The dollar amounts and probabilities are shown in Table C-1.

Amount Value	Probability of Winning	Expected Value
$50	0.01	$0.50
2	0.10	0.20
0	9.89	0.00
Totals	1.00	$0.70

Table C-1. Expected Values Example

The bettor would like to know, before actually paying $1, what the expected winnings are. The expected value of winnings is the sum of the winning amounts multiplied by their respective probability of occurrence:

$$(\$50)(0.01) + (\$2)(0.10) + (\$0)(0.89) =$$
$$\$0.50 + \$0.20 + \$0 =$$
$$\$0.70$$

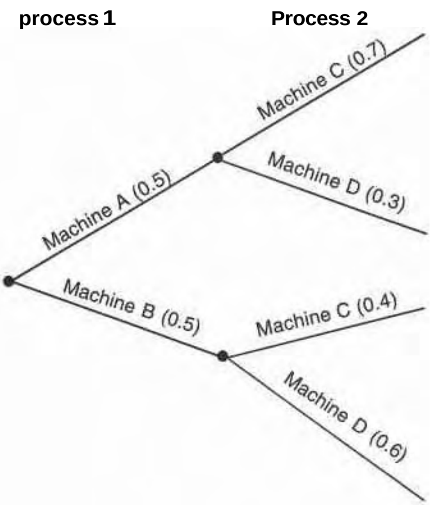
Because the bettor can expect winnings on the average of only $0.70 but pays $1 to play the game, the net profit is a negative $0.30.

This is a very realistic example of gambling and risk. Most individuals, when forced to face this logic, would choose not to play. However, many would play. They are willing to accept the risk of losing $1 to take a chance at winning $50. These individuals are risk prone. The individuals who follow the basic logic of this example and do not play are risk averse.

The notion of expected value is a prerequisite for discussing decision tree analysis, which attempts to break down a series of events into smaller, simpler, and more manageable segments. Many similarities exist between decision tree analysis and more complicated forms of management and risk analysis, such as the Program Evaluation and Review Technique (PERT) and the critical path method (CPM). All three forms of analysis presume that a sequence of events can be broken down into smaller and smaller segments that more accurately represent reality.

Decision tree analysis helps the analyst break down a problem into various sectors or branches to simplify potential decision making. As an example, suppose a widget is being manufactured as follows: Either machine A or machine B can be used for the first step (of a two-step manufacturing process) with equal probability of 0.5. Either machine C or D can be used for the second step. Machine C is used 70 percent of the time if the widget was first processed with machine A and 40 percent of the time if the widget was first processed with machine B. The rest of the time, machine D is used for the second step. Decision tree analysis can help compute the probability of the widget's being produced by these various combinations (AC, AD, BC, BD). Figure C-7 illustrates the decision tree and the expected probability for each manufacturing process alternative.

Note that each alternative's probability is merely the product of the individual processes making up that alternative because the individual processes are independent of each other. Note also that the sum of the probabilities for all of the four processing alternatives is 1.



Alternatives

AC is **(0.5)(0.7)**=	0.35
AD is **(0.5)(0.3)**=	0.15
BC is **(0.5)(0.4)**=	0.20
BD is **(0.5)(0.6)=**	0.30
Sum of probabilities=	1.00

Figure C-7. Decision Tree Analysis

Appendix D

Quantifying Expert Judgment

All risk assessment techniques or models share a common requirement: acquiring expert judgment as inputs. Inherent in judgment is a degree of uncertainty. When acquiring quantifiable expressions of judgment, the axioms of probability must not be violated:

- The probabilities of all possible events must sum to 1.
- The probability of any event, $P(A)$, must be a number greater than or equal to 0 and less than or equal to 1 $(0 \leq P(A) \leq 1)$.
- The probability of joint events is the product of the probability that one event occurs and the probability that another event occurs, given that the first event has occurred, $(P(A) \times P(B \mid A))$. Under these circumstances, the events are termed dependent.
- When the probability of joint events' occurring is simply the product of the probabilities of each $P(A) \times P(B)$, the events are said to be independent. That is, the two events have nothing in common or can occur simultaneously.

The challenge for the analyst is to obtain expert judgment, which is qualitative by nature, in the areas of cost, schedule, and technical performance. Next, the analyst must convert that judgment into a quantitative form so that the results can be depicted in the form of a probability density function (PDF), which serve as inputs to the various risk models. (This is necessary only when a quantitative model has been selected.)

A PDF is a smooth line or curve, as shown in Figure D-1. The PDF of a random variable, x, is a listing of the various values of x with a correspon-ding probability associated with each value of x. In the example shown in Figure D-1, x would be a cost, schedule, or performance value. Note that the total area under the curve equals 1.

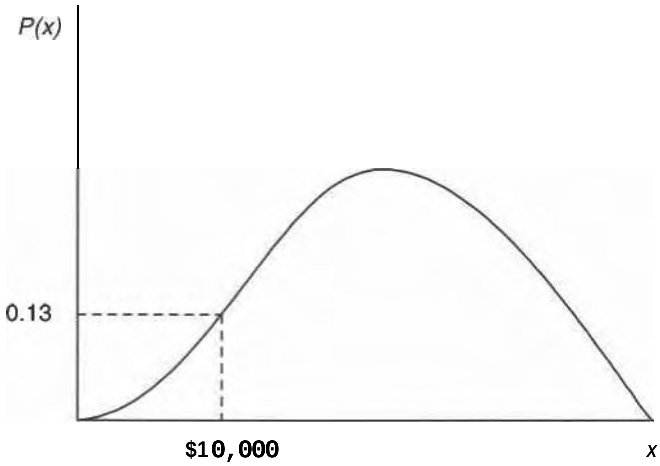


Figure D-1. Probability Density Function

In Figure D-1, the random variable x might represent a hardware system cost, where the probability of the system costing $10,000 is 0.13.

Several methods can be used to convert qualitative judgment into quantitative probability distributions. The remainder of this appendix focuses on a few of the most popular, practical, and accurate techniques for doing so, chosen because they are relatively simple and easy to master. This factor is of paramount importance because, in most cases, the analyst performing this task will have neither the time nor the knowledge of the advanced probability concepts required to perform more complex techniques. Those interested in more exotic, complex techniques are referred to "Sources of Additional Information" at the end of this appendix.

The following techniques are discussed in this appendix: diagrammatic, direct, betting, and modified Churchman-Ackoff.

Description of Techniques

Diagrammatic

Many analysts prefer the diagrammatic method as a way of capturing and representing an expert's judgment. This method describes an expert's uncertainty by presenting the expert with a range of PDF diagrams and having the expert select the shape of the PDF that most accurately reflects the schedule, cost, or technical parameter in question. Using this method, the analyst can ascertain whether the PDF is symmetric or skewed, the degree of variability, and so on. For example, if the expert believes that there is a great amount of risk associated with completing an activity within a certain period of time, a PDF skewed to the right may be selected. Likewise, activities with little risk may be skewed to the left. If the expert believes that each value over a given range is equally likely to occur, a uniform distribution may be most appropriate. The analyst and the expert, working together, can select the PDF that most accurately reflects the schedule, cost, or technical item in question.

The diagrammatic method of obtaining PDFs is applicable when the expert has a sound understanding of probability concepts and can merge that understanding with his or her understanding of the parameters in question. In this way, the expert can accurately identify the appropriate PDFs.

Direct

The direct method is used to obtain subjective probability distributions by asking the expert to assign probabilities to a given range of values. This method of obtaining PDFs is applicable (1) when questions can be phrased to the respondents in such a way that no confusion is likely to exist in the respondents' minds and (2) when the results will not violate the axioms of probability. The direct method is applicable when time or resource constraints do not allow for more complex, resource-intensive methods.

By applying the direct method, the analyst defines a relevant range and discrete intervals for the parameters for constructing the PDE For example, the analyst might define the relevant time duration for a project activity (test of a piece of equipment) to be between 0 and 27 days. The analyst then breaks down this relevant range into intervals, say of 4 days. The resulting formulation would be as follows:

0-3 days	16-19 days
4-7 days	20-23 days
8-11 days	24-27 days
12-15 days	

Given these intervals over the relevant range, the analyst then queries the expert to assign relative probabilities to each range. From this, the form of the PDF could be identified. It is imperative that the axioms of probability not be violated.

In addition to the application already described, the analyst could request that the expert provide a lowest possible value, a most likely value, and a highest possible value. The analyst then makes an assumption about the form of the density function. That is, is the PDF normal, uniform, triangular, or beta?

Betting

One method of phrasing questions to experts in order to obtain probabilities for ranges of values (cost and schedule) states the problem in terms of betting. A form of this method helps the expert (assessor) assess probabilities of events that are in accordance with his or her judgment (Winkler 1967). The assumption with this method is that the judgment of the expert may be fully represented by a probability distribution, $f(x)$, of a random variable, x. This method offers the expert a series of bets.

Under ideal circumstances, the bets are actual, not hypothetical. That is, in each case the winner of the bet is determined and the amount of money involved actually changes hands. (This is not feasible, however, because betting is illegal.) In each case, the expert must choose between two bets (the expert may not refrain from betting). The expert must choose between a bet with a fixed probability of winning (q) and of losing $(1 - q)$, and a bet dependent on whether some event (a particular project activity duration range or cost range) occurs (E). The bet can be depicted as follows:

Bet 1a
- Win $A if event E occurs.
- Lose $B if event E does not occur.

Bet 1b
- Win $A with probability of q.
- Lose $B with probability of $1 - q$.

The expected values of bets 1a and 1b to the expert are respectively $Ap + Bp = B$ and $Aq + Bq = B$, where p is the probability of the occurrence of event E. The following inferences may be drawn from the expert's decision: if bet 1a is chosen, $Ap + Bp - B \geq Aq + Bq - B$, so $p \geq q$; likewise, if 1b is selected, $p \leq q$.

By repeating the procedure, varying the value of q, the probability of event E can be ascertained. It is the point at which the expert is indifferent to both bets 1a and 1b that $p = q$. The degree of precision depends on the number of bets and the incremental changes of the value of q. To avoid the problem of a large number of bets to obtain p is to assess the probabilities by using direct interrogation and then using the betting situation as a check on the assumed probabilities.

To complete a PDF, the analyst repeats this procedure over a relevant range of interval values. The analyst then plots the points at the center of the range for each event and smooths in a curve so that the area under it equals 1, as in Figure D-2. The analyst must ensure that all relevant axioms of probability are maintained.

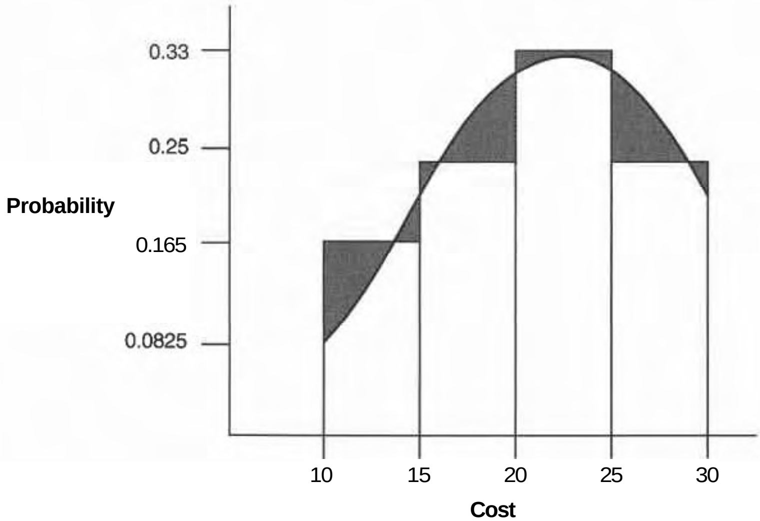


Figure D-2. Fitting a Curve to *Expert Judgment*

When questioned one way, many people are likely to make probability statements that are inconsistent with what they will say when questioned in another equivalent way, especially when they are asked for direct assignment of probabilities. As the number of events increases, so does the difficulty of assigning direct probabilities. When this is a problem, the betting method is most appropriate.

To apply the betting technique, select one interval for the relevant range to demonstrate how this method can be used to obtain probability estimates and, hence, PDFs. The bet is established as follows:

Bet 1a
- Win $10,000 if cost is between $15,100 and $20,000.
- Lose $5,000 if cost is not between $15,100 and $20,000.

Bet 1b
- Win $10,000 with probability of q.
- Lose $5,000 with probability of $1-q$.

The value of q is established initially, and the expert is asked which of the two bets he or she would take.

The value of q is then varied systematically (either increased or decreased). The point at which the expert is indifferent between the two bets (with the associated q value) provides the probability of the cost's being between $15,100 and $20,000. This process is repeated for each interval, and the results create the PDF associated with the cost of that particular project event.

Modified Churchman-Ackoff

Another way to ascertain PDFs for cost, schedule, or performance parameters is the modified Churchman-Ackoff method (Churchman-Ackoff 1951). This technique was developed as a way to order events in terms of likelihood. The technique was modified so that after the event likelihoods were ordered, relative probabilities could be assigned to the events and, finally, PDFs could be developed. For relevancy, events are defined as range values for cost, schedule, or performance (activity durations) relating to the outcome of a specific activity in a project.

The modified Churchman-Ackoff technique is most appropriate when there is one expert and that expert has a thorough understanding of the relative ranking of cost and schedule ranges and a limited understanding of probability concepts. The remainder of this section is extracted and modified from the Compendium on Risk Analysis Techniques (Atzinger 1972). Note that although the mathematical calculations appear to make this a precise technique, it is still an approximation of an expert's judgment and should not be interpreted to be more exact than other similar techniques.

The first step in applying the modified Churchman-Ackoff technique is to define the relevant range of values. That is, the end points along a range of values with 0 probability of occurrence must be specified. These values can be any low and high values the expert specifies as having 0 probability of occurrence. Next, ranges of individual values within the relevant range must be determined. These ranges of values, which will form the set of comparative values for this technique, are specified by the following approach:

Step 1 Start with the low value in the relevant range.

Step 2 Progress upward on the scale of values until the expert is able to state a simple preference regarding the relative probabilities of occurrence of the two characteristic values. If the expert is able to voice a belief that one value has either a greater or lesser chance of occurring than the other of the two values, then it is inferred that the expert is able to discriminate between the two values.

Step 3 Using the higher of the two previously specified scale values as a new basis, repeat Step 2 to determine the next value on the scale.

Step 4 Repeat Steps 2 and 3 until the high end-point value of the range of parameter values is approached.

Using this procedure for the duration required to test a piece of equipment successfully may yield the results shown in Table D-1.

Value	Duration (days)
O_1	0-3
O_2	4-7
O_3	8–11
O_4	12-15
O_5	16-19
O_6	20-23
O_7	24-27

Table D-1. Characteristic Values for Equipment Test Durations

The descending order of probability of occurrence can be determined by applying the following paired comparison method. Ask the expert to compare, one at a time, the first interval value (O_1) of the set to each of the other values (O_2, O_3, and so on), stating a preference for that value in each group of two values that he or she believes has the greater chance of occurring (denoting a greater probability of occurrence by >, an equal chance by =, and a lesser chance by <). The following hypothetical preference relationships could result for a set of seven values: $O_1 < O_2$, $O_1 < O_3$, $O_1 < O_4$, $O_1 < O_5$, $O_1 < O_6$, $O_1 < O_7$.

Next, ask the expert to compare, one at a time, the second interval value (O_2) of the set to each of the other interval values succeeding it in the set (that is, O_3, O_4, and so on). The following preference relationships might result: $O_2 < O_3$, $O_2 < O_4$, $O_2 < O_5$, $O_2 > O_6$, $O_2 > O_7$. Continue this process until all values have been compared.

Now total the number of times a given value was preferred over other values. The results for this procedure are listed in Table D-2.

Value	Times
O_4	6
O_3	5
O_5	4
O_2	3
O_6	2
O_1	0
O_7	0

Table D-2. Summary of Preference Relationships

List the values in descending order of simple ordinal probability preference and change the symbols for each value from O_i to X, as shown in Table D-3.

Characteristic	Value (days)	Reference Rank	New Symbol
12–15	O_4	1	X_1
8–11	O_3	2	X_2
11–19	O_5	3	X_3
4–7	O_2	4	X_4
20–23	O_6	5	X_5
0–3	O_1	6	X_6
24-27	O_7	7	X_7

Table D-3. Transformation

Arbitrarily assign a rating of 100 points to the characteristic value with the highest subjective probability (that is, X,). Then, as in the first step, question the expert regarding the relative chance of occurrence of each of the other values on the ordinal scale in Table D-3 with respect to the value at the top of the scale. Assigning X_1 a rating of 100 points, the expert is first interrogated as to his or her feeling of the relative chance of occurrence of the second highest scale value (X,), with respect to X_1. Does it have a 25, 60, 70, or 80 percent chance? Or even as much chance of realization as X_1 has? The relative probability rating, based on 100 points, then will be posted for X,.

Next, question the expert about the relative chance of occurrence of the next highest scale (X,), first with respect to the most preferred value (X_1) and then with respect to the second most preferred scale value (X_2). The resulting numerical ratings should occur. For example, if the expert decides that X_2 has 80 percent as much chance of occurring as does X_1, and that X, has 50 percent as much chance as X_1 and 62.5 percent as much chance as X,, the ratings would be X_1 = 100 points, X_2 = 80 points, and X_3 = 50 points.

This process continues for each successively lower interval value on the ordinal scale as shown in Table D-3. Determine the relative number of points to be accorded each value with respect to the top scale and with respect to all other values down the scale that are above the characteristic value in question.

If there are minor disparities between relative probability ratings for a given value, the average of all such ratings for that characteristic value might be computed. For example, X_4 might be determined to be 30 percent as probable as X_1, 25 percent as probable as X_2, and 50 percent as probable as X_3. The three absolute ratings for X_4 are thus inferred to be 30, 20, and 25 points, respectively. The average of these ratings is 25. However, before averaging such figures, it might be beneficial to have the expert reevaluate the relative ratings for X_4 with respect to X_1, X_2, and X,.

As a result of this process, the relative probability values shown in Table D-4 might be attained.

Value	Probability Points
RX_1	100
RX_2	80
RX_3	50
RX_4	25
RX_5	10
RX_6	0
RX_7	0

Table D-4. Relative Probability Ratings

Finally, the scale of relative probability values can be converted directly into a scale of actual probability density values by having $P(X_1)$ equal the actual subjective probability or occurrence of the highest value. Then $P(X_2)$ is defined as—

$$\frac{RX_2}{RX_1}\left[P(X_1)\right]$$

Similarly, for i = 2, 3, . . . 7, $P(X_i)$ is defined as—

$$\frac{RX_i}{RX_1}\left[P(X_1)\right]$$

Assuming that the independent characteristic values evaluated represent all possible values attainable by the component characteristic, the respective probabilities must total 1 (that is, $P(X_1) + P(X_2) + P(X_3) + P(X_4) + P(X_5) + P(X_6) + P(X_7) = 1$). Substituting the expressions for $P(X_i)$, i = 2 , . . . 7, it follows that—

$$P(X_1)+\frac{RX_2}{RX_1}\left[P(X_1)\right]+\frac{RX_3}{RX_1}\left[P(X_1)\right]+\frac{RX_4}{RX_1}\left[P(X_1)\right]$$
$$+\frac{RX_5}{RX_1}\left[P(X_1)\right]+\frac{RX_6}{RX_1}\left[P(X_1)\right]+\frac{RX_7}{RX_1}\left[P(X_1)\right]=1$$

Solving this equation for $P(X_1)$, the remaining $P(X_i)$, i = 2 , . . . 7 can be determined using the relationship—

$$P(X_1)=\frac{RX_i}{RX_1}\left[P(X_1)\right]$$

As an illustration, consider the relative probability ratings in Table D-4. Using the values, the preceding equation is given by—

$$P(X_1)+\frac{80}{100}P(X_1)+\frac{50}{100}P(X_1)$$
$$+\frac{25}{100}P(X_1)+\frac{10}{100}P(X_1)=1$$

Solving this equation, $P(X_1) = 0.377$

This value can be used to determine the remaining probabilities as follows:

$$P(X_2) = \frac{RX_2}{RX_1} P(X_1) = 0.80\,(0.377) = 0.301$$

$$P(X_3) = \frac{RX_3}{RX_1} P(X_1) = 0.50\,(0.377) = 0.189$$

$$P(X_4) = \frac{RX_4}{RX_1} P(X_1) = 0.25\,(0.377) = 0.095$$

$$P(X_5) = \frac{RX_5}{RX_1} P(X_1) = 0.10\,(0.377) = 0.038$$

$$P(X_6) = \frac{RX_6}{RX_1} P(X_1) = 0\,(0.377) = 0$$

$$P(X_7) = \frac{RX_7}{RX_1} P(X_1) = 0\,(0.377) = 0$$

The resulting probability density appears in Table D-5.

Component Characteristic Value	Probability
X_1	0.377
X_2	0.301
X_3	0.189
X_4	0.095
X_5	0.038
X_6	0.000
X_7	0.000
Total	1.000

Table D-5. Probability Density

Sources of Additional Information

Atzinger, E.M., et al. *Compendium on Risk Analysis Techniques.* AD 746245, LD 28463. Aberdeen Proving Ground, Md.: DARCOM Material Systems Analysis Activity, 1972.

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Appendix *E*
Special Notes on Software Risk

Although the techniques and processes discussed in *Risk Management: Concepts and Guidance* apply to software, they do not address some of the peculiarities that are a part of software development. Software has a tendency to change dramatically during the development cycle when compared with hardware. This appendix suggests some useful actions in managing software development efforts. Additional information can be obtained from Chapter 20 of the DSMC *Systems Engineering Management Guide* (1990).

One of the most effective risk management (handling) techniques for software is establishing a formal software quality assurance program early in the development cycle. The program should establish a team of experts whose charter is to look at issues that will ensure a reliable product in a reasonable time and at a reasonable cost. Some of the questions the team must answer include the following:

- Is independent verification and validation warranted?
- Is the development environment adequate (tool sets, compiler)?
- Is the higher-order language selection appropriate?
- Are the requirements clearly stated?
- Will rapid prototyping be used?
- Has the software approach been baselined?
- Has the testing philosophy been established?
- Has the development philosophy been established?

Addressing these issues early in the development cycle will help avoid surprises. The basic process for risk management-plan, assess, analyze, and handle-still applies to software. Tables E-1 to E-5, which are extracts from government pamphlets (AFSC 1985, 1987), may prove useful in quantifying software risk.

	Magnitude		
Technical Drivers	Low **(0.0–0.3)**	Medium **(0.4-0.5)**	High **(0.6–1.0)**
Requirements			
Complexity	Simple or easily allocatable	Moderate, can be allocated	Significant or difficult to allocate
Size	Small or easily broken down into work units	Medium or can be broken down into work units	Large or cannot be broken down into work loads
Stability	Little or no change to established baseline	Some change in baseline expected	Rapidly changing or no baseline
Reliability and maintainability	Allocatable to hardware and software components	Requirements can be defined	Can be addressed only at the total system level
Constraints			
Computer resources	Mature, growth capacity within design, flexible	Available, some growth capacity	New development, no growth capacity, inflexible
Personnel	Available, in place, experienced, stable	Available, but not in place, some experience	High turnover, little or no experience, not available
Standards	Appropriately tailored for application	Some tailoring, all not reviewed for applicability	No tailoring, none applied to the contract
Buyer-furnished equipment and property	Meets requirements, available	May meet requirements, uncertain availability	Not compatible with system requirements, unavailable
Environment	Little or no effect on design	Some effect on design	Major effect on design

Table E-1. Quantification of Probability and Impact of Technical Drivers

	Magnitude		
Technical Drivers	Low **(0.0–0.3)**	Medium **(0.4-0.5)**	High **(0.6–1.0)**
Technology			
Language	Mature, approved high-order language used	Approved or nonapproved high-order language	Significant use of assembly language
Hardware	Mature, available	Some development or available	Total new development
Tools	Documented, validated, in place	Available, validated, some development	Unvalidated, proprietary, major development
Data rights	Fully compatible with support and follow-on	Minor incompatibilities support and follow-on	Incompatible with support and follow-on
Experience	Greater than 3 to 5 years	Less than 3 to 5 years	Little or none
Developmental Approach			
Prototypes and reuse	Used, documented sufficiently for use	Some use and documentation	No use and/or no documentation
Documentation	Correct and available	Some deficiencies, available	Nonexistent
Environment	In place, validated, experience with use	Minor modifications, tools available	Major development effort
Management approach	Existing product and process controls	Product and process controls need enhancement	Weak or nonexistent
Integration	Internal and external controls in place	Internal or external controls not in place	Weak or nonexistent
Impact	Minimal-to-small reduction in technical performance	Some reduction in technical performance	Significant degradation to non-achievement of technical performance

Table E-1. Quantification of Probability and Impact of Technical Drivers (continued)

	Magnitude		
Operational Drivers	Low **(0.0–0.3)**	Medium **(0.4-0.5)**	High (0.6–1.0)
User Perspective			
Requirements	Compatible with user environment	Some incompatibilities	Major incompatibilities with operations concepts
Stability	Little or no change	Some controlled change	Uncontrolled change
Test environment	Representative of the user environment	Some aspects are not representative	Major disconnects with user environment
Test results	Test errors/ failures are correctable	Some errors/failures are not correctable before implementation	Major corrections necessary
Quantification	Primarily objective	Some subjectivity	Primarily subjective
Technical Performance			
Usability	User friendly	Mildly unfriendly	User unfriendly
Reliability	Predictable performance	Some aspects unpredictable	Unpredictable
Flexibility	Adaptable with threat	Some aspects not adaptable	Critical functions not adaptable
Supportability	Timely incorporation	Response times inconsistent with need	Unresponsive
Integrity	Responsive to update	Hidden linkages, controlled access	Insecure
Performance Envelope			
Adequacy	Full compatibility	Some limitations	Inadequate
Expandability	Easily expanded	Can be expanded	No expansion
Enhancements	Timely incorporation	Some lag	Major delays
Threat	Responsive to change	Cannot respond to some changes	Unresponsive
Impact	Full mission capability	Some limitations on mission performance	Severe performance limitations

Table E-2. *Quantification of Probability and Impact of Operational Drivers*

	Magnitude		
Support Drivers	Low **(0.0–0.3)**	Medium **(0.4–0.5)**	High **(0.6–1.0)**
Design			
Complexity	Structurally maintainable	Certain aspects difficult	Extremely difficult to maintain
Documentation	Adequate	Some deficiencies	Inadequate
Completeness	Few additional support requirements	Some support requirements	Extensive support requirements
Configuration management	Sufficient, in place	Some shortfalls	Insufficient
Stability	Little or no change	Moderate, controlled change	Rapid or uncontrolled change
Responsibilities			
Management	Defined, assigned responsibilities	Some roles and mission issues	Undefined or unassigned
Configuration management	Single-point control	Defined control points	Multiple control points
Technical management	Consistent with operational needs	Some inconsistencies	Major inconsistencies
Change implementation	Responsive to user needs	Acceptable delays	Nonresponsive to user needs
Tools and Management			
Facilities	In place, little change	In place, some modification	Nonexistent or extensive change
Software tools	Delivered, certified, sufficient	Some resolvable concerns	Not delivered, certified, or sufficient
Computer hardware	Compatible with operations system	Minor incompatibilities	Major incompatibilities
Production	Sufficient for distributed units	Some capacity questions	Insufficient
Distribution	Controlled, responsive	Minor response concerns	Uncontrolled or nonresponsive

Table E-3. Quantification of Probability and Impact of Support Drivers

	Magnitude		
Support Drivers	**Low (0.0–0.3)**	**Medium (0.4–0.5)**	**High (0.6–1.0)**
Supportability			
Changes	Within projections	Slight deviations	Major deviations
Operational interfaces	Defined, controlled	Some hidden linkages	Extensive linkages
Personnel	In place, sufficient experience	Minor discipline mixed concerns	Significant concerns
Release cycle	Responsive to user requirements	Minor incompatibilities	Nonresponsive to user needs
Procedures	In place, adequate	Some concerns	Nonexistent or inadequate
Impact	Responsive software support	Minor delays in software modifications	Nonresponsive or unsupportable software

Table E-3. *Quantification of Probability and Impact of Support Drivers (continued)*

	Magnitude		
Cost Drivers	Low **(0.0–0.3)**	Medium **(0.4-0.5)**	High **(0.6–1.O)**
Requirements			
Size	Small, noncoplex, or easily broken down	Medium, moderate complexity, can be broken down	Large, highly complex, or cannot be broken down
Resource constraints	Little or no hardware-imposed constraints	Some hardware imposed constraints	Significant hardware-imposed constraints
Application	Non-real-time, little system interdependency	Embedded, some system inter-dependency	Real-time, embedded, strong interdependency
Technology	Mature, existent, in-house experience	Existent, some in-house experience	New or new application, little experience
Requirements stability	Little or no change to established baseline	Some change in baseline expected	Rapidly changing or no baseline
Personnel			
Availability	In place, little turnover expected	Available, some turnover expected	High turnover, not available
Mix	Good mix of software disciplines	Some disciplines inappropriately represented	Some disciplines not represented
Experience	High experience ratio	Average experience ratio	Low experience ratio
Management engineering	Strong management approach	Good personnel management approach	Weak personnel management approach
Reusable Software			
Availability	Compatible with need dates	Delivery dates in question	Incompatible with need dates
Modifications	Little or no change	Some changes	Extensive changes
Language	Compatible with system require-ments	Partial compatibility with requirements	Incompatible with system require-ments
Rights	Compatible with competition requirements	Partial compatibility some competition	Incompatible with concept, non-competitive
Certification	Verified perfor-mance, applica-tion compatible	Some application-compatible, some competition	Unverified, little test data available

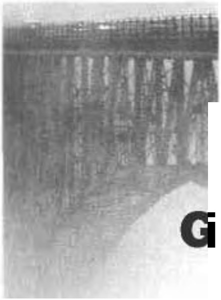
Table E-4. *Quantification of Probability and Impact of Cost Drivers*

Cost Drivers	Magnitude Low (0.0–0.3)	Medium (0.4-0.5)	High (0.6–1.0)
Tools and Environment			
Facilities	Existent, little or no modification	Existent, some modification	Nonexistent, extensive changes
Availability	In place, meets need dates	Some compatibility with need dates	Nonexistent, does not meet need dates
Rights	Compatible with development plans	Partial compatibility with development plans	Incompatible with development plans
Configuration management	Fully controlled	Some controls	No controls
Impact	Sufficient financial resources	Some shortage of financial resources, possible overrun	Significant financial shortages, budget overrun likely

Table E-4. *Quantification of Probability and Impact of Cost Drivers (continued)*

	Magnitude		
Schedule Drivers	Low **(0.0–0.3)**	Medium **(0.4-0.5)**	High **(0.6–1.0)**
Resources			
Personnel	Good discipline mix in place	Some disciplines not available	Questionable mix and/or availability
Facilities	Existent, little or no modification	Existent, some modification	Nonexistent, extensive changes
Financial	Sufficient budget allocated	Some questionable allocations	Budget allocation in doubt
Need Dates			
Threat	Verified projections	Some unstable aspects	Rapidly changing
Economic	Stable commitments	Some uncertain commitments	Unstable, fluctuating commitments
Political	Little projected sensitivity	Some limited sensitivity	Extreme sensitivity
Buyer-furnished equipment and property	Available, certified	Certification or delivery questions	No application evidence
Tools	In place, available	Some deliveries in question	Little or none
Technology			
Availability	In place	Baselined, some unknowns	Unknown, no baseline
Maturity	Application verified	Controllable change projected	Rapid or uncontrolled change
Experience	Extensive application	Some dependency on new technology	Incompatible with existing technology
Requirements			
Definition	Known, baselined	Baselined, some unknowns	Unknown, no baseline
Stability	Little or no change projected	Controllable change projected	Rapid or uncontrollable change
Complexity	Compatible with existing technology	Some dependency on new technology	Incompatible with existing technology
Impact	Realistic achievable schedule	Possible slippage in implementation	Unachievable implementation

Table E-5. Quantification of Probability and Impact of Schedule Drivers



Glossary

acceptance
Risk response strategy that prepares for and deals with the consequences of a risk, either actively (for example, by developing a contingency plan to execute if the risk event occurs) or passively (for example, by accepting a lower profit if some activities run over budget). See *also* avoidance, mitigation, *and* transference.

activity
Element of work that is required by the project, uses resources, and takes time to complete. Activities have expected durations, costs, and resource requirements and may be subdivided into tasks. See *also* task.

activity duration
Best estimate of the time (hours, days, weeks, months, or, sometimes, years) needed to accomplish the work involved in an activity, considering the nature of the work and resources required for it.

activity-on-arrow
See arrow diagramming method.

activity-on-node
See precedence diagramming method.

actual cost
Cost determined on the basis of incurred costs as distinguished from forecasted costs.

analogy comparisons
Risk identification technique that involves comparing past or existing programs to the current project effort and reviewing and using these data in the risk process to understand relationships among project characteristics and particular aspects of the current project. See also lessons learned.

analogycbased estimating
Using the actual duration or cost of a previous, similar activity as the basis for estimating the duration or cost of a present or future activity; a form of expert judgment.

arrow
In ADM, graphic presentation of an activity. The tail of the arrow represents the start of the activity; the head of the arrow represents the finish. Unless a time scale is used, the length of the arrow stem has no relation to the duration of the activity.

arrow diagramming method (ADM)
Network diagramming technique in which activities are represented by arrows. The tail of the arrow represents the start of the activity; the head of the arrow represents the finish of the activity. The length of the arrow does not represent the expected duration of the activity. Activities are connected at points called nodes (usually drawn as circles) to illustrate the sequence in which the activities are expected to be performed. Also called activity-on-arrow.

assumption
A factor that is considered to be true, real, or certain and is often used as a basis for decision making.

assumptions analysis
Technique for conducting a thorough review of all project assumptions and validating or invalidating those assumptions at the beginning of the project and any time when the project environment changes.

audit
(1) Formal examination of a project's accounts or financial situation.

(2) Methodical examination of the project, either in whole or in part, usually conducted according to a pre-established schedule, to assess overall progress performance.

avoidance
Risk response strategy that eliminates the threat of a specific risk event, usually by eliminating its potential cause. The project management team can never eliminate all risk, but certain risk events often can be eliminated. See also acceptance, mitigation, and transference.

bar chart
See Gantt chart.

baseline

(1) Original plan (for a project, work package, or activity), plus or minus any approved changes. May be used with a modifier (for example, cost baseline, schedule baseline, performance measurement baseline).

(2) Nominal plan to which deviations will be compared.

brainstorming

Problem-solving technique that can be used for planning purposes, risk identification, improvement efforts, and other project-related endeavors. Participants are invited to share their ideas in a group setting where no disapproving verbal or nonverbal behaviors are permitted. The technique is designed to generate a large number of ideas by helping people to think creatively and allowing them to participate fully without feeling inhibited or criticized by others.

breakdown

Identification of the smallest activities or tasks in a project for estimating, monitoring, and controlling purposes.

budget

Quantitative expression of management's plans to perform specified work. Used to present management's intentions and objectives to all levels of the organization, monitor implementation of the plans, and provide a quantitative basis for measuring and rewarding individual and unit performance.

business risk

Risk—with an inherent potential for either profit or loss—that is associated with any particular endeavor.

cause-and-effect diagram

See Ishikawa diagram.

chance

Possibility of an indicated outcome in an uncertain situation. See also probability.

checklists

Classic risk identification technique that uses simple lists of questions or statements based on lessons learned from previous projects. Allows the project manager to build risk lists early in the project.

closeout phase

Fourth phase in the generic project life cycle where all outstanding contractual issues are completed and documented in preparation for turning over the product or service to the customer.

concept phase

First of four sequential phases in the generic project life cycle where the idea or notion for a project is first articulated. Also called idea, economic analysis, feasibility, or prefeasibility phase.

confidence interval

Limits of an uncertain quantity (like cost) between which there is a given probability of occurrence. Expressed as in "the n percent confidence interval." The confidence level is the left-hand lower confidence interval, so that one may say, "C is the nth confidence level," meaning there is an n percent probability of cost being between zero and C.

confidence level

Percentile. Used to indicate what certainty or faith is to be put into the sample being taken as representative of the entire population. The most common measure in the area is the confidence level for the mean.

contingency

(1) Provision for any project risk elements within the project scope; particularly important when comparison of estimates and actual data suggest that certain risk events are likely to occur. If an allowance for escalation is included in the contingency, such should be a separate item calculated to fit expected price level escalation conditions for the project.

(2) Possible future action that may stem from presently known causes, the cost outcome of which cannot be determined accurately. See also reserve and contingency plan.

contingency plan

Plan that identifies alternative strategies to be used if specified risk events occur. Examples include a contingency reserve in the budget, alternative schedule activity sequences, and emergency responses to reduce the impacts of risk events.

contingency reserve

Quantity of money or time that is intended to reduce the impact of missed cost, schedule, or performance objectives, which can be only partly planned (sometimes called "known unknowns"), and that is normally included in the project's cost and schedule baseline. Also called contingency allowance.

contract

Mutually binding agreement that obligates the seller to provide the specified product or service and obligates the buyer to pay for it.

contract work breakdown structure
Tool used to describe the total product and work to be done to satisfy a specific contract. Normally prepared by a contractor to reflect the statement of work in a specific contract or request for proposal. Used to define the level of reporting the contractor will provide the buyer. See also work breakdown structure.

control
(1) Process of comparing actual performance with planned performance, analyzing variances, evaluating alternatives, and taking corrective action as needed.

(2) One of the key risk response strategies, calling for reduction of the probability of a risk, reduction of the risk's impact, or deflection of the risk to another party. Also calkd mitigation.

cost baseline
Time-phased budget used to measure and monitor cost performance on the project. Developed by summing estimated costs by period.

cost estimate
(1) Prediction of the expected monetary cost required to perform a task or acquire an item.

(2) Quantitative assessment of the likely costs of the resources required to complete project activities. May constitute a single value or a range of values and is based on understanding at a specific point in time.

cost estimating
Process of estimating the cost of the resources needed to complete project activities. Includes an economic evaluation, an assessment of project investment cost, and a forecast of future trends and costs.

cost estimating relationship (CER)
Mathematical relationship that defines cost as a function of one or more noncost parameters, such as performance, operating characteristics, or physical characteristics.

cost performance report (CPR)
Written account of cost and schedule progress and earned value, normally prepared monthly.

cost risk
(1) Risk associated with failing to complete tasks within the estimated budget allowances.

(2) Assessment of possible monetary loss or gain from the work to be done on a project.

Crawford Slip Method (CSM)

Risk information gathering technique that involves establishing a clear premise, collecting participants' responses (on paper slips), and then repeating the process 10 times in order to extract all information available.

critical path

In a project network diagram, the series of activities that determine the earliest completion of the project. Will change as activities are completed ahead of or behind schedule. Although normally calculated for the entire project, may also be determined for a milestone or subproject. Often defined as those activities with float less than or equal to a specified value, often zero. See also critical path method.

critical path method (CPM)

Network analysis technique used to predict project duration by analyzing the sequence of activities (path) that has the least amount of scheduling flexibility (the least amount of float). Early dates are calculated by a forward pass using a specified start date. Late dates are calculated by a backward pass starting from a specified completion date (usually the forward pass's calculated early finish date for the project).

critical risk

Risk that can jeopardize achievement of a project's cost, time, or performance objectives.

cumulative density function (CDF)

A curve or mathematical expression that associates a probability to all values in the set of values over which it is defined so that the probability is that of the occurrence of a value less than or equal to a given value.

decision analysis

The examination of decision problems by analysis of the outcomes of decision alternatives, the probabilities of arrival at those outcomes, and the intervening decisions between selection of alternatives and arrival of outcomes. The attributes of the outcomes are examined and numerically matched against preference criteria.

decision making

Analyzing a problem to identify viable solutions and then making a choice among them.

decision tree
Diagram that shows key interactions among decisions and associated chance events as they are understood by the decision maker. Branches of the tree represent either decisions or chance events. The diagram provides for the consideration of the probability of each outcome.

deflection
Transference of all or part of a risk to another party, usually by means of a contract provision, insurance policy, or warranty.

Delphi technique
Form of participative expert judgment; an iterative, anonymous, interactive technique using survey methods to derive consensus on work estimates, approaches, and issues.

dependency
Logical relationship between and among tasks of a project's WBS, which can be graphically depicted on a network diagram. *See also* logical relationship.

development phase
Second of four sequential phases in the generic project life cycle, where project planning and design typically occur. *Also called* planning phase.

documentation review
Risk review technique that analyzes the breadth of project support documentation to identify the potential risks a project may face.

duration
Number of work periods required to complete an activity or other project element. Usually expressed as hours, workdays, or workweeks. Sometimes incorrectly equated with elapsed time. *See also* effort.

earned value (EV)
Analysis of a project's schedule and financial progress as compared to the original plan.

effort
Number of labor units required to complete an activity or other project element. May be expressed as staff hours, days, or weeks. Should not be confused with duration.

estimate

Assessment of likely quantitative result, usually applied to project costs and durations. Should include some indication of accuracy (for example, ± X percent). Generally used with a modifier (such as preliminary, conceptual, or feasibility). Some disciplines use modifiers that imply specific accuracy ranges (such as order-of-magnitude, budget, and definitive, which have been traditionally used in engineering and construction projects), but are increasingly used in other industry applications.

estimating relationships

Risk estimating technique for evaluating project costs and then applying an equation to determine an appropriate contingency or risk funds budget. See *also* cost estimating relationship and parametric cost estimating.

expected monetary value (EMV)

Product of an event's probability of occurrence and the gain or Loss that will result. For example, if there is a 50 percent probability of snow, and snow will result in a $100 loss, the expected monetary value of the snow is $50 (0.5 × $100).

expert interviews

Risk identification and qualification technique that relies on obtaining accurate risk judgments based on the experience of technical experts.

expert judgment

Opinions, advice, recommendations, or commentary proffered, usually upon request, by a person or persons recognized, either formally or informally, as having specialized knowledge or training in a specific area.

feasibility

Assessment of the capability for successful implementation; the possibility, probability, and suitability of accomplishment.

finish-to-finish (FF)

Relationship in a precedence diagramming method network in which one activity must end before the successor activity can end. See *also* logical relationship.

finish-to-start (FS)

Relationship in a precedence diagramming method network in which one activity must end before the successor activity can start. The most commonly used relationship in the precedence diagramming method. See *also* logical relationship.

fishbone diagram
See Ishikawa diagram.

float
Amount of time that an activity may be delayed from its early start without delaying the project end date. Derived by subtracting the early start from the late start or early finish from the late finish, and may change as the project progresses and as changes are made to the project plan. Also called slack, total float, and path float.

flow diagram
Graphic representation of work flow and the logical sequence of the work elements without regard to a time scale. Used to show the logic associated with a process rather than a duration for completion of work.

Gantt chart
Graphic display of schedule-related information. Generally, activities or other project elements are listed down the left side of the chart, dates are shown across the top, and activity durations are displayed against the x and y axes as date-placed horizontal bars. Named after its developer, Henry Gantt.

general and administrative (G&A) expense
Management, financial, or other expense incurred by or allocated to an organizational unit for the general management and administration of the organization as a whole.

Graphical Evaluation and Review Technique (GERT)
Network analysis technique that allows for conditional and probabilistic treatment of logical relationships (for example, some activities may not be performed).

histogram
Timeline chart that shows the use of a resource over time.

impact
Estimate of the effect that a risk will have on schedule, costs, product quality, safety, and performance.

impact analysis
Qualitative or quantitative assessment of the magnitude of loss or gain to be realized should a specific risk or opportunity event—or series of interdependent events—occur.

implementation phase
Third of four sequential phases in the generic project life cycle where the project plan is executed, monitored, and controlled. Also called execution or operation phase.

independence (also statistical independence)

The relationship between two or more events when knowledge of the probability of occurrence of one does not alter the probability of another.

independent cost estimate

(1) Estimate of project costs conducted by individuals outside the normal project management structure.

(2) Estimate of anticipated project costs by the project team; used to compare the reasonableness of contractor proposals.

independent technical assessment

A formal technical review that an expert (or experts) in the field conducts to determine the project's potential for achieving specific objectives. Used for substantially reducing project risk, especially risk associated with multi-organizational involvement.

inputs

(1) Information or other items required to begin a process or activity.

(2) Documents or documentable items to be acted upon.

(3) Information, thoughts, or ideas used to assist in decision making.

insurable risk

Risk that can be covered by an insurance policy, normally expressed as a risk with only the opportunity for loss. Also called pure risk.

Ishikawa diagram

Diagram used to illustrate how various causes and subcauses create a special effect. Named after its developer Kaoru Ishikawa. Also called cause-and-effect diagram or fishbone diagram.

lessons learned

Documented information, usually collected through meetings, discussions, or written reports, to show how both common and uncommon project events were addressed. This information can be used by other project managers as a reference for subsequent project efforts.

level of effort

Support-type activity (such as vendor or customer liaison) that does not readily lend itself to measurement of discrete accomplishment and is generally characterized by a uniform rate of activity over a specific time period.

Life cycle

The entire life of a project, product, or service, usually divided into sequential phases, which include initiation, development, execution, operation, maintenance, and disposal or termination.

life-cycle cost (LCC)

Broad view of project cost management that considers the effect of project decisions on the cost of using the project's product. Evaluation of all costs associated with the project life cycle, including acquiring, operating, supporting, and (if applicable) disposing of the items being acquired so decisions can be made among alternatives.

logical relationship

Dependency between two project activities or between a project activity and a milestone. The four types of logical relationships in the precedence diagramming method are (1) finish-to-start—the "from" activity must finish before the "to" activity can start, (2) finish-to-finish—the "from" activity must finish before the "to" activity can finish, (3) start-to-start—the "from" activity must start before the "to" activity can start, and (4) start-to-finish—the "from" activity must start before the "to" activity can finish. Also called link.

management reserve

Separately planned quantity of money or time intended to reduce the impact of missed cost, schedule, or performance objectives, which are impossible to plan for (sometimes called "unknown unknowns").

mean

The average value of a set of numbers.

median

The middle value in a distribution, above and below which lie an equal number of values.

metrics

Units of measurement used to assess, calculate, or determine progress performance in terms of monetary units, schedule, or quality results.

milestone

(1) Task, with a zero duration and requiring no resources, that is used to measure the progress of a project and signifies completion or start of a major deliverable.

(2) Identifiable point in a project or set of activities that represents a reporting requirement or completion of a large or important set of activities. Also called key event.

mitigation

Risk response strategy that decreases risk by lowering the probability of a risk event's occurrence or reducing the effect of the risk should it occur. *See also* acceptance, avoidance, *and* transference.

mode

The highest point on a probability density function. The point on the function at which the probability changes from increasing to decreasing.

model

A way to look at an item, generally by abstracting and simplifying it to make it understandable in a particular context.

modified Churchman-Ackoff method

A means of ordering events in terms of likelihood to occur.

Monte Carlo analysis

A technique in which outcomes of events are determined by selecting random numbers subject to defined probabilities. If the random number falls within the limits of an outcome's probability, that outcome is chosen. The process is done on an iterative basis to determine "statistical" likelihood.

most likely time

In PERT estimating, the most realistic number of work periods the activity will consume.

network

(1) Graphic depiction of the relationships of project work (activities or tasks). *See also* network diagram.

(2) Communication facility that connects end systems; interconnected series of points, nodes, or stations connected by communication channels; or assembly of equipment through which connections are made between data stations.

network analysis

Identification of early and late start and finish dates for uncompleted portions of project activities. Also *called* schedule analysis. *See also* critical path method, Program Evaluation and Review Technique, and Graphical Evaluation and Review Technique.

network-based scheduling

Process of determining logical relationships among WBS work packages, activities, and tasks and then arranging same to establish the shortest possible project duration. Examples of these techniques include PERT, CPM, and PDM.

network diagram

Schematic display of the logical relationships of project activities, usually drawn from left to right to reflect project chronology. Also called logic diagram and often incorrectly referred to as a PERT chart.

node

Junction point joined to some or all of the other dependency lines in a network; an intersection of two or more lines or arrows. See also arrow diagramming method and precedence diagramming method.

nominal group technique

Specific structured process of team brainstorming and creative problem solving that draws on individual and group strengths but prevents domination by any one individual. Consists of five separate steps as follows: (1) silent generation—individual team members write responses to a problem statement in silence; (2) round robin—each team member recites his or her responses, which are written on a chart; (3) clarification—the group discusses the remarks; (4) selection and ranking--each team member selects and ranks in priority order the top 3 to 10 ideas collected; and (5) final selection and ranking—the facilitator tallies the results and prepares the group's ranked set of ideas.

odds

The ratio of probabilities of occurrence and nonoccurrence. For example, for a throw of a fair die the probability of getting a 4 is $1/6$. The odds are 5 to 1.

opportunity

(1) Future event or series of events that, if occurring, will have a positive impact on a project.

(2) Benefit to be realized from undertaking a project.

optimistic time

In PERT estimating, the minimum number of work periods the activity will consume.

outputs

Documents or deliverable items that are the result of a process.

parametric cost estimating

Estimating approach that uses a statistical relationship between historical data and other variables (for example, lines of code in software development) to calculate an estimate.

performance

Determination of achievement to measure and manage project quality.

performance tracking

Risk measurement technique that establishes exacting project performance criteria to assess them against acceptable ranges around those criteria. See *also* technical performance measurement.

PERT

See Program Evaluation and Review Technique (PERT).

pessimistic duration

In PERT estimating, the maximum number of work periods the activity will consume. *Also called* pessimistic time.

plan evaluation

Risk technique that evaluates traditional, formal project plans used to guide the project for contradictions and voids.

planning meetings

Project planning technique that brings together key stakeholders on risk to determine the risk practices to be pursued and the approach to be used in pursuing them.

PMBOK®

See project management body of knowledge.

PMI®

See Project Management Institute, Inc.

PMP®

See project management professional.

precedence diagramming method (PDM)

Network diagramming technique in which activities are represented by boxes (or nodes) and linked by precedence relationship lines to show the sequence in which the activities are to be performed. The nodes are connected with arrows to show the dependencies. Four types of relationships are possible: finish-to-finish, finish-to-start, start-to-finish, and start-to-start. *Also called* activity-on-node.

probabiity

(1) Likelihood of occurrence.

(2) Ratio of the number of chances that an event may or may not happen to the sum of the chances of both happening and not happening.

probability density function (PDF)

A probability expression in which the area under the function between defined limits of the values on which it is defined represents the probability of the values within those limits.

Program Evaluation and Review Technique (PERT)

Event-oriented, probability-based network analysis technique used to estimate project duration when there is a high degree of uncertainty with the individual activity duration estimates. PERT applies the critical path method to a weighted average duration estimate. The formula is $\frac{O + 4(ML) + P}{6}$

where O = optimistic time, ML = most likely time, and P = pessimistic time.

programmatic risk

The risks involved in obtaining and using applicable resources and activities that may be outside the project manager's control but that can affect the project's direction.

project management body of knowledge (PMBOK[a])

Totality of knowledge within the project management profession. As in other professions, such as law, medicine, and accounting, the body of knowledge rests with the practitioners and academics involved in its application and advancement. The **PMBOK[a]** includes practices that have been widely applied and proven, as well as innovative and advanced practices with more limited use and application.

Project Management Institute (PMF), Inc.

International, nonprofit professional association dedicated to advancing the discipline of project management and state-of-the-art project management practices. See *also* project management professional.

project management professional (PMP®)

Professional certification awarded by the Project Management Institute, Inc. to individuals who have met the established minimum requirements in knowledge, education, experience, and service in the discipline of project management.

project manager

Individual responsible for managing the overall project and its deliverables. Acts as the customer's single point of contact for the project. Controls planning and execution of the project's activities and resources to ensure that established cost, time, and quality goals are met.

project risk

(1) Cumulative effect of the probability of uncertain occurrences that may positively or negatively affect project objectives.

(2) Degree of exposure to negative events and their probable consequences (opposite of opportunity). Characterized by three factors: risk event, risk probability, and amount at stake.

project risk management

That part of project management that includes the processes involved with identifying, analyzing, and responding to project risk; consists of risk identification, risk quantification, risk response development, and risk response control.

project stakeholder

Individual or organization who is actively involved in the project or whose interests may be affected, either positively or negatively, as a result of project execution

project templates

Risk identification technique that builds early risk lists based on risk experience from previous projects.

qualitative risk assessment

Nonnumeric description of a risk, including the likelihood that it will occur, its impact, the methods for containing the impact, possible fallback or recovery measures, and ownership data.

quality risk

Failure to complete tasks to the required level of technical or quality performance.

quantitative risk assessment

Numeric analysis of risk estimates including probability of occurrence to forecast the project's schedule and costs using probabilistic data and other identified uncertainties to determine likely outcomes.

range

The set of all values a given function may take on.

rating scheme

See risk rating scheme.

regression analysis
Determination of the values of constants in a mathematical expression that gives results that are the closest to the observed values associated with values of the data used in the expression. Regression analysis is a process by which the relationship between paired variables can be described mathematically using the tendency of jointly correlated random variables to approach their mean.

request for proposals (RFP)
Type of bid document used to solicit proposals from prospective contractors for products or services. Used when items or services are of a complex nature and assumes that negotiation will take place between the buyer and the contractor.

reserve
Money or time provided for in the project plan to mitigate cost, schedule, or performance risk. See *also* management reserve and contingency reserve.

risk
See project risk.

risk allowance
Time or money budgeted to cover uncertainties because of inaccuracies in deterministic estimates or the occurrence of risk events. See *also* contingency reserve *and* management reserve.

risk analysis
Analysis of the probability that certain undesirable and beneficial events will occur and their impact on attaining project objectives. See *also* risk assessment.

risk assessment
(1) Review, examination, and judgment to see whether the identified risks are acceptable according to proposed actions.

(2) Identification and quantification of project risks to ensure that they are understood and can be prioritized. *Also called* risk evaluation.

risk avoidance
See avoidance.

risk budget
Cost and schedule allowance that is held in reserve and spent only if uncertainties or risks occur. A combination of contingency and management reserves.

risk database
Database for risks associated with a project.

risk deflection
See deflection.

risk description
Documentation of the risk element to identify the boundaries of the risk.

risk drivers
The technical, programmatic, and supportability facets of risk.

risk evaluation
See risk assessment.

risk event
Discrete occurrence that may affect a project, positively or negatively. See *also* project risk.

risk exposure
(1) Impact value of a risk multiplied by its probability of occurring.

(2) Loss provision made for a risk; requires that a sufficient number of situations in which this risk could occur have been analyzed.

risk factor
Risk event, risk probability, or amount at stake.

risk handling
The last critical element in the risk management process. The action or inaction taken to address risk issues identified and evaluated in the risk assessment and risk analysis efforts. See *also* risk response control.

risk identification
Determining the risk events that are likely to affect the project and classifying them according to their cause or source.

risk indicators
The cost and schedule facets of risk.

risk management
See project risk management.

risk management plan
Documentation of the procedures to be used to manage risk during the life of a project and the parties responsible for managing various areas of risk. Includes procedures for performing risk identification and quantification, planning risk response, implementing contingency plans, allocating reserves, and documenting results.

risk management planning
The effort, organizationally, to draw together the risk policies, practices, and procedures of the organization into a cohesive whole that will address the nature of risk peculiar to the project.

risk management strategy
Formal statement of how risk management will be implemented for a project, what resources will be used, and, if applicable, what roles subcontractors will play.

risk mitigation
See mitigation.

risk modeling
Risk identification technique that involves constructing a set of questions that, when answered candidly, will provide a metric value as to the overall risk and opportunity associated with the project.

risk monitoring and control
The process of continually monitoring and correcting the condition of the project.

risk planning
Forcing organized purposeful thought to the subject of eliminating, minimizing, or containing the effects of undesirable occurrences. It allows for isolating and minimizing risk, eliminating risk wherever possible, developing alternative courses of action, and establishing time and money reserves to cover risks that cannot be avoided.

risk practice methodology
Risk identification technique that outlines clear process steps, forms, and practices that are applied consistently and are stored in a common repository within an organization.

risk probability
Assessment of the likelihood that a risk event will occur.

risk qualification
Evaluating risks according to nonnumeric assessment protocols that help to organize and stratify the identified risks.

risk quantification
Evaluation of the probability of a risk event's occurring and of its effect.

risk rating scheme
An evaluation structure, based on agreed-to values denoting probability of occurrence and severity of the effect of failure, used to rank risks.

risk response control
Process of implementing risk strategies, documenting risk, and responding to changes in risk during the life of the project.

risk response development
Identification of specific actions to maximize the occurrence of opportunities and minimize the occurrence of specific risks in a project.

risk response matrix
Risk technique that analyzes and generates strategies that deal with multiple risks in the form of a grid populated by plus and minus signs reflecting their influence on other risks.

risk review
Risk evaluation technique conducted at regular intervals that reassesses the risk environment, risk events, and their relative probability and impact. See also audit.

risk symptom
See risk trigger.

risk trigger
Indirect manifestation of an actual risk event, such as poor morale serving as an early warning signal of an impending schedule delay or cost overruns on early activities pointing to poor estimating. Also called risk symptom.

schedule
Time-sequenced plan of activities or tasks used to direct and control project execution. Usually shown as a milestone chart, Gantt or other bar chart, or tabular listing of dates.

schedule risk
Risk that jeopardizes completing the project according to the approved schedule.

schedule simulation
Use of the project network as a model of the project with the results used to quantify the risks of various schedule alternatives, project strategies, paths through the network, or individual activities. Most schedule simulations are based on some form of Monte Carlo analysis.

scope
Sum of the products and services to be provided by the project.

simulation

Technique used to emulate a process; usually conducted a number of times to understand the process better and to measure its outcomes under different policies.

skew

The asymmetry of a probability density function. The skew is to the side of the mode under which lies the greatest area.

slack

See float.

sources of risk

Categories of possible risk events that may affect the project positively or negatively. Descriptions of risk sources should include rough estimates of the probability that a risk event from that source will occur, the range of possible outcomes, the expected timing, and the anticipated frequency of risk events from the source.

stakeholder

See project stakeholder.

standard deviation

The square root of the variance. Often used because it is expressed in the same units as the random variable itself and can be depicted on the same axes as the probability density function of which it is a characteristic.

start-to-finish

Relationship in a precedence diagramming method network in which one activity must start before the successor activity can finish.

start-to-start

Relationship in a precedence diagramming method network in which one activity must start before the successor activity can start.

statement of work (SOW)

Narrative description of products or services to be supplied under contract that states the specifications or other minimum requirements; quantities; performance dates, times, and locations, if applicable; and quality requirements. Serves as the basis for the contractor's response and as a baseline against which the progress and subsequent contractual changes are measured during contract performance.

strategy

Action plan to set the direction for the coordinated use of resources through programs, projects, policies, procedures, and organizational design and establishment of performance standards.

strengths-weaknesses-opportunities-threats (SWOT) analysis
Analysis used to determine where to apply special efforts to achieve desired outcomes. Entails listing (1) strengths and how best to take advantage of them; (2) weaknesses and how to minimize their impacts; (3) opportunities presented by the project and how best to take advantage of them; and (4) threats and how to deal with them.

supportability risk
The risks associated with fielding and maintaining systems that are being developed or have been developed and are being deployed.

SWOT analysis
See strengths-weaknesses-opportunities-threats analysis.

task
Well-defined component of project work; a discrete work item. There are usually multiple tasks for one activity. See *also* activity.

technical performance measurement
Risk measurement technique that is conducted by establishing exacting project performance criteria and assessing them against the acceptable ranges around those criteria.

technical risk
The risk associated with developing a new design to provide a greater level of performance than previously demonstrated or to accommodate new constraints, such as size or weight.

templates
Set of guidelines that provides sample outlines, forms, checklists, and other documents.

transference
Risk response strategy that shifts the responsibility or consequence for a risk to a third party. See *also* acceptance, avoidance, *and* mitigation.

uncertainty
(1) Situation in which only part of the information needed for decision making is available.

(2) Lack of knowledge of future events.

value analysis
Activity concerned with optimizing cost performance. Systematic use of techniques to identify the required functions of an item, establish values for those functions, and provide the functions at the lowest overall cost without loss of performance.

variance

Actual or potential deviation from an intended or budgeted amount or plan. Difference between a plan and actual time, cost, or performance.

Venture Evaluation and Review Technique (VERT)

Network analysis technique that allows for the incorporation of event probabilities, cost, and resource considerations.

WBS dictionary

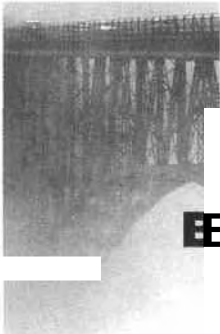
Collection of work package descriptions that includes, among other things, planning information such as schedule dates, cost budgets, and staff assignments.

work breakdown structure (WBS)

Deliverable-oriented grouping of project elements that organizes and defines the total scope of the project. Each descending level is an increasingly detailed definition of a project component. Project components may be products or services. See *also* contract work breakdown structure.

workaround

Unplanned response to a negative risk event. Distinguished from contingency plan because it is not planned in advance of the occurrence of the risk event.



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