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Project Rick and Cost Analysis

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AMA American Management Association®

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Chapter 8 contains material on preparing a network diagram and scheduling that was originally published in a slightly different form in Chapter 5 of *Managing Multiple Projects*, Dobson and Dobson (New York: American Management Association, 2011). Reprinted by permission of the publisher. www.amacombooks.org.

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About This Course

In this new Self-Study course, *Project Risk and Cost Analysis*, we focus on risk in the context of project management, primarily in the area of risk's effects on project costs, with emphasis on the many modern tools that help you and your organization quantify and manage project risk. You will learn how to perform a formal risk and cost analysis, apply the Earned Value Method to risk management, and adjust schedule and budget reserves appropriately for your project conditions.

We will follow the basic project risk management approach as laid out in *A Guide to the Project Management Body of Knowledge (PMBOK® Guide), 4th Edition*, popularly known as the *PMBOK® Guide*, along with other sources listed in the bibliography and suggested reading. Risk cuts across many disciplines, not merely project management, and we strongly encourage you to read and study widely. In the wise words of the classic science fiction film *Plan 9 from Outer Space* (1959), "We are all interested in the future, for that is where you and I are going to spend the rest of our lives."

Michael S. Dobson, PMP, is an internationally known authority on project management and author of 22 previous books, including *The Juggler's Guide to Managing Multiple Projects* (PMI, 1999). As principal of Dobson Solutions (www.dobsonsolutions.com) and the Sidewise Institute (www.sidewiseinsights.com), Michael consults, speaks, and trains on project management topics throughout the world. His clients range from the U.S. Navy's nuclear propulsion program to Calvin klein Cosmetics. As an operating executive and project manager, Michael has been vice president, Discovery Software International; vice president, Games Workshop; and director of marketing and games development, TSR, Inc. He was part of the team that built the Smithsonian Institution's National Air and Space Museum in the 1970s. He holds a bachelor's degree from the University of North Carolina at Charlotte.

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The Dobsons live in Bethesda, Maryland.

How to Take This Course

This course consists of text material for you to read and three types of activities (the pre/post tests, in-text exercises, and end-of-chapter review questions) for you to complete. These activities are designed to reinforce the concepts brought out in the text portion of the course and to enable you to evaluate your progress.

Pre-Test and Post-Test

A pre-test and post-test are included in this course. Take the pre-test before you study any of the course material to determine the amount of prior knowledge you have on the subject matter. Submit one of the scannable answer forms enclosed with this course for grading. On return of the graded pre-test, complete the course material. Take the post-test after you have completed all the course material. By comparing results of the pre-test and the post-test, you can measure how effective the course has been for you.

To have your pre-test and post-test graded, please mail your answer forms to:

American Management Association
Educational Services
P. O. Box 133
Florida, NY 10921

All tests are reviewed thoroughly by our instructors and will be returned to you promptly.

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The Text

The most important component of this course is the text, for it is here that the concepts and methods are first presented. Reading each chapter twice will increase the likelihood of your understanding the text fully.

We recommend that you work on this course in a systematic way. Only by reading the text and working through the exercises at a regular and steady pace will you get the most out of this course and retain what you have learned.

In your first reading, concentrate on getting an overview of the chapter's contents. Read the learning objectives at the beginning of each chapter first. They serve as guidelines to the major topics of the chapter and enumerate the skills you should master as you study the text. As you read the chapter, pay attention to the headings and subheadings. Find the general theme of the section and see how that theme relates to others. Don't let yourself get bogged down with details during the first reading; simply concentrate on remembering and understanding the major themes.

In your second reading, look for the details that underlie the themes. Read the entire chapter carefully and methodically, underlining key points, working out the details of the examples, and making marginal notations as you go. Complete the exercises.

Exercises

Interspersed with the text in each chapter you will find numbered exercises. These take a variety of forms, including brief essay, short answer, charts, and questionnaires. Answers to many of the exercises can be found in the back of the book in the section titled "Answers to Exercises and Case Studies."

The Review Questions

After reading a chapter and before going on to the next, work through the review questions. By answering the questions and comparing your own answers to the answers provided, you will find it easier to grasp the major ideas of that chapter. If you perform these self-check exercises conscientiously, you will develop a framework in which to place material presented in later chapters.

Grading Policy

The American Management Association will continue to grade examinations and tests for one year after the course's out-of-print date.

If you have questions regarding the tests, the grading, or the course itself, call Educational Services at 1-800-225-3215.

Introduction

"I cannot conceive of any vital disaster happening to this vessel. Modern shipbuilding has gone beyond that."

—*RMS Titanic* Captain Edward J. Smith, 1907

"We are ready for any unforeseen event that may or may not occur."

—Dan Quayle, quoted in *Cleveland Plain Dealer*, 27 September 1990

Things don't always go according to plan. That's why we have risk management.

In the case of *RMS Titanic*, both management and operations thought the risk of catastrophe was low, and indeed—measured objectively—it was. The *Titanic* was, in many respects, a marvel of safety engineering, with watertight compartments designed to keep it buoyant even in case of collision. It traveled in shipping lanes filled with other ships, so that even in case of disaster, help would arrive quickly. All of these steps reduced the risk, but as we all know, did not eliminate it altogether.

A report on the late-2000 financial crisis by the leaders of the Group of Twenty (G20) nations focused on the failure of risk management as one of the root causes. They wrote, "During a period of strong global growth, growing capital flows, and prolonged stability earlier this decade, market participants sought higher yields without an adequate appreciation of the risks and failed to exercise proper due diligence. At the same time, weak underwriting standards, unsound risk management practices, increasingly complex and opaque financial products, and consequent excessive leverage combined to create vulnerabilities in the system. Policy-makers, regulators and supervisors, in some advanced countries, did not adequately appreciate and address the risks building up in financial markets, keep pace with financial innovation, or take into account the systemic ramifications of domestic regulatory actions." When risk management fails, the damage can be incalculable.

Risk, fundamentally, is the measurement of uncertainty about the future as it applies to us—our project objectives, corporate goals, or personal goals. How long will the project take? How much will the project cost? Will the project be successful? The answer is, of course, that even when probability is firmly on our side, certainty is elusive. We can make educated guesses; we can analyze probability; we can identify potential scenarios. But we don't—we can't—*know*, at least not until an event happens, or until we pass the point when the event could happen.

Lack of knowledge, however, does not equal helplessness. Risk management and cost analysis provide tools to help us measure the limits of our knowledge, estimate the range of potential futures, and empower us to take action.

The discipline of risk and cost analysis helps managers—project and others—integrate risk into cost proposals and estimates, to determine the likelihood of achieving cost objectives, to determine appropriate levels of reserve, and to establish a common vocabulary to enable project teams to manage risks effectively.

Managers and leaders are often asked to provide cost estimates under conditions of uncertainty, and then to manage according to those estimates regardless of subsequent events or issues. To do that, the estimates have to take into account uncertainty: they must measure—and act upon—risk.

Risk management as a formal discipline is a relatively recent idea. Before the development of statistics beginning in the 17th century, the modern word "risk" didn't even appear in the English language! Uncertainty, of course, was well known. The ancients sacrificed animals to the local gods as insurance against risk, and prayer is still a well-known and well-respected response to life's many dangers: "From lightning and tempest; from earthquake, fire, and flood; from plague, pestilence, and famine/Good Lord, deliver us." (*Book of Common Prayer*, 148)

The root of the word "risk" goes back to Homer's *Odyssey*: when the crew of Odysseus' ship are devoured by the monster Scylla, Odysseus survives by clinging to the roots (*rhiza*) of a fig tree high atop a cliff face. This became a metaphor for any difficulty or danger at sea, evolving into the Latin *risicum* and the Spanish *risico.* As the first use of what we think of as modern risk management involved sea trade, it was altogether natural that the word, stripped now of its naval heritage, became a stand-in for all sorts of danger.

In common language, risk is often used as a synonym for bad potential events, but risks can be positive as well. A stock market investment can gain as well as lose in value; a technology business started in a garage can turn into Hewlett-Packard—or end up in an even smaller garage.

Nobel physicist Niels Bohr and baseball malapropist Yogi Berra are both credited as having said, "Prediction is hard—especially when it's about the future." The future is, indeed, uncertain. How long will it take? How much will it cost? The answer to those questions often depends on events that haven't happened yet. What if something goes wrong? Alternatively, what if we get lucky?

Risk management doesn't (and can't) predict the future. It is instead an attempt to measure the uncertainty of the future as it applies to the objectives of the project, no matter whether those events are negative (downside risks) or positive (upside risks). We identify risks, we analyze risks, we develop potential responses to risks, we execute our response plans—and we adjust as necessary.

Good luck!

Pre-Test

Project Risk and Cost Analysis

Course Code 98008

INSTRUCTIONS: *Record your answers on one of the scannable forms enclosed. Please follow the directions on the form carefully. Be sure to keep a copy of the completed answer form for your records. No photocopies will be graded. When completed, mail your answer form to:*

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1. Qualitative risk analysis is defined as:
   (a) numerically analyzing the effect of identified risks on overall project objectives.
   (b) measuring the accuracy and quality of risk data in objective terms.
   (c) identifying risks that may affect your project.
   (d) prioritizing risks for further analysis by assessing and combining their probability and impact.

2. If the cost of insurance for a particular risk is greater than the value of the underlying risk, the difference between the two numbers is known as:
   (a) risk premium.
   (b) contingency reserve.
   (c) degree to which the policy is overpriced.
   (d) price-to-book ratio.

3. One category of threat risk response is:
   (a) mitigation.
   (b) exploitation.
   (c) sharing.

(d) enhancement.

4. If there is a 20% probability of an event that would cost the project $20,000, what is the value of the risk?
   (a) $20,000
   (b) $4,000
   (c) $24,000
   (d) $2,000

5. To run a Monte Carlo simulation program, you must first:
   (a) prepare three-point estimates for task durations.
   (b) perform decision tree analysis of make vs. buy options.
   (c) calculate the root sum square of the schedule standard deviation for tasks on the critical path.
   (d) perform a full PERT analysis of the schedule network.

6. In developing risk responses for opportunities, you may consider:
   (a) avoidance.
   (b) mitigation.
   (c) transfer.
   (d) sharing.

7. What does a project network diagram do?
   (a) Displays a project schedule graphically
   (b) Shows a project schedule as a bar graph over time
   (c) Connects project resources with project activities
   (d) Establishes the communication plan for the project

8. How does negative brainstorming differ from conventional brainstorming?
   (a) Negative brainstorming is the result of failure of a conventional brainstorming.
   (b) Negative brainstorming allows criticism and evaluation of ideas during the process.
   (c) Negative brainstorming looks at the potential problems with conventional brainstormed answers.
   (d) Negative brainstorming involves brainstorming a negative question to identify downside risks.

9. What is a characteristic of a black swan event?
   (a) Hard to predict and rare
   (b) Something that cannot possibly occur
   (c) Conforms to project assumptions
   (d) Has a relatively small impact

10. To compare costs and benefits, you must:
   (a) describe all costs and benefits in deterministic form.
   (b) perform expected monetary value analysis on costs and benefits impacting 10% or more of total project value (TPV).
   (c) perform a PERT analysis of the project network to determine schedule risk.
   (d) quantify all aspects of the project in the same unit of measurement and at the same point in

time.

11. In the PMBOK® model, which of the following processes involves studying risks to understand their nature, probability, and impact?
(a) Risk response planning
(b) Risk identification
(c) Risk monitoring and control
(d) Risk analysis

12. What does a decision tree analysis do?
(a) Filters risks during qualitative risk analysis
(b) Shows causes and effects of risks in a "fishbone" diagram
(c) Calculates total risk exposure on a project
(d) Compares expected monetary values (EMV) of different alternatives, choices, or conditions

13. What is the probability that you will *not* roll a 4 or a 6 on a six-sided die?
(a) 2/6
(b) 2/12
(c) 4/24
(d) 4/6

14. The confidence level for a project measures:
(a) how much we know about project risks.
(b) how good the project manager's track record has been.
(c) how stable the customer's requirements will be.
(d) how likely the project will finish on or before a given date.

15. What technique should you use to perform risk triage of your identified risks?
(a) Cause-and-effect diagramming
(b) Filtering
(c) PERT analysis
(d) Risk response planning

16. Which measure of central tendency describes the average of a group of numbers?
(a) Median
(b) Mode
(c) Mean
(d) Medium

17. When you write a risk as an "if–then" statement, what are the two parts called?
(a) Business risk and pure risk
(b) Condition and consequence
(c) Probability and impact
(d) Problem and solution

18. Which of the following words is one of the named categories in a SWOT analysis?
(a) Supervision
(b) Wildly-Aimed Guess
(c) Other Factors
(d) Threat

19. Convergence risk is the risk that:
(a) a task will take longer than scheduled.
(b) a sequence of dependent tasks will take longer than scheduled.
(c) critical tasks will take longer than scheduled.
(d) at least one predecessor of a task with multiple predecessors will take longer than scheduled.

20. What does a risk matrix do?
(a) Combines word descriptions of probability and impact into a grid
(b) Applies a numerical scale to risk probability and impact
(c) Classifies risks when probability and impact are known and definite
(d) Supports Boolean analysis of risk data

21. In qualitative risk analysis, what can you do with the risks you identify?
(a) Avoid, transfer, or accept them
(b) Exploit, enhance, or share them
(c) Accept them or prepare a contingent response
(d) Accept, transfer, or do something about the risk

22. A risk management plan should be prepared:
(a) only after important project milestones have been missed.
(b) as an integral part of any well-prepared project management plan.
(c) as part of a postmortem project review.
(d) after serious organizational consequences have been incurred.

23. One strategy for approaching risks that are very low in probability but potentially catastrophic in outcome is:
(a) decision-tree analysis.
(b) cost-benefit analysis.
(c) Monte Carlo simulation.
(d) multi-stage solution.

24. Business risk differs from pure risk in what way?
(a) Business risk is about the potential for loss.
(b) To manage a business risk, you can purchase insurance.
(c) Business risk combines the possibility of positive and negative outcomes in the same decision or event.
(d) Business risk is upside risk.

25. In risk management, a cause-and effect diagram allows you to:

(a) find better solutions to specific risks.
(b) find the critical path in a project network diagram.
(c) brainstorm root causes of risk in a structured fashion.
(d) filter risks during qualitative risk analysis.

1

Introduction to Project Risk and Cost Analysis

Learning Objectives

By the end of this chapter, you will be able to:

- Define the terms risk and risk management, upside and downside risk, pure and business risk.
- Describe the fundamental formula for pricing a risk.
- Identify the two ways to manage pure risk and the four ways to manage business risk.
- List the five steps in the project risk management process.
- Explain why it is necessary to update a risk management plan throughout the project lifecycle.
- Identify the three categories of risk management costs and provide examples of each.

Estimated timing for this chapter:

Reading	40 minutes
Exercises	1 hour 30 minutes
Review Questions	10 minutes
Total Time	2 hours 20 minutes

Fundamental Concepts of Risk and Risk Management

We often don't—and can't—be sure what's actually going to happen. There is often more than one possibility. Depending on the likelihood and potential impact of these possibilities, some strategies increase your chances of good results. Understanding the potential environment and making choices are the essence of managing risk.

The goal of risk management is not to predict the future. The goal of risk management is to make decisions in the present. Risk and risk management are widely misunderstood, so it's important to establish some fundamental concepts about the topic. In this section, we'll identify and define common terms in project risk and cost analysis to provide a common basis going forward.

Risk Defined

There are a number of common definitions of *risk*:

- *Merriam-Webster Dictionary:* Possibility of loss or injury; a person or thing that is a specified hazard to an insurer.
- *Princeton WordNet:* a source of danger; a possibility of incurring loss or misfortune.
- *Wikipedia:* The deviation of one or more results of one or more future events from their expected value; the value may be positive or negative.
- *Dictionary.com:* Exposure to the chance of injury or loss; a hazard or dangerous chance.
- *PMBOK® Guide:* Risk is an uncertain event or condition that, if it occurs, has an effect on at least one project objective.

Most definitions of risk focus on the possibility of adverse events: loss, injury, or hazard. But risk-taking often has a positive connotation. Famed management theorist Peter Drucker argues, "To take risks is the essence of economic activity." (Drucker, 125) successful risk-takers are often praised and lauded. If indeed risk is only about the negative, such praise is hard to understand.

Both the *PMBOK Guide* and Wikipedia acknowledge the more complicated truth: while risk certainly includes the possibility of adverse effects, it can also include the possibility of positive effects as well. Some 80% of businesses fail within five years, but the leaders of the remaining 20% may become very rich indeed.

What all the definitions agree upon, however, is that risk is about the uncertainty of future events. There is always a possibility that things can go wrong, but there is also a possibility of potential gain. Problems are in the here-and-now; the risks with which we are concerned may—or may not—occur.

The *PMBOK Guide* definition of risk limits the discussion to potential events that might affect project objectives. However, there is also the possibility of collateral damage (or benefit). For example, a project may successfully dispose of hazardous waste in a way that achieves its internal objectives and benefits the company, yet negative effects may land on the shoulders of other people.

Conversely, a project that is a failure on its own terms may provide secondary benefits. In 1968, 3M research scientist Dr. Spence Silver invented an unusual adhesive that did not stick very strongly. It was useless and the project was abandoned. It was not until 1974 that another 3M researcher, art Fry, had problems with bookmarks falling out of his hymnbook, and thought of the long-abandoned weak adhesive. The result, of course, was Post-It® notes.

For the purposes of our discussion, we'll modify the *PMBOK Guide* definition slightly: Risk is an uncertain event or condition that if it occurs will have a significant impact, whether negative (*downside risk*) or positive (*upside risk*). Our definition is agnostic as to whether the risk must affect a project objective or something outside the official boundary of the project.

This implies two conditions: the uncertainty and the effect. Uncertainty is measured as a likelihood or probability of the event. Sometimes our knowledge of the probability is quite accurate; other times we have very little idea whether the event is likely to happen or not. Sometimes we know the effect; at other times the effect is itself uncertain. The effect of a car accident covers quite a range, from the trivial to the catastrophic. By comparison, a problem, because it's something that has already happened, only contains an effect.

The Value of a Risk

The fundamental formula for pricing a risk is to multiply its probability of occurrence by the cost if it should occur, expressed as:

$$\text{Risk} = \text{Probability} \times \text{Impact}$$

If there is one chance in ten that a risk event will cause you to lose $1,000, we say the value of the risk is 10% × $1,000, or $100. That implies that if you can avoid the risk at a cost of less than $100, there's a presumption that this would be a good investment.

There's more to a risk decision than that, of course. For example, what if the cost of getting rid of the risk is $101? should you pay the extra $1? What else could you do with that $100 if you chose to accept the risk instead? are you really sure that those numbers are accurate in the first place? What about the upside risk? If there's a 90% chance you'll make $2,000, a 10% chance of losing $1,000 may be a completely reasonable risk to take.

The base value of the risk isn't necessarily the final value of the risk, because not all considerations lend themselves to being expressed in financial terms. However, the financial basis of any risk is certainly information worth knowing, and often influences the appropriate decision.

Types of Risk

Downside risk, as we've established, is the likelihood of a negative outcome from an uncertain event or condition, and upside risk is the likelihood of a positive outcome.

- *Pure risk* (also known as *insurable risk*) is a risk situation that only has a negative outcome. If the negative outcome doesn't happen, you don't receive a benefit, but only avoid a loss. The possibility of your being in a car accident, for example, is a pure risk. If it doesn't happen, your life continues the way it was; the best you can do is avoid the downside.
- *Business risk*, on the other hand, combines the possibility of positive and negative outcome in the same decision or event. If you buy stock, for example, there's a possibility that the stock will increase in value, and a possibility that the stock will decrease in value.

Theoretically, there are also risks that are pure upside, with no cost or effort that needs to be invested to achieve the result, and no negative consequence (*status quo*) for failing to achieve them. These are normally considered outside the sphere of risk management thinking because there's no real decision that must be made: they are the essence of "no-brainer."

There are two basic ways to change the value of a risk: you can change the likelihood that it will happen, or you can change the impact or consequences if it does happen. To make it less likely that you'll be in an accident, you can drive safely. Obeying the speed limit, being sober, paying attention, and keeping both hands on the wheel lower the chance of being in an accident. To make it less expensive to be in an accident, you can buy car insurance. (The total financial effect of an accident isn't actually changed by the act of buying insurance. What changes is who signs the check.)

Pure risks have a cost if they occur, and there is normally a cost associated with reducing or eliminating them: there's a cost of being in a car accident and there's a cost associated with buying insurance. The *risk mitigation cost* is what you would need to spend (including the effort involved in improving your driving skill) to reduce the risk to an acceptable level. When you make decisions about risks, you are comparing the risk mitigation cost to the cost of simply accepting the risk—doing nothing about it unless the risk should actually occur.

In managing business risk, you have to consider the costs and benefits of both the upside and downside possibilities. To improve your outcome as a stock market investor, you can improve the potential outcome of your investments *four* ways:

- *Reduce likelihood of negative outcomes.* Pick safer stocks.
- *Reduce impact of negative outcomes.* Invest smaller amounts.
- *Increase likelihood of positive outcomes.* Pick stocks with the possibility of large gains.
- *Increase impact of positive outcomes.* Invest greater sums of money.

It will be obvious that any of these strategies taken to excess is inappropriate. Picking safer stocks and investing smaller amounts reduces the chance of positive outcomes as well as negative ones. Stocks with the potential of big gains often have uncertainty associated with them (or else the price would already have gone up), so larger investments increase the potential impact of losses.

Balancing upside and downside risk has elements of both art and science. As you can see, risk plays an important consideration in virtually every aspect of business and life. Indeed, virtually every conceivable management activity involves developing and executing risk management strategies. As Drucker continues, "While it is futile to try to eliminate risk, and questionable to try to minimize it, it is essential that the risks being taken must be the right risks." (Drucker, 125)

Of course, figuring out which are the "right" risks and what to do about them isn't so easy. Fortunately, there is the discipline of risk management. From its origins in the financial and insurance world, the art and science of identifying, analyzing, responding to, and acting on risk has developed into a robust and comprehensive set of constantly evolving tools and techniques.

Exercise 1-1
Managing Important Risks

We all practice risk management on a daily basis, whether we're aware of it or not. In this exercise, you will identify important risks you are currently managing. For commentary on the exercise and your answers, see Answers to Exercises and Case Studies at the end of the course.

Risk	Likelihood	Impact	Seriousness	What Am I Doing About It?
CAREER. Identify a risk involving your professional life. Example: There is a chance we'll have layoffs this year?	*Unknown; depends on how the market accepts our new product and whether a failure is blamed on design.*	*In the current market, it normally takes 3-6 months to find a job; this would put a substantial dent in savings.*	*Could be very serious. If the product fails, and design is blamed, this could not only increase layoff risk but damage my professional reputation long term.*	*Waiting and watching for now. Updated my résumé and am keeping an eye on job boards. Will evaluate in two months.*
YOUR CAREER.				
PHYSICAL HAZARD. Identify a physical hazard risk you experience every day. *Example: I could be in an automobile accident.*	*Not likely to happen.*	*Range of outcomes, from trivial to potentially catastrophic.*	*Low probability, but potentially catastrophic impact is a risk that requires attention.*	*I have car insurance (which also eliminates risk of being fined for violating the law); I try to drive safely.*
YOUR PHYSICAL HAZARD.				
OPPORTUNITY. Identify a risk that has a potential	*The product idea is controversial and market acceptance is not*	*If the company is successful, the financial upside could be*	*This is a high-risk situation. Both the upside risk and downside*	*I decided how much I could afford to lose and limited my*

upside. Describe both upside and downside. *Example: I have the opportunity to invest in this hot new company.*	*assured, but some analysts think highly of the idea. Odds of success no better than 50-50.*	*tremendous. If it fails, I'll lose most, if not all, of my investment.*	*risk have serious potential consequences. I do have a range of potential investments I can make.*	*investment.*
YOUR OPPORTUNITY.				
ACCEPTANCE. Identify a risk you smartly choose to do little or nothing about and explain why. *Example: I could win millions by playing Lotto.*	*Odds are millions to one against this happening.*	*Potential positive impact is extremely high; cost of losing is relatively low.*	*While the upside would indeed be pleasant, the probability is absurdly low, and the act of playing isn't intrinsically fun for me.*	*Response: I don't buy Lotto tickets…but if someone gives me one as a present, I will scratch off the numbers.*
YOUR ACCEPTANCE.				
SURRENDER. Identify a risk you know you should act on but don't and explain why. *Example: I could lose 20 pounds.*	*Many people attempt to lose weight and fail; success is not of high probability.*	*Potential impact is extremely high.*	*The arguments for losing some weight are very strong, but it's difficult to succeed and the actions involved (dieting, exercise) aren't pleasant to me. As a result, I haven't tried very hard.*	*Realistically, I don't expect to do anything differently right now, but I keep thinking about it and my doctor keeps reminding me. In the meantime, I try not to gain any more weight.*
YOUR SURRENDER.				

Risk Management Defined

As the name implies, *risk management* is the process of managing the risks in your environment. It can be formal or informal; it can be done well or poorly; it can use rigorous methodology or the notorious Wildly-aimed Guess (WAG) approach; you can act or you can fail to act.

Some disciplines inherently use more formal risk management techniques than others. Safety practices in engineering, quantitative risk analysis in finance, and quality control in business processes all involve the application of formal risk management tools. But risk management doesn't always have to be rigorous and mathematical to be effective. Managing risks in, say, a sales office is likely to be a more informal process, but that doesn't mean the resulting risk management is necessarily ineffective.

In the world of project management, risk management is an activity that parallels the other project processes. Because a project is a "temporary endeavor undertaken to create a unique product, service, or result," (*PMBOK Guide*, 1.2) it cannot possibly be devoid of risk: uncertainty is implicit in the definition. In the PMBOK model, the core risk management activities begin in the planning process, resulting in the development of a risk management plan. These activities are:

1. *Identify* the risks (risk identification)
2. *Study* the risks to understand their nature, probability, and impact (quantitative and qualitative risk analysis)
3. *Decide* what, if anything, is to be done about specific risks (risk response planning)
4. *Integrate* risk management decisions and actions into the project plan (risk management planning)

As the project gets underway, *risk monitoring and control* parallels project execution and other project monitoring and control activities. As the wave front of actual project knowledge moves forward in time, the risks of the project naturally evolve. There comes a point where a given risk can no longer happen: if the prototype passed its test, the risk that it might fail to do no longer exists.

On the other hand, if a risk occurs—thereby changing into a problem or opportunity—it may also trigger a domino effect on other risks, changing both their probabilities and impacts as well as your intended strategy. That means once is not enough when it comes to a risk management plan. Your initial plan needs constant review and updating as the risk profile of the project changes.

We suggest you keep a companion file to this course. Use it to hold your notes and any documents or forms from the text that will be helpful as you work through the chapters. Please access www.amaselfstudy.org/go/Project Risk for a list of documents that can be downloaded.

Exercise 1-2
Your Current Risk Management Process

In this exercise, your goal is to describe the risk management process that currently exists with respect to the projects for which you are responsible, either as a manager or a participant.

1. Does your organization or department have a formal requirement for risk management planning on projects? Yes____ No____
2. Describe the formal requirement if one exists. Specify whether all projects are included, or whether there is a minimum project size for the requirement. If there's a written standard, add that to the companion file of notes and documents you will keep with this self-study course.

____

____

____

____

____

3. If there is no formal risk management policy or process (or if it's not well followed in practice), how are risks currently managed on your projects?

4. What works well about the way risks are currently managed on your projects?

5. In what ways could your project risk management be improved?

Cost Analysis and Risk Management Planning

The actual cost of the project, as we all know, is not always or necessarily the cost originally planned or intended. Whether particular risks occur or don't occur has a dramatic effect on the cost. And, as you've seen, responding to risk also has costs.

We've described the basic formula for valuing a risk. The cost of responding to risk falls into three basic categories:

- *Risk management infrastructure*. The cost of developing policies and programs, training people in their use, recording and tracking risk data, improving risk management performance. These costs are usually not charged directly to your project except as company overhead.

- *Project risk management*. The portion of project resources spent on identifying, analyzing, strategizing, and tracking risks; developing risk plans and reports; developing risk metrics.
- *Specific risk mitigation costs*. The costs associated with responding to individual risks.

Straightforward cost analysis is easier to perform when numbers are known and stable. How much you spent last year is a matter of record; what you will spend next year is subject to change. The cost of responding to risk involves actual expenditures. The value of the unmanaged risk, however, is best expressed as a range of probabilities. You don't *know* what will actually happen. And yet it's often incumbent upon you to come up with numbers that have some reasonable basis in reality.

As noted earlier, financial and statistical analysis is not necessarily the sole or always even the primary basis on which a given decision is made. That is not to say the numbers are ever inconsequential or irrelevant. Importantly, numbers change over time, hinting at trends or outcomes that may help you respond early when plans need adjusting. Risk management needs to be an ongoing process throughout the entire project life cycle.

Exercise 1-3

What You Spend on Risk Management

In this exercise, you will develop a rough estimate of how much of your project budget currently goes toward risk management activities.

RISK MANAGEMENT INFRASTRUCTURE

Case	Estimated Cost	Charged to Your Project?
Example: Training course in risk management with outside vendor	*$1000/participant for two-day workshop; 300 people trained*	*No*
TOTAL COST	*Value of your project as a percent of company revenue*	*Total cost × % project value = Amount attributable to your project*

PROJECT RISK MANAGEMENT COSTS

Case	Estimated Cost	Identified as Risk Management expense?
Example: Write and develop a risk management plan	*3 meetings attended by 5 people, average length 90 minutes, plus 15 hours writing time, at roughly $200/hour = $7500*	*No; considered part of general planning budget*

TOTAL COST		*AMOUNT IDENTIFIED AS RISK MANAGEMENT*

SPECIFIC RISK MITIGATION COSTS

Risk Being Mitigated	**Estimated Cost**	**Identified as Risk Management Expense?**
Example: Risk that the DigiWigit® prototype will be damaged in transit	*Need to fabricate special insulated shipping case to ensure prototype is protected; cost $15,000*	*No; shipping container cost built into original price and charged to customer*
TOTAL COST		*AMOUNT IDENTIFIED AS RISK MANAGEMENT*

TOTAL INVESTMENT IN RISK MANAGEMENT

Infrastructure costs attributable to your project	$/£/€/¥
Project risk management costs	$/£/€/¥
Specific risk mitigation costs	$/£/€/¥
TOTAL	$/£/€/¥
Less costs charged officially to risk management	$/£/€/¥
Costs not listed as risk management	$/£/€/¥

recap

Risk is an uncertain event or condition that if it occurs will have a significant impact, whether negative (downside risk) or positive (upside risk). Risks may affect project objectives, or they may have an impact that falls outside the official boundary of the project.

The fundamental formula for pricing a risk is to multiply its probability of occurrence by the cost if it should occur, expressed as:

$$\text{Risk} = \text{Probability} \times \text{Impact}$$

If the cost of dealing with the risk is significantly less than the price of the risk, there is a strong business case for action. If the cost is higher, action may still be appropriate, but additional justification is normally required.

In the real world, exact information on probability and impact is not always available or accurate. Factors other than financial analysis may enter into the decision. Still, the basic price of a risk is important information to support decision-making.

Downside risk is the likelihood of a negative outcome from an uncertain event or condition, and *upside risk* is the likelihood of a positive outcome.

Pure risk (also known as *insurable risk*) is a risk situation that only has a negative outcome. *Business risk* combines the possibility of positive and negative outcome in the same decision.

The two basic ways to change the value of a risk are to change the likelihood it will happen, or to chance the impact or consequences if it does happen. There is often a cost associated with changing a risk, so decision-makers must always consider those costs in comparison to the value of the risk. Not all risks require—or warrant—action.

When you consider a business risk, you must consider probability and impact of both the upside and downside elements in order to reach a balanced decision. Sometimes it may be wise to accept an increased risk of loss in exchange for a substantially increased risk of gain.

Risk management is the process of managing the risks in your environment, whether it is done as a formal, systematic process or not. Different disciplines, such as engineering, finance, and project management, have their own specific tools and approaches to risk management.

In project management, risk management is an activity that parallels the other project processes. Because a project is a "temporary endeavor undertaken to create a unique product, service, or result," (*PMBOK Guide*, 1.2), uncertainty and risk are always present.

In the PMBOK model, the core risk management activities begin in the planning process, resulting in the development of a risk management plan. These activities are:

1. *Identify* the risks (risk identification).
2. *Study* the risks to understand their nature, probability, and impact (qualitative and quantitative risk analysis).
3. *Decide* what, if anything, is to be done about specific risks (risk response planning).

4. *Integrate* risk management decisions and actions into the project plan (risk management planning).

5. *Risk monitoring and control* parallels project execution and other project monitoring and control activities. Risks change as the project moves forward in time, meaning that your initial plan needs constant review and updating as the risk profile of the project changes.

There are three basic categories of costs in dealing with risks:

- *Risk management infrastructure*. Organizational expenditures on risk management
- *Project risk management*. Costs of risk management processes on your project
- *Specific risk mitigation costs*. The costs associated with responding to individual risks

In risk management, you have strict limits on the knowledge available to you. Nevertheless, there are many tools that can help you manage and prosper even in the face of the unforeseen and unforeseeable.

Review Questions

INSTRUCTIONS: Here is the first set of review questions in this course. Answering the questions following each chapter will give you a chance to check your comprehension of the concepts as they are presented and will reinforce your understanding of them.

As you can see below, the answer to each numbered question is printed to the side of the question. Before beginning, you should conceal the answers by placing a sheet of paper over the answers as you work down the page. Then read and answer each question. Compare your answers with those given. For any questions you answer incorrectly, make an effort to understand why the answer given is the correct one. You may find it helpful to turn back to the appropriate section of the chapter and review the material of which you were unsure. At any rate, be sure you understand all the review questions before going on to the next chapter.

1. The cost of training staff members in risk management is an example of:
(a) specific risk mitigation cost.
(b) project risk management cost.
(c) risk management infrastructure cost.
(d) training in risk management cost.

1. (c)

2. For the purposes of risk management, risk is defined as:
(a) an uncertain event or condition that if it occurs will have a significant impact.
(b) a hazard or bad thing that might happen.
(c) a problem or situation you are currently experiencing.
(d) something that only affects the project on which you are working.

2. (a)

3. If there is a 20% chance of a price increase on a key project component that will increase your total cost by $10,000, the value of the risk is:
(a) $10,000
(b) $1,000
(c) $20,000
(d) $2,000

3. (d)

4. The activity of risk monitoring and control happens:
(a) during the project planning process.
(b) in parallel with project execution and other monitoring and control activities.
(c) throughout the project from initiation through closeout.
(d) at the weekly project status meeting.

4. (b)

5. Integrating risk management decisions and actions into the plan and other project management process is known as risk.

(a) response planning.

(b) management planning.

(c) analysis.

(d) identification.

5. (b)

2

Risk Identification

Learning Objectives

By the end of this chapter, you will be able to:

- Describe the process of risk identification on projects.
- Create and populate a risk register.
- Examine project requirements, goals, conditions, and circumstances to identify risks.
- Determine whether a particular risk belongs to the project or is being sufficiently managed elsewhere.
- Write a statement of risk in the "condition and consequence" format.
- Apply a variety of tools and techniques to systematically identify and reduce project risk, including document review, standard and negative brainstorming, cause-and-effect diagramming and SWOT analysis, and checklists.

Estimated timing for this chapter:

Reading	55 minutes
Exercises	1 hour 10 minutes
Review Questions	10 minutes
Total Time	2 hours 15 minutes

Identifying Risks

What, exactly, are you worried about?

Figuring that out is the process known as *risk identification*: listing the risks that give us potential concern. That includes business as well as pure risks, of course. We're concerned with downside risks because of the negative impact; we're concerned with upside risk because we'd really like to reap the benefits. We need to balance the level of risk and the level of response.

It's not always obvious at the outset how significant a given risk may turn out to be. In risk identification, the best choice is to err on the side of inclusion, not exclusion. The tools of risk analysis will help us winnow out the risks that justify response, but that's in subsequent steps. For now, the best strategy is to go for quantity over quality.

While the process of risk identification is normally described as something that takes place at the beginning of the project, that's not enough. Risks change as the project moves forward. Some risks drop off the radar while other grow in intensity. Risk identification, therefore, must be a continual activity, not merely a one-time action.

Risk Register

The number of risks on a project can grow quite large, and managing your risk information can pose challenges. Start by creating a *risk register*, a centralized place where you write down the risks you collect. This can be as simple as a spreadsheet, or in some cases, even as low-tech as a legal pad. At the high end, advanced risk management and monitoring systems can take many millions of dollars to develop and implement. If you're in the kind of business that warrants such an approach, you probably already have something in place, even if there's room for improvement.

The basic information you need to gather about a given risk is pretty much the same, however, whether you're dealing with one risk or thousands, or with one dollar or millions. Exhibit 2-1 illustrates a basic risk register format and identifies the fundamental information you need to gather about any given risk.

Risk ID

The risk identification number labels the risk. If you decide to number risks, make sure the number cannot be confused easily with other numbering systems at work on your project.

Description of Risk

A description of risk is often written as an "if–then" statement, containing the *condition* (the circumstances that would make the risk event occur) and the *consequence* (the description of the outcome should it occur).

- "If our competition releases its new product before ours is ready, the chance our product will dominate its market is reduced."
- "If we do not complete the documentation by January 21, we will have to pay a contract penalty of $37,000."

Category of Risk

Grouping risks together by common factors helps you manage them more easily. If there are numerous safety risks involved with the construction portion, safety would be a useful risk category. If there are risks involving interest rates and the stock market, financial risks would make another good category.

Some organizations establish standard risk categories; if your organization has such categories, you should use them. If all the projects in your functional area are close enough in subject matter and circumstances, you may wish to establish standard risk categories for those projects, even if your organization doesn't require it.

Where Found?

The systematic search for risk includes a list of places where risks might be found. For example, if there is a list of requirements, you would normally inspect the requirements for risks associated with them. Under "Where Found?" you would list "Requirements." If the plan contains a *Work Breakdown Structure* (WBS) listing all the tasks, you would normally look at the individual tasks for associated risks. Under "Where Found?" you would list "WBS."

Probability of Occurrence

Occasionally, you may have a specific number for this space based on a long history of actual data: "There is a 20% chance of component failure." More often, you can only provide a general indication —or your best guess. You might rate probability as "Low," "Medium," or "High," or on a 1-5 scale. This estimate is subject to revision as you look more closely at a given risk.

Nature and Degree of Impact

Here too, you may have a specific number ("This would cost us $15,000"), or you may only be able to provide a general description of the impact. ("It would embarrass us in the eyes of the customer and jeopardize repeat business"). Sometimes, you can only say "Low," "Medium," or "High." This information also tends to evolve as you look deeper.

For business risk, you must list both upside and downside values. "If the information from the preliminary engineering study is confirmed by these tests, per-unit manufacturing costs should drop by 40%. If the results are negative, per-unit manufacturing costs will remain at current levels."

Risk Rating

This is the answer to the equation $R = P \times I$. If you do not have numbers for probability and impact, the risk rating will also be imprecise: low, medium, or high. That's usually enough to get started.

Exhibit 2-1 Risk Register Categories

ID	Description of Risk	Category of Risk	Where Found?	Probability	Impact	Risk Rating	Disposition	Comments

Disposition

What do you do with the risk after you have analyzed it? Does it go on a "parking lot" with other minor risks that won't receive much attention? is it a major priority requiring significant effort and resources? Should you handle the risk yourself, or should another department or group (or the customer, for that matter) be the proper owner and manager of the risk? your choice of action goes here: the disposition of the risk.

Comments

If there is additional information necessary to the understanding of this risk, it goes here.

How to Identify Risks

A potential risk exists in every declarative statement about your project. "The deadline is February

15" contains the potential risk that you won't be done by February 15. Perhaps February 15 gives you plenty of time and the risk is quite low; perhaps February 15 gives you a wholly inadequate amount of time to get the work done and the risk of failure is high.

Then there's the cost of failure. Perhaps there's a $1,000,000 contract penalty if you're late; perhaps no one really cares as long as they get it by the end of the month. The risk is the likelihood you'll be late times the cost if you are. Inadequate time and big penalty = serious risk. Plenty of time and no penalty for missing the deadline = trivial risk.

Risks can be about deadlines, budgets, or performance goals: the risk of not being done on February 15; the risk of spending more than the budgetary estimate of $125,000; the risk that the product won't pass acceptance testing.

Risks can be about outside factors: the risk that customer requirements will change; the risk that interest rates will rise or fall; the risk that your competitors will beat you to market or vice versa.

Risks can be about the potential outcome of events: the risk that your prototype will fail its initial test; the risk that your proposed solution won't work as well as you hope; the risk that good safety practices can't prevent every conceivable accident.

The process of risk identification involves looking for the risk events and situations of potential concern. Exhibit 2-2 lists questions to ask as you look at the details of your project environment.

You don't have to write down everything in this level of detail. We are doing so here so that the thought process is made explicit. The only things you need to write down are the risks that you decide are serious enough to warrant further study—and the place to write those risks is on the risk register.

Exhibits 2-3, 2-4, and 2-5 provide examples of the risk identification process. Following those three exhibits, Exercise 2-1 provides you with a practice opportunity to do it yourself.

Exhibit 2-2 Questioning Risks

Question	Answer
What is being asked of us? What force or circumstance could affect us?	Write this as a description of what would occur if you were guaranteed the desired outcome, or a statement of how reality will look if it goes the way you prefer. *Desired outcome*: If you're being asked to meet a budget of $125,000, then write "Keep costs within total budget of $125,000." *Circumstance*: If the profitability or benefit of the project will change dramatically if the prime rate changes, write what you want to happen. "Prime rate will stay under 4.25%."
Is this difficult, problematic, or uncertain?	Desired outcomes and circumstance only contain risks if there's a chance they won't happen the way you prefer. If $125,000 is ample, then you expect no unusual difficulties in meeting it: low or no risk. If $125,000 is tight, then the risk rises. If interest rates appear stable and the project is short term, the risk of a sudden jump is low. If the time horizon stretches out over years, the risk tends to rise. Sometimes this is scenario-based. If your ability to meet the $125,000 cost figure is dependent on using a supplier able to meet your specific needs, and the supplier is financially shaky, the risk of not meeting the budget is a function of the financial health of the supplier. The risk in this case is focused on a specific scenario.
What are the consequences of failure?	Define the likely downside if the risk should occur. A supplier going bankrupt might affect the prices you pay—or it might affect your ability to buy the components at all. The latter could be a more serious risk than the former. If interest rates spike suddenly and unexpectedly, both your project and your customers might be affected.

Are there any circumstances or conditions that would result in failure?	Looking for early warning signs and triggers is often one of the more valuable results of risk management. In some cases, you have direct control over whether a risk occurs; in other cases, the best you can do is achieve an earlier warning.
Are there any opportunities to do this work better, faster, or cheaper, or to gain additional benefit from the work?	Look for upside opportunity as well as downside threat when you look for risks. If your key supplier is financially weak, you might look at acquiring it yourself, or working to develop alternate sources of supply in advance of need. If interest rates spike, your competition is also likely to be affected, as are your customers. There may be an opportunity for gain if everyone's in the same boat.
Are these risks being managed elsewhere?	Some risks are real, but not necessarily your problem. There's a risk someone might get hurt on the plant floor, but there's usually a set of safety policies and procedures already in place. Unless what you're doing adds unusual amounts of risk to the normal routine, there may be nothing to do specifically on your project. Other risks are outside your authority even if you're the project manager. If a project contains potential for litigation, it's usually not the engineering department that manages this area of risk—even if they are project managers for the project as whole.
Should we add any of these risks to our project risk identification list?	Sometimes the answer to this is no. Not every task or requirement contains risks demanding of your attention. Some risks are so minor and remote they don't deserve further attention. With luck, large amounts of your project fall into this category.
Conclusion	If you decide there is no risk to manage here, then you're done. If there is a risk, what's your first impression of the probability and the impact? It's okay if that's a guess for now.
Statement of Risk	You may find multiple risks in a given situation. For each risk, go to the risk register and write the risk in the "condition and consequence" format. Add your initial estimates of probability and impact.

Exhibit 2-3 Sample Risk from a Requirements Document

Question	Answer
What is being asked of us? What force or circumstance could affect us?	Requirement: Parts must be machined to a tolerance of ±1/32".
Is this difficult, problematic, or uncertain?	No. The machinery we use is capable of machining to much smaller tolerances, as low as ±1/128". We have trained operators who have done this hundreds of times. The schedule provides sufficient time for the job.
What are the consequences of failure?	Parts outside tolerance may result in more mechanical failures in use. The consequence to the customer of failure is loss of capacity, which can be measured in money. Safety risk (harm to people) as a result of a mechanical failure is not an issue in this case.
Are there any circumstances or conditions that would result in failure?	Yes. If the schedule is too aggressive, the rate of error tends to increase. Here, the schedule does not appear to be aggressive. Failure to maintain and properly operate the machinery would also result in problems. However, we do have a maintenance program. Even trained operators with good equipment can make mistakes. That's why we have a quality control procedure to verify that parts are within tolerance before they get assembled into the final product.

Are there any opportunities to do this work better, faster, or cheaper, or to gain additional benefit from the work?	Doing quality work on time and budget is one of the competitive strengths of this company; we should be able to reinforce and add to that reputation. There is new machinery available that could potentially improve what we do, but it's not cost-effective to buy it for this project alone. Management is currently reviewing whether it makes sense for the company as a whole.
Are these risks being managed elsewhere?	Yes. Plant maintenance and quality control processes already exist and appear sufficient to the potential risk.
Should we add any of these risks to our project risk identification list?	No. They are being managed elsewhere.
Conclusion	No project level risks.
Statement of Risk	N/A

Exhibit 2-4 Sample Risk from a Project Charter or Statement of Work

Question	Answer
What is being asked of us? What force or circumstance could affect us?	*Goal:* Produce 25,000 widgets and ship them to the customer no later than the end of next month.
Is this difficult, problematic, or uncertain?	There is some potential uncertainty. The 25,000 number itself is not too much for the capacity of the plant. We do, however, experience occasional overload with multiple jobs that can severely disrupt delivery dates.
What are the consequences of failure?	Damage to reputation; effect on future business from this customer, in rare cases, claims for damages.
Are there any circumstances or conditions that would result in failure?	Uncertainty in scheduling sometimes means capacity is strained more than usual. The priority of other work may be higher than the priority of our own. Equipment breakdowns sometimes happen even with excellent maintenance.
Are there any opportunities to do this work better, faster, or cheaper, or to gain additional benefit from the work?	Our existing initiative to improve shop floor scheduling has the potential to improve performance in time and cost. By supporting it, we make all the projects a little better.
Are these risks being managed elsewhere?	Partially. There is a plant scheduling function that has primary jurisdiction over this part of our project. However, we are still responsible for getting the product to the customer on time, and plant scheduling problems won't excuse our failure to do so.
Should we add any of these risks to our project risk identification list?	Yes. While scheduling problems don't occur often, they can result in serious problems when they do. It's our responsibility to make sure we get things done.
Conclusion	Low Probability/High Impact Risk
Statement of Risk	If too many other projects schedule manufacturing time to coincide with ours, the plant production schedule may not be able to support our deadline.

Exhibit 2-5

Sample Risk from a Work Breakdown Structure (WBS) Work Package

Question	Answer
What is being asked of us? What force or circumstance could affect us?	*Work Package:* Manuals *Description of work:* Prepare online searchable product manuals for operation of the product and for maintenance and repair of the product.
Is this difficult, problematic, or uncertain?	Problematic. It isn't inherently difficult to do, but it's often done under difficult conditions. It often can't start until late in the project cycle because the needed information is not yet available or is subject to change. Engineers and other technical experts may have other things to do than provide support and documentation to tech writers.
What are the consequences of failure?	There are two kinds of failure: being late and being wrong. The consequences of being as much as six weeks late with the manuals are minor, because we have warranty responsibility for repair work during that period anyway. The consequences of being wrong are potentially more serious, and can expose the company to significant financial risks.
Are there any circumstances or conditions that would result in failure?	If we put emphasis on schedule rather than emphasis on quality, the potential damage will be worse than if it's the other way around.
Are there any opportunities to do this work better, faster, or cheaper, or to gain additional benefit from the work?	The Q-38 design is based on the Q-37 design, so there's a good chance that parts of the Q-37 manual can be used as an outline and rough first draft for the Q-38 design. This has the potential to improve quality while at the same time speeding schedule and lowering cost. Similarly, the archive of tech manuals that we are building makes it easier to do each new one. The output of this project will add one more to the growing database.
Are these risks being managed elsewhere?	No. All the risks involved with the manuals belong to this project.
Should we add any of these risks to our project risk identification list?	Yes. We can accept the risk that we might be as much as six weeks late with the manual, but no more than that. We can't accept the risk that there will be material errors in the manual.
Conclusion	Multiple risks; both Low Probability/Medium Impact (second risk has higher impact than the first)
Statement of Risk	There are two risks here. Both have direct consequences to the customer, and indirect consequences for us (need to provide additional services or compensation; damage to reputation and customer relationships). 1) If the manual is more than six weeks late, the customer will not be able to take over maintenance and repair of the equipment at the end of our warranty period. 2) If the manual contains errors, the customer may not be able to maintain and repair the equipment correctly and in extreme cases, could suffer significant losses as a result of our errors.

Exercise 2-1 Risk Identification Practice

For this exercise, your project is to conduct an end-of-year inventory in a large warehouse. The warehouse will be closed for shipping for a three-day period, and must be able to resume operations on the fourth day. Your project team consists of three warehouse workers and two people from the supply department. There are approximately 10,000 items in the inventory.

Question	First Exercise	Second Exercise	Third Exercise
What is being asked of us? What force or circumstance could affect us?	Goal: Inventory 10,000 items in 3 days.	Assumption: No items will be received or shipped from the warehouse during the inventory period.	Resources: You have five people (in addition to you) to accomplish the project.
Is this difficult, problematic, or uncertain?			
What are the consequences of failure?			
Are there any circumstances or conditions that would result in failure?			
Are there any opportunities to do this work better, faster, or cheaper, or to gain additional benefit from the work?			
Are these risks being managed elsewhere?			
Should we add any of these risks to our project risk identification list?			
Conclusion			
Statement of Risk			

Systematic Risk Identification

There are many tools to help you root out risk wherever it may be hiding. Approach risk identification in a systematic manner. Make a list of the places you will look and the tools you will use to ensure you've done a comprehensive job.

Find risks by examining project documentation; brainstorming, analyzing and deconstructing project elements; and using formal risk management tools.

Documentation

A project or operation tends to produce a lot of paper (or its electronic equivalent). There are contracts, instructions, requirements, project charters, plans, standards, policies, and much more. Many items in all this documentation involve risk, so the first place to start in identifying the risks in your environment is with a thorough and systematic document review. Start by identifying and collecting the documentation available.

Exhibit 2-6 lists common types of project documentation. There's some extra space provided so you can write down which of these sources apply to your situation. The amount of information and documentation tends to increase over time, so this step needs to continue as you move through the project life cycle.

Brainstorming

Both structured and unstructured brainstorming sessions uncover project risks. A simple unstructured brainstorming session is as simple as gathering parties together and saying "Let's brainstorm the risks." The purpose of risk identification—looking at all risks—matches well with the fundamental brainstorming rule of welcoming all ideas and withholding criticism.

Standard Brainstorming Techniques

Aside from the subject matter, there's nothing particularly different about brainstorming risks as opposed to brainstorming anything else. Exhibit 2-7 lists standard rules common to all brainstorming sessions.

After a brainstorming session, there's usually a process to winnow out the valuable ideas. The output—couched as statements of risk—is added to the risk register.

Negative Brainstorming

There are many different ways to brainstorm, and we've had good results with multiple techniques. One specific brainstorming technique has particular value when the topic is risk: *negative brainstorming* (Dobson and leemann, 111)—the focus on why things won't work or will go wrong. Exhibit 2-8 describes the process.

As with all brainstorming, welcome all ideas and withhold criticism until the session is over. The purpose of risk identification is to make sure all potential risks are considered, so err on the side of inclusion.

Exhibit 2-6 Common Types of Documentation for Risk Identification

Category	Description	Examples	What You Have
Charter	The documents that establish the project in the first place. If a project charter is done according to PMBOK standards, it will contain lists of constraints (factors that limit your potential actions as a project manager, such as a budget or a deadline) and assumptions (factors you assume to be true without evidence, such as the idea that something you haven't done before is in fact technically feasible, or that it will satisfy the underlying customer need). Both constraints and assumptions carry risk.	Contract, instructions from customer or boss, formal project charter, statement of work	
Codes	Includes rules, regulations, and procedures that must be followed, whether required by law or required by organizational policy.	Building codes, safety codes, OSHA requirements, privacy laws, generally accepted accounting practices (GAAP), certifications, licenses	
Require-ments	A requirement describes some element of what a particular product or service should be or how it should perform.	Preliminary and final requirements documents, requirements for certifications and approvals, functional analysis, change orders	
Planning	The process of planning work normally produces documentation.	Work Breakdown Structure (WBS), Gantt chart, network diagram, cost estimates, budgets, reporting requirements, approvals, resource assignment matrices (RAM)	
Analysis	Products of studies and investigations	Systems engineering analysis, systems analysis, error reporting, test results, financial stress testing, trend data, surveys, statistical studies	
Historic	Information gathered from previous projects and operations	Lessons learned, industry case studies, track record on similar projects, experience with specific processes and tools, checklists	

Exhibit 2-7 Brainstorming Rules

1. Define the problem.
2. Select participants.

3. Set ground rules.
4. Define the brainstorming question or goal.
5. Welcome all ideas.
6. Focus on quantity, not quality.
7. Withhold criticism.

Diagramming Techniques

Risk identification borrows tools from other management disciplines as well. Two often-used tools are the cause-and-effect diagram and SWOT analysis.

Exhibit 2-9 shows a *cause-and-effect diagram*, also known as an Ishikawa diagram or fishbone diagram. The cause-and-effect diagram is a structured way to brainstorm root causes of risk by focusing on all the areas where the risk might live. To use this diagram the brainstorm team should address a potential problem area, then look for the ways each of the categories might contribute to the problem.

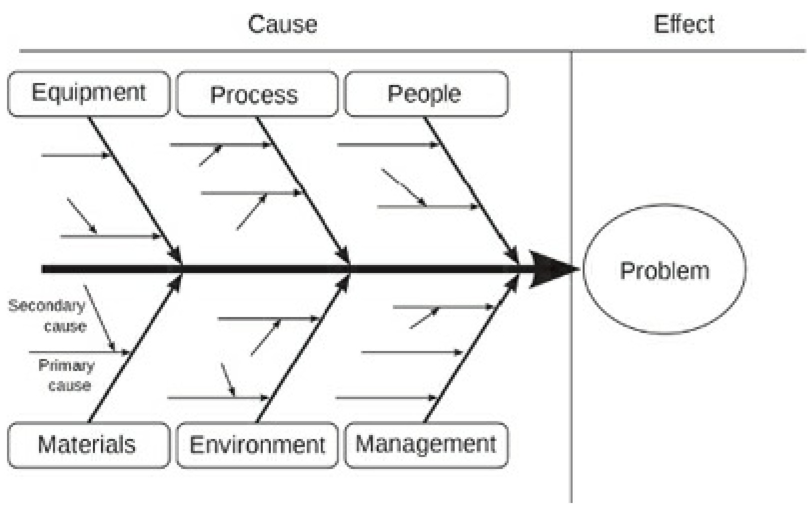
Exhibit 2-8 Negative Brainstorming

The goal of negative brainstorming is to identify areas of downside risk and vulnerability in your project environment so that you can decide how to address these areas. (Regular brainstorming does a fine job on upside risk and opportunity.)

1. Follow the normal brainstorming process from Exhibit 2-7 except as noted.
2. For the brainstorming question, select a negative question, one that focuses on failure and bad luck.
    - Why is this project impossible?
    - What can't we do?
    - How will other people and circumstances keep us from succeeding?
    - What ideas are absolutely not worth trying?
    - What's the worst possible decision or action we could take right now?
    - What could turn this into a complete catastrophe?
    - Why are we already doomed to fail?
3. Strive for a maximum number of answers. Do not provide happy thoughts, corrective actions, or solutions.
4. When the negative brainstorming session is over, discuss which risks need to be added to the risk register, which risks are unimportant, and which risks are easily solved or dealt with by

existing systems.

Exhibit 2-9 Cause-and Effect Diagram



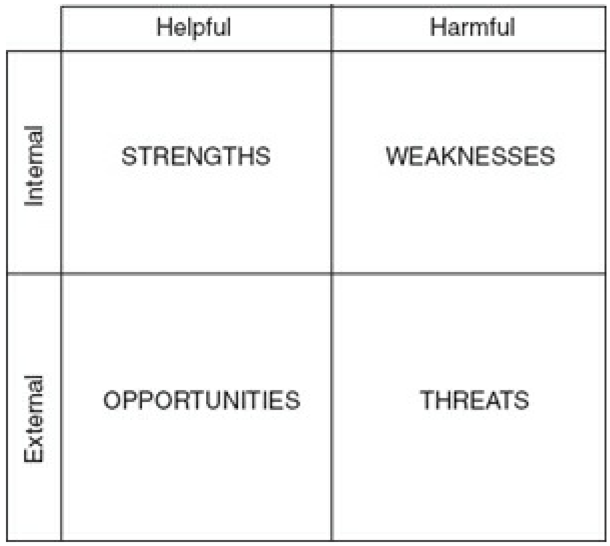
Credit: Fabian Lange

A format for a *SWOT analysis* is shown in Exercise 2-2. In a SWOT analysis, the group brainstorms a particular area of the project, looking at four different characteristics: strengths, weaknesses, opportunities, and threats. Strengths and opportunities are beneficial to the project; they help achieve the objective or make it better. Weaknesses and threats are harmful to the objective; they make it less likely that you will achieve it or that you will achieve less.

Strengths and weaknesses are *internal* to the project; that is, they are characteristics of the organization and the people in it. Opportunities and threats are *external* to the project; that is, they are part of the environment.

Exercise 2-2 SWOT Analysis

Continuing with the inventory project from Exercise 2-1, prepare a SWOT analysis for the project.



Checklists

Before an airplane takes off, the pilot typically uses a checklist to make sure nothing has been overlooked. A checklist isn't ever exhaustive, of course, but it guards against common errors and provides early warning of certain risks. If you do the same kind of project over and over again, checklists are useful tools for risk management. A good checklist not only identifies risk but also reduces it at the same time. "Landing gear handle down" addresses the risk that the landing gear handle might be in the wrong position for takeoff.

While checklists don't substitute for comprehensive risk management, they are a significant aid to compensating for inattention or memory lapses—something almost all of us have been guilty of at one time or another.

Expert Judgment

If you and the project team have little experience in a particular risk area, it's a very good idea to experts who can advise you about risks and responses. The two concerns, of course, are whether the person being consulted is in fact an expert, and whether the expert has a bias you need to take into account.

Output from Risk Identification Process

The output of risk identification is simply the risk register—a list of the risks you've identified. Of course, you're not nearly done. Risk identification is only the first step in a good risk management process. Many of the risks you identify need further analysis to determine how serious they are. Some risks you'll end up choosing to accept, and others will need a comprehensive response. In between identifying the risks and deciding what (if anything) to do about them comes the stage known as *risk analysis*, the subject of the next several chapters.

Remember that risk management continues throughout the life of the project. No matter how well your initial risk identification process goes, the nature of the project always evolves over time.

Continue to add items to the risk register as you discover them, and follow through the rest of the process steps with these new risks as well.

recap

Risk identification, as the name suggests, is the process of identifying potential risks that may require some action on our part. Risk identification includes both business risks and pure risks. Because it's not always obvious from the outset how serious a potential risk is, risk identification tries to err on the side of inclusion. If you're not sure whether it's a risk, write it down.

Start by creating a *risk register*, a centralized place where you write down the risks you collect. A risk register contains a description of the risk, the category in which it belongs, where you located it, your initial estimate of its probability and impact, an overall initial risk rating (low, medium, or high), and any comments or background needed to understand the context of the risk.

A potential risk exists in every declarative statement about your project. If it's less than certain you'll achieve the stated goal, then there is a risk. Risks, of course, vary in seriousness, and some risks are so improbable or have such a minor effect that there is no value in addressing them. Some risks involve circumstances of the project or the consequences of your own actions; other risks are part of the environment and you may have little control over whether they occur.

To make an initial assessment of a risk, consider the following questions:

- What is being asked of us, or what force or circumstance could affect us?
- is this difficult, problematic, or uncertain?
- What are the consequences of failure?
- Are there any circumstances or conditions that would result in failure?
- Are there any opportunities to do this work better, faster, or cheaper, or to gain additional benefit from the work?
- Are these risks being managed elsewhere?
- Should we add any of these risks to our project risk identification list?

If the answer is yes, add them to the risk register. Please note that for the most part you can ask these questions without writing everything down; only write down what you discover that is of significance. If there's doubt, of course, err on the side of inclusion.

A systematic process of risk identification normally starts with a comprehensive document review, and may also including techniques of brainstorming, various diagramming tools (such as cause-and-effect diagrams and SWOT analysis), and checklists. It's also a good idea to identify experts to advise you in risk areas with which you and your team are not familiar.

The output from the risk identification process is a completed risk register. No matter how well your initial risk identification process goes, the nature of the project always evolves over time. Continue to add items to the risk register as you discover them.

The next step in the risk management process is risk analysis.

Review Questions

1. Two factors in assessing the seriousness of a given risk are:
(a) contract penalties and customer satisfaction.
(b) risk rating and risk register position.
(c) the likelihood of the risk occurring and the consequences if it should occur.
(d) the cost of responding to the risk compared to the total budget of the project.

1. (c)

2. A systematic risk identification process needs to be performed:
(a) only at the outset of the project as part of the risk plan.
(b) every six weeks.
(c) by professional risk managers.
(d) throughout the project life cycle because of changes in circumstances and information.

2. (d)

3. in describing a risk formally, the statement of risk should always include:
(a) the probability and impact estimate for the identified risk.
(b) any proposed solutions or responses to the risk.
(c) the condition that provides concern and the consequence that would result.
(d) the category in which the risk falls.

3. (c)

4. Risk identification is concerned primarily with:
(a) listing risks that give us potential concern.
(b) identifying pure risks on projects.
(c) identifying business risks on projects.
(d) analyzing risks for probability and impact.

4. (a)

5. in the negative brainstorming technique, risk managers should:
(a) select a negative question to focus brainstorming efforts.
(b) ensure that the group develops corrective actions for the risks it identifies before moving on.
(c) focus on costs associated with risks.
(d) keep the brainstorming group small.

5. (a)

3

Qualitative Risk Analysis

Learning Objectives

By the end of this chapter, you will be able to:

- Define common terms and concepts in risk analysis, including qualitative risk analysis, quantitative risk analysis, risk triage, and filtering.
- Identify appropriate risk categories to organize identified risks for further action.
- Use a filtering process to perform risk triage, sorting risks according to priority, urgency, ownership, and solvability.
- Implement a variety of qualitative concepts and techniques, including cause-and-effect diagramming to analyze impact, assessment of non-numerical factors in determining risk probability, identification of proper risk ownership, and the mechanism for transferring risks.
- Apply risk triage and other processes to confirm that risks have been correctly identified and categorized.

Estimated timing for this chapter:

Reading	40 minutes
Exercises	50 minutes
Review Questions	10 minutes
Total Time	1 hour 40 minutes

Introduction to Risk Analysis

In between deciding what the risks actually are and deciding what, if anything, you plan to do about them, comes *risk analysis*—the process of studying the risks to measure and define their probability, impact, and other characteristics. Armed with improved understanding, you can separate important risks from trivial ones and identify the opportunities you have to influence our risk environment in the right direction.

There are many different techniques used in risk analysis. Some are specific to a given industry or technical area. You don't normally need a systems engineering risk assessment for a marketing plan, nor are the tools of financial risk analysis generally of primary value in determining whether the shop floor is safe. This self-study course will focus on the tools most commonly used and those with widest application. Depending on your industry, profession, and circumstances, you may want to explore a certain set of tools in much greater depth.

In general, risk analysis techniques fall into two groups. The *PMBOK Guide* (11.3, 11.4) defines them as follows:

- *Qualitative risk analysis* is the process of prioritizing risks for further analysis by assessing and combining their probability of occurrence and impact.
- *Quantitative risk analysis* is the process of numerically analyzing the effect of identified risks on overall project objectives.

Quantitative risk analysis as a process normally follows qualitative risk analysis, but the *PMBOK Guide* observes that, in some cases, quantitative risk analysis may not be required to develop effective risk responses. In certain categories of projects, quantitative tools may be used first, with qualitative analysis filling in the gaps. What's important is that you use these processes and tools in the order and sequence they make most sense to you.

Qualitative Risk Analysis

When we performed risk identification in the last chapter, we decided to lean in favor of including risks rather than excluding them. Our risk register, therefore, includes a number of risks that fall below the reasonable threshold requiring response.

In qualitative risk analysis, we define the characteristics of the risk in more detail. We gather additional information. We rate the relative importance of the risk in terms of probability and impact—without, in many cases, being able to put specific numbers to those values.

Qualitative risk analysis accomplishes the following:

- By defining and assessing probability and impact, even in general terms, it ranks the relative importance of the identified risks to the project, the organization, and to specific stakeholders, enabling resources to be focused where they'll achieve the most benefit.
- By classifying risks into categories, it helps reveal potential common causes and vulnerability areas where action can be highly productive, and ensures risks are routed to the proper owners and managed properly.
- By defining risk characteristics and potential common causes, it provides the basis for effective risk response planning.

Quantitative Risk Analysis

Quantitative risk analysis, as previously noted, is the process of numerically analyzing the effect of identified risks on overall project objectives. As the name "quantitative" implies, the key word in this definition is "numerically." Quantitative risk analysis is classical risk analysis, the probability-based tools developed to assess risk in financial instruments such as insurance.

Quantitative risk analysis tools exist in many disciplines from finance to nuclear engineering. Any field in which it's possible to calculate the likelihood of certain events based on either theoretical or actual probability uses quantitative analysis. (Theoretical probability is saying the chance of flipping heads is 1 in 2, because there are only two outcomes. Actual probability is flipping the coin a few hundred times and reporting the result.)

If you're in a field with few available numbers to crunch, your opportunity to use quantitative risk analysis is limited, but you may be surprised by how many numbers you can find if you look hard enough—and what you can do with them if you find them.

Certain advanced project management techniques such as the Program Evaluation and Review Technique (PERT) and Monte carlo simulations have application to quantitative risk management, as you'll learn in upcoming chapters. Other common analysis tools we'll cover include expected monetary value (EMv), sensitivity analysis, and decision trees.

Quantitative risk analysis accomplishes the following:

- By analyzing the range of outcomes and their associated costs, it provides decision-makers with the data to establish reserves, set confidence levels, and identify whether the overall project is in line with stakeholder risk tolerances.
- By simulation and probability analysis, it provides an estimate of the likelihood of achieving a given set of time and cost objectives.
- By developing detailed numerical insights into risk characteristics, it refines the prioritization of risks and ensures that risk responses are cost effective and appropriate.

Qualitative Risk Analysis

In qualitative risk analysis, you sort the risks from the risk register based on their probability and impact, and then route them for further action. For any given risk, there are really only three choices: accept the risk, transfer it to someone else, or do something about it.

Accept the risk. When you accept a risk, you don't do anything further about it unless it occurs. If it occurs, you may take some remedial action, or you may simply absorb whatever it does to you.

Transfer the risk to someone else. some risks aren't yours. They may belong to the customer, to someone higher up in the organization, or to someone with specific authority or expertise. You do have the responsibility for making sure that the correct risk owner is aware of the risk. You often need to follow up and monitor their risk responses.

Do something about the risk. For now, this means that you put the risk in a stack with other risks requiring action. Some risks are so urgent you need to move them to the head of the line and start working on them now. Others can wait until you start your risk response planning process, which follows risk analysis.

If you've ever been in a hospital emergency room—or, for that matter, watched an episode of

M*A*s*H—you know about *triage*, a formal method of prioritizing medical patients based on the severity of the situation and what can be done about it. Qualitative risk analysis is, in a fundamental sense, a triage approach to risks. Before you can act, you have to sort.

The project management process that accomplishes this is known as *filtering*. Your goal is to filter the risks on the project so that the top risks are singled out for action. Exhibit 3-1 outlines the filtering process as a flowchart, and the copy that follows describes the action steps in more detail.

Start

Take each risk from the risk register, and go through the process one risk at a time. Update the risk register based on the result of the filtering process; record the outcome on the risk register—even for risks that will go no further. This is an important step, to make sure that no risk is inadvertently overlooked.

Impact

You wrote down a description of the impact when you filled out the original entry in the risk register. Now it's time to revisit that statement and amplify it.

First, make sure you've considered all the potential areas in which the risk impact may occur. In risk identification, you encountered the cause-and-effect diagram (Exhibit 2-9). You can use the same tool to great effect in risk analysis. Let's revisit the risk of tech manual errors, introduced in Exhibit 2-5. Here's the statement of risk:

> "If the manual contains errors, the customer may not be able to maintain and repair the equipment correctly and in extreme cases could suffer significant losses as a result of our errors."

Here are six categories of potential impact for this particular risk. Don't forget to add opportunities as well as threats. Often, the impact contains both. Exhibit 3-2 shows the cause-and-effect diagram.

- *Project risks*. Risks to the project and its objectives, primarily to the project's constraints of time, cost, and performance.

Exhibit 3-1 Risk Triage Process

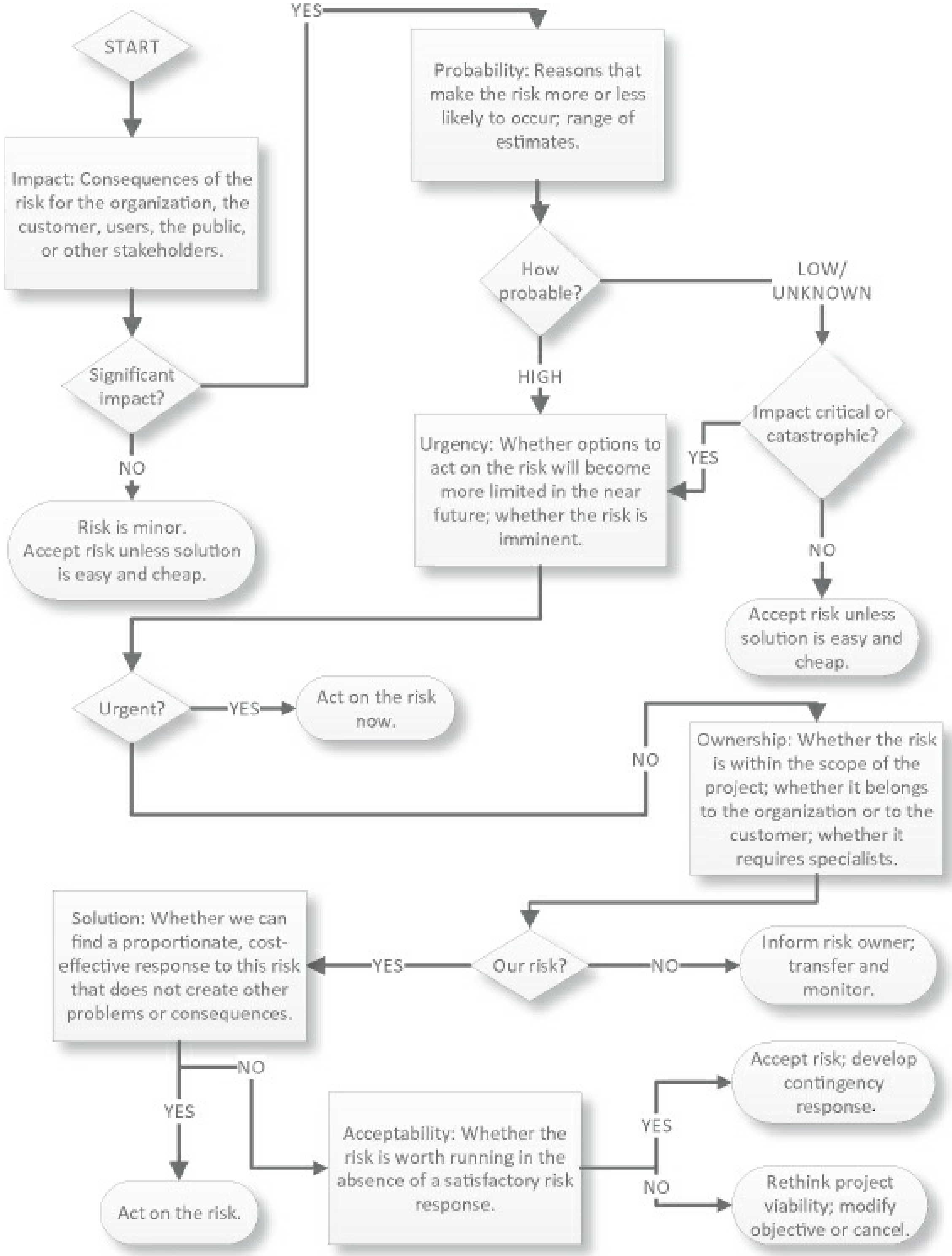
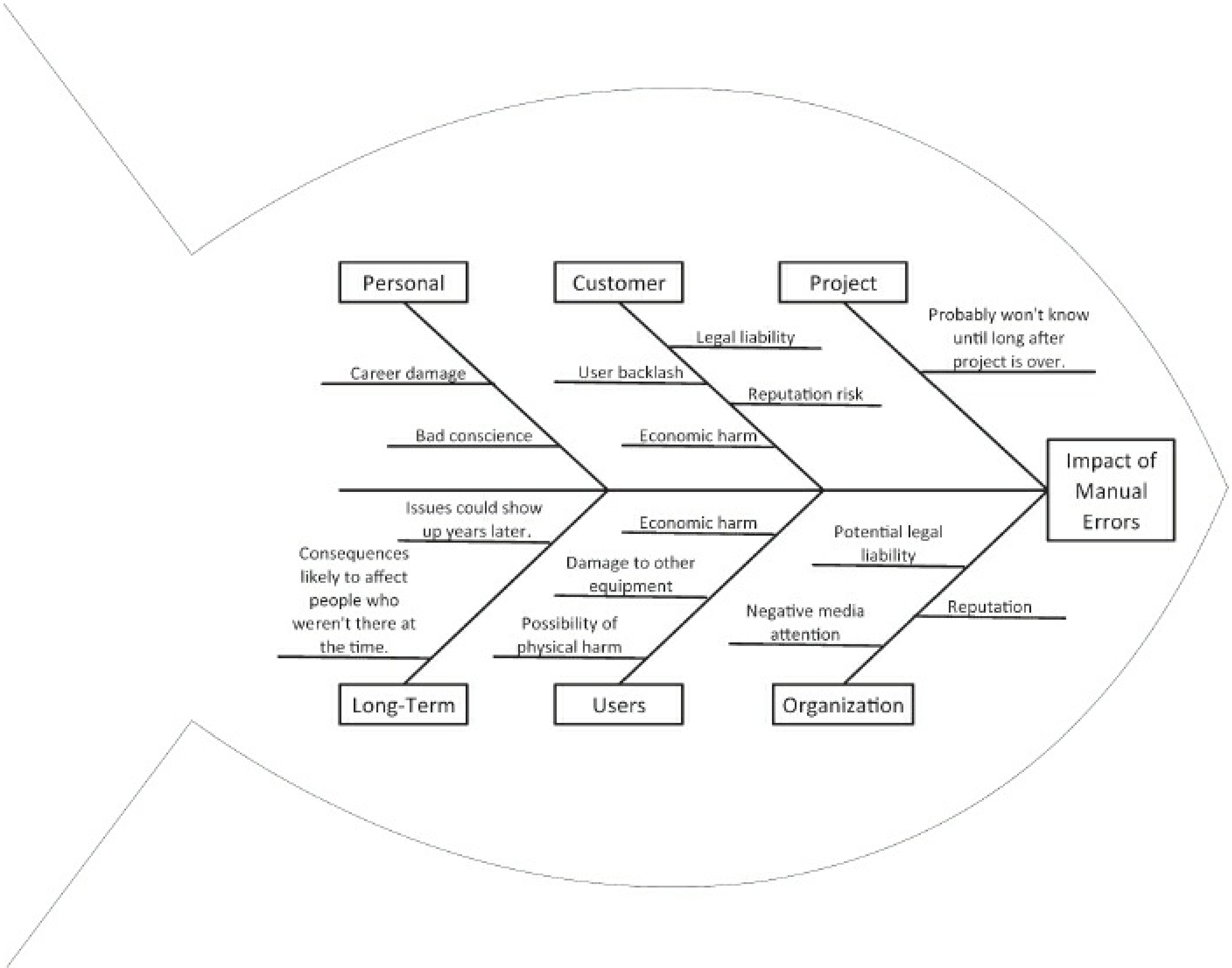


Exhibit 3-2 Cause-and-Effect Diagram for Impact Analysis



- *Organizational risks.* Risks to the organization sponsoring or managing the project. Could include such factors as reputational or business consequences, legal exposure, marketing issues, media exposure.
- *Customer risks.* Risks to the customer and the customer's organization.
- *User risks.* Risks to the end user of the product or service, including physical risks, economic risks, or other factors.
- *Personal risks.* Risk to you and your team members, such as continued employment, consideration for promotion or advancement, chance of getting other projects, effects on career or family.
- *Long-term risks.* Risks that are likely to outlast the life cycle of the project, the product, or the service.

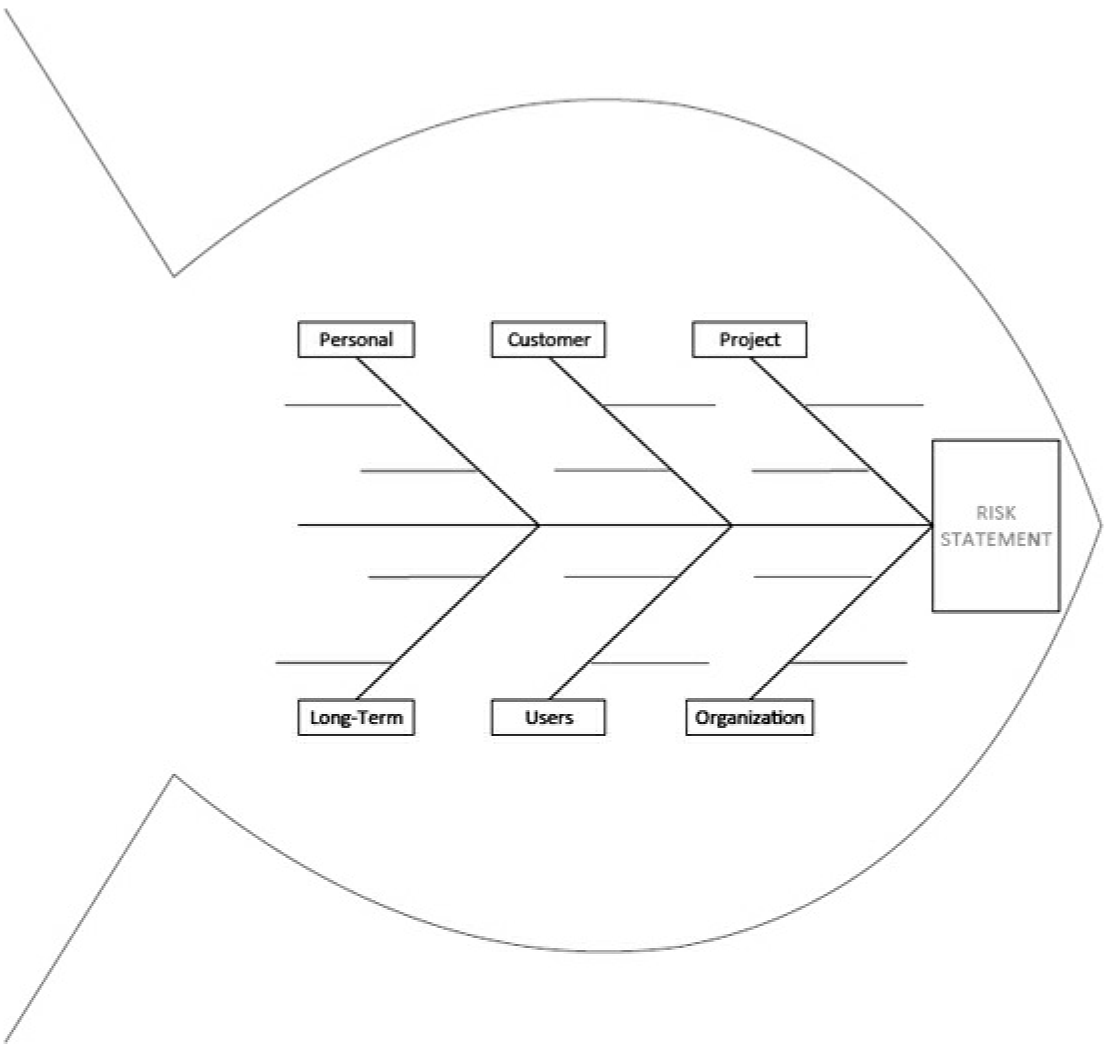
Obviously, a risk that carries with it legal liability and the chance of physically harming others is a serious risk and one that requires appropriate action. But notice how the impact falls out. Its effects are extremely unbalanced. The project itself is hardly affected at all. It might be years before the consequences of errors in the tech manual come to light.

The customer and the users are exposed to the greatest share of the impact. Depending on the standards for legal liability or warranty claims, they may be able to transfer some part of those costs to the organization. The danger here is not so much that an unscrupulous project team will take the easy way out (though that has been known to happen), but that human nature puts our focus on dangers that affect us most immediately. When the impact falls outside the sphere of the project, it sometimes also falls through the cracks. That's why this kind of risk assessment is so important.

In Exercise 3-1, you'll take one of the statements of risk you wrote in Exercise 2-1, and give it the same treatment.

Exercise 3-1 Cause-and-Effect Diagram

Take one of the three statements of risk you wrote in Exercise 2-1, and enter it into the "Risk Statement" box. Identify potential consequences of the event (both opportunities and threats), considering all six areas. You may not find meaningful impact in all six, but make sure you look at all of them carefully.



If the overall impact of the risk is not significant, then it may be sensible to accept the risk, unless the solution is easy and cheap. If the overall impact of the risk is significant, however, move to the next item on the list.

Probability

What (if anything) makes you believe this risk event may actually happen to your project? There are any number of potential reasons to believe a given event is more likely to occur. Consider the list of questions in Exhibit 3-3 as they apply to a particular risk. (The exhibit provides space for you to follow along, using either a risk from one of your own projects or continuing with the risk you used in the previous exercise.)

Sometimes you can arrive at a reasonable judgment that a given risk is low or high in probability, and other times there simply isn't enough data to hazard a reasonable guess. Since we've already established that the impact is significant (otherwise, we'd have accepted the minor risk), risks of low or unknown probability and no greater than moderate impact are good candidates for acceptance unless, as before, the solution is easy and cheap. Low or unknown probability combined with serious impact, however, is normally worthy of further attention.

Urgency

Some risks just can't wait. What really matters isn't the timing of the risk event itself, but how fast any potential solutions may become unusable. In the previous example, we discussed reviewing the manual prior to publication to catch any errors. Notice that you can only do this up until the time you ship the manual to the customer. After that, it's too late.

If the only, best, or cheapest solution is about to expire, or if the risk event is imminent, you don't have time to take the risk through the rest of the process. Assign the risk to a risk owner or manager (it may be you), and get started on it without waiting for all the rest of the qualitative and quantitative analysis results to come in.

Ownership

Some risks are very serious, but that doesn't automatically mean they're yours. If the failure of your project could result in the bankruptcy of your organization, it's the prerogative of senior management, not you, to determine whether the risk is worth running. If the customer signs a cost-plus contract for development, the customer owns the risk that the project will go over budget.

As we've mentioned, risk specialists exist in organizations to handle specific categories. If you're an engineer, you probably aren't the right person to manage legal risks on the project; if you're a lawyer, you probably aren't the right person to manage risks in systems engineering. As the project manager, you still have responsibility for risks that are not appropriate for you to manage. You should:

- Identify risks in all areas, not just inside the project boundaries.
- Gather basic information about these risks.

Exhibit 3-3 Probability Boosters

Question	Example	Your Risk

What's the statement of risk?	If the manual contains errors, the customer may not be able to maintain and repair the equipment correctly, and in extreme cases could suffer significant losses as a result of our errors.	
Has this ever happened before, either in our experience or in the experience of others?	We've discovered minor typographical errors in published manuals, but nothing of significance. This is at least partially because we already do a lot of checking to keep serious errors out of the product. Major mistakes have, however, been known to happen elsewhere, and the consequences have in some cases been very severe.	
Are there any circumstances or conditions that would make this risk more likely to happen? Are these circumstances or conditions present on this project?	The most likely reason for such an error occurring in the first place would be late-project engineering and design changes not being properly documented, so that manuals reflected out-of-date information. We do not currently see this happening, but if it does, we will revise our probability for this risk upward.	
Is this risk linked to other risks in the project environment?	Yes. A major late-project engineering or design change normally increases risk throughout the rest of the project. If such an event happens, a number of project assumptions will be called into question and a comprehensive risk reassessment may be in order, especially if deadline remains the same and cost pressures are also high.	
Conclusion	Probability of a major error is low in absolute terms, but high enough that our current review and quality control process should be continued.	

- Route risks to their proper risk owners, and provide relevant documentation.
- Support risk owners with information and technical advice.
- Review proposed risk responses for secondary impact on other project objectives.
- Integrate actions of risk owners into your project plan.
- Monitor risk responses and advise risk owners of trends and results.

While it's usually appropriate (if not required) that you are deferential to risk owners outside your project, remember that risk owners tend to focus on *their* risk areas and may not always be in tune with the bigger picture. Try to accommodate the needs of risk owners as much as possible, but if you can't and if the stakes are high enough, it may be appropriate to escalate the decision to a higher level of management.

Solution

So far, we've identified the following categories of risks:

- Risks without significant impact. You will probably end up accepting the majority of these risks unless the solution is easy and cheap.
- Risks with low probability and only moderate impact. You will also end up accepting the majority of these risks unless the solution is easy and cheap.
- Risks that require urgent response. Those risks are removed from the rest of the process and assigned to a person or team for immediate action.
- Risks that belong to someone else. You should route these risks and associated information to the proper risk owner, respond to the instructions and requirements provided by the risk owner, and

monitor the risk.

This leaves a final category: risks that are serious in impact, at least moderately high in probability (if unlikely to happen, the impact is very serious indeed), and that belong to you.

The next question, naturally, becomes what (if anything) can you do about it? For now, it's not necessary to come up with a detailed point-by-point action strategy, but to concern yourself with the general question. A risk is solvable if the response is proportional, cost-effective, and doesn't create major secondary problems or negative consequences. If it appears to be solvable, move it into the stack of risks requiring further analysis and action.

Acceptability

It may be apparent from the beginning that there is no way to bring a particular risk down to an acceptable level. There may be some unavoidable dangers, or factors you can't do anything about. Risk is a fact of life.

As mentioned earlier, accepting minor risks can be perfectly appropriate and sensible. When you're confronted with a major risk outside your control, it's not so simple. Ultimately, you have two choices:

1. Accept the risk and prepare a contingency response if possible.
2. Rethink the viability of the project, which may involve changing the objectives or cancelling the project.

This decision often doesn't belong to the project manager, but is the province of higher levels of management or the customer. If that's the case, treat it like an ownership issue, and make sure the risk, options, and supporting documentation are routed to the appropriate decision-maker.

Risk Triage and Other Risk Analysis Processes

It's worth repeating that filtering your risks is only the first step in risk analysis. By grouping your risks into various action stacks, you can route risks to their proper owners, identify low priority risks requiring little or no action, and focus your attention on the subset of high risks that fall within your purview.

There isn't a clear, bright line that separates risk triage (filtering) from qualitative or quantitative risk analysis processes. When answering the questions on the flowchart from Exhibit 3-1, you often need to apply certain of these tools even in your initial screening. Given also that your initial knowledge of risks may be incomplete, you also need to verify that your pile of low-ranking risks doesn't accidentally end up including one or more risks deserving more serious attention.

Exhibit 3-4 summarizes risk triage categories and next steps.

Exhibit 3-4 Risk Triage Categories and Next Steps

Category	Proposed Action	Intermediate Steps	Issues
Low Impact Risks	Accept unless response is easy and cheap	Review to make sure impact of risk is well understood and that nothing important is being overlooked	Linkages among risks may be overlooked; risks may change in impact based on other events
Low Probability Risks	If impact is moderate or less, accept unless response is easy and cheap	Review to make sure impact of risk is well understood and that nothing important is being overlooked	Linkages among risks may be overlooked; risks may change in likelihood based on other events
Urgent Risks	Start working on them as quickly as possible	Further information may be necessary to make a good decision; information about other risks and project issues may change understanding	May draw attention from issues of potentially greater seriousness; hard to determine proportional response when other project variables remain undefined
Risks with Other Owners	Route risks to proper owners; support risk decisions; integrate risk actions; monitor and provide information	Develop necessary information for risk owners	Need to define proper ownership; ensure risk owners take appropriate action; balance risks across ownership lines
Risks Requiring Response	Develop and implement appropriate risk responses	Analyze risks to develop better understanding	Cost of response, levels of residual and secondary risk, opportunity costs
Serious Risks without Effective Response	Decide whether the project objectives or circumstances can be changed; whether the risk is worth taking; whether the project is worth pursuing; develop contingency plans and recovery plans to implement if the risk occurs	Perform further data analysis; identify stakeholders and proper decision-makers; provide decision-makers with support	Impact of risk, secondary consequences of risk, cost of response

In between deciding what the risks actually are and deciding what, if anything, you plan to do about them, comes *risk analysis*, the process of studying the risks to measure and define their probability, impact, and other characteristics. In general, risk analysis techniques fall into two groups:

- *Qualitative risk analysis* is the process of prioritizing risks for further analysis by assessing and combining their probability of occurrence and impact.
- *Quantitative risk analysis* is the process of numerically analyzing the effect of identified risks on overall project objectives.

Not every risk requires both kinds of analysis. Although it is most common to perform qualitative risk analysis first and quantitative risk analysis second, situations vary.

Qualitative risk analysis begins as risk triage: a filtering process in which you sort risks by category, threat level, and ownership. You define the characteristics of the risk in more detail. You gather additional information. You rate the relative importance of the risk in terms of probability and impact—without, in many cases, being able to put specific numbers to those values.

Your basic choices about a given risk are to accept the risk, transfer the risk to someone else, or to do something about the risk. To make a decision about each risk, ask yourself a series of questions.

1. Is the impact significant? If not, consider accepting the risk unless the solution is easy and cheap.
2. Is the probability high? If not, consider accepting the risk unless the impact is very high.
3. Do we need to act immediately? If so, assign the risk to a person or team and get to work.
4. Is the risk ours? If the risk owner is outside the project team, route the risk (and relevant information) to the proper owner, and monitor the results.
5. can we do anything about this risk? If there's a potential solution that's appropriate, we are likely to implement it.
6. Is the risk worth taking? If there's no potential solution, or if significant risk remains even after you've done what you can, you may choose to accept the risk, or it may be appropriate to modify or even cancel the project.

In the risk triage stage, you shouldn't normally dig too deeply into risks or their solutions, but focus instead on sorting them into piles requiring different actions. In every case, it's a good idea to review what you've done, because it's all too likely that some risks have ended up in the wrong pile.

Review Questions

1. In performing risk analysis, the correct sequence is to:
(a) perform risk triage, qualitative risk analysis, and quantitative risk analysis in that order.
(b) apply qualitative and quantitative risk analysis tools simultaneously.
(c) apply quantitative risk analysis tools on every risk.
(d) use qualitative and quantitative risk analysis tools in the order that is appropriate for your project.

1. (d)

2. Factors such as reputation risk, business consequences, legal exposure, and unfavorable publicity are considered to be:
(a) project risks.
(b) customer risks.
(c) organizational risks.
(d) personal risks.

2. (c)

3. If a risk does not properly fall under the jurisdiction of the project manager or the project team, what should you do?
(a) Transfer the risk to the proper risk owner and monitor the risk.
(b) Take action if the risk is serious and consequences to the project are significant.
(c) Accept that the risk is not your business, and focus your attention elsewhere.
(d) Escalate any adverse decision to higher management.

3. (a)

4. The purpose of qualitative risk analysis is to:
(a) analyze numerically the effect of identified risks on project objectives.
(b) identify pure risks on projects.
(c) ensure all identified risks are fully analyzed and acted upon.
(d) analyze risks for probability and impact.

4. (d)

5. Advanced project management techniques such as PERT and the Earned value Method are useful in performing:
(a) qualitative risk analysis.
(b) quantitative risk analysis.
(c) risk triage and filtering.
(d) qualitative risk identification.

5. (b)

4

Tools for Qualitative Risk Analysis

Learning Objectives

By the end of this chapter, you will be able to:

- Identify research needs and strategies for qualitative risk analysis.
- Implement qualitative risk analysis tools to define the level of current knowledge available to determine probability and impact, establish range scales for risk probability and impact, and define risk thresholds for different categories of risk.
- Establish a risk scoring system using either words or numbers, and rank risks according to either.
- Measure overall project risk for a project using three different techniques.
- Update risk register data showing disposition of all identified risks and prepare a risk information sheet for significant project risks.

Estimated timing for this chapter:

Reading	40 minutes
Exercises	1 hour 40 minutes
Review Questions	10 minutes
Total Time	2 hours 30 minutes

Qualitative Risk Analysis Tools

As you filter the risks using qualitative risk analysis, you need to establish a common set of terminology and process to ensure consistency and good results. In this chapter, we'll go into additional depth about common qualitative risk analysis tools for assessing risk probability and impact.

A common thread through this process is the importance of research. Since our goal is to establish measurements of probability and impact, at least in rough terms, the obvious questions are

(1) how do we figure out the probability and (2) how do we figure out the impact? The latter is often easier than the former. We may not know how likely it is that a machine will malfunction, but we do know the replacement cost if we have to put in a new one. At the same time, some aspects of impact are not so clear: damage to reputation, for example.

Where can you go to learn more about a given risk? depending on the risk, the possibilities are numerous, and include:

- Lessons learned files and historical data from previous projects
- Test and evaluation results
- Interviews with people who have knowledge or experience related to the risk
- User surveys and customer satisfaction data
- Industry data
- Scenario analysis or simulations

Of course, there's often no end to how much investigation you can do, but there's a definite limit to how much you *should* do. For the (hopefully) large percentage of risks classified as "probably accept" (low in some combination of probability and impact), all you need to do is to review them to see if there are any that deserve reclassification. Even when risks are important, you may already have all the information you need readily available. Save your maximum energy and effort for risks that are potentially very serious and not well understood.

Think About It …

What specific sources of information can you think of that will help you learn more about the risks you have to manage on your projects?

Assessing Probability and Impact

Because projects are notoriously "temporary and unique," we often don't have detailed information to help us judge the critical questions of how likely a given risk is, and how serious its consequences would be, should it occur. The information you have, of course, can change over time. That's why research is so important.

You can't always find out everything you ideally want to know, however, no matter how deep you're willing to dig. That's not necessarily a fatal problem when it comes to risk management. We can live with uncertainty. What we can't afford is to get ahead of our actual knowledge and pretend to a level of certainty that just isn't real.

Exhibit 4-1 defines the different levels of information you may have about the probability and impact of a given risk at a given point in time. You will certainly learn more in the future. Through research and systematic analysis, you can often know more *now*.

It's more common to have an exact figure for impact than probability, because many costs are known and fixed. Unless you're dealing with a very small number of known possible outcomes (heads or tails, for example), probability estimates usually describe a range more than a single point.

Establishing Ranges

Project managers frequently use a range scale rather than numerical values because that more often reflects the honest level of knowledge available. To avoid confusion and misinterpretation (Is 40% "moderate"? Is $1 million "very high"?), make sure you establish and use standard terminology. Here are some considerations for establishing a scale for your risks.

Exhibit 4-1 Levels of Knowledge

Level of Knowledge	Probability	Impact	Technique
Exact numbers	42%	$1,112,416	Specific, known conditions
Round numbers	40%	$1 million	Historical data
Ranges	Moderate	Very high	Preponderance of the evidence
No Knowledge	Unknown	Unknown	Research and further analysis

1. *How many levels in the range?* Having more levels creates finer distinctions among risks. Do you have enough information to support those distinctions, and if so, will the extra levels help you prioritize risks more usefully? (Examples: Range of 1 (low) to 6 (very high); range of Low, Medium, and High.)
2. *Midpoint, or high/low?* When you use an odd number of levels, one level represents the middle—probability around the 50/50 point. When you use an even number of levels, risks have to be pushed into higher or lower categories because there's no middle. (Examples: A range of 1–6 does not have a midpoint; Low/Medium/High does.)
3. *Equal or skewed distribution?* The most logical approach might be to divide the range equally. With four categories, each would represent 25% of the total probability. But that doesn't always draw the best picture. If probability and impact are lopsided, a lopsided scale might be more useful. (Example of skewed distribution (Probability): Low = 1-25%, Medium = 25%-50%, High = over 50%. Skewed distribution (Impact): Minor = Under $1 million; Moderate = $1 million-$1.5 million; High = over $1.5 million.)
4. *Numbers or words?* numbers make it easier to calculate a risk score, but sometimes mislead people into thinking they're more precise than they really are. You can create a probability grid

using words, but words can also mislead because we hear the same words in different ways. In teaching risk management classes, we often ask people to say what number comes to mind when they hear the phrase "moderately probable." Student answers have ranged from 18% to 87%. This means you should always define your terms.

Think About It …

Do you currently use a risk scale? How does it relate to the criteria above? How does it work in practice?

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If you don't currently have a risk scale, how would you apply these criteria to develop one?

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Risk Thresholds

Risk can be both relative and absolute. Relatively speaking, it's worse to lose $1 million than to lose $100,000. But if your affordable loss threshold is only $50,000, then in one fundamental sense, both risks are identical—that is to say, they're both unacceptable.

A risk threshold is a maximum level you're willing to suffer for a particular type of impact: financial risk (how much we're willing to risk losing), safety (chance of physical harm to workers or users we're willing to accept), legal liability (vulnerability to lawsuits or other accusations), image (risk that public perception will suffer), or career (chance that our personal advancement and job security will suffer). You may need additional risk thresholds for the specific risk categories that most affect your project or environment. If you're in the nuclear power business, there's a standard for allowable risk of radiation leakage (very low). If you're in the airline business, there's a threshold for acceptable flying weather.

Risk thresholds help the organization control its projects. If a risk violates a risk threshold in a particular category, it's automatically on the list of risks that must be managed. If the risk can't be reduced enough to fall safely below the threshold, it's up to the organization—not the project manager—to decide whether the risk should be accepted, or whether the project should be modified or cancelled instead.

Exercise 4-1 Establishing Risk Thresholds

For each of the following risk categories, develop a risk threshold appropriate for your organization and your projects. Who would have the authority to make any exceptions?
Your projects and your organization often have specialized risk thresholds. What additional categories would you consider adding, and how would you define them?

Category	Definition	Threshold	Authority to Make Exceptions
Schedule Risk	Risks that would make the project tend to miss its time constraint		
Cost Risk	Risks that would add cost to the project or to the organization		
Business Risk	Risks that would cause the organization to be seen less favorably		
Security Risk	Risk that sensitive or classified information will be released inappropriately; risk of theft or pilferage		
Quality Risk	Risk that the product or service will fail to meet its standards		
Safety Risk	Risk that people may be physically harmed as a result of the project or its output		
Legal Risk	Risk of violating laws or regulations; risk of being sued		
Other			
Other			
Other			

Combining Probability and Impact

The risk formula, Risk = Probability × Impact (R = P × I), calculates the *risk score*, a measurement of the value of a risk.

If there's a 40% chance of $1 million lost (or, for that matter, gained), the risk score is 40% of $1 million, or $400,000. If the risk is losing $1 million, the implication is that if you can get rid of the risk for less than $400,000, it's probably wise.

If the risk is a 40% chance to *gain* $1 million, the same logic applies: if the opportunity costs less than $400,000, the numbers are in your favor. (The opposite is, of course, not necessarily true.

Sometimes it's wise to spend more than the raw value of the risk when other factors are at stake.)

When you move away from numbers, the risk score no longer provides a clear guide to how much money you should consider spending, but it still has value.

Calculating Risk Scores with Non-Numerical Information

The two ways to calculate risk scores without reasonably accurate probabilities or firm dollar amounts for impact are (1) using words and (2) using a numerical scale.

Exhibit 4-2 shows how to combine word descriptions of probability and impact into a matrix grid. The intersection of the probability and impact estimates tells you whether the risk should be considered high, medium, or low. You can, of course, use different words, more or fewer words, or different ranges for each word, depending on your preferences.

Exhibit 4-3 shows how to apply a numerical scale to create risk scores and rank risks. We've used a scale of 1-5 for both probability and impact, with higher numbers representing greater values. You can, of course, use more or fewer numbers in the scale, or weight the results differently.

Note that we rank risks two ways in Exhibit 4-3, by descending order of risk score (highest risk 1, second highest 2, and so forth), and separately by High, Medium, and Low. Both metrics have value; you aren't restricted to a single way to look at risk severity.

Exhibit 4-2 Risk Matrix

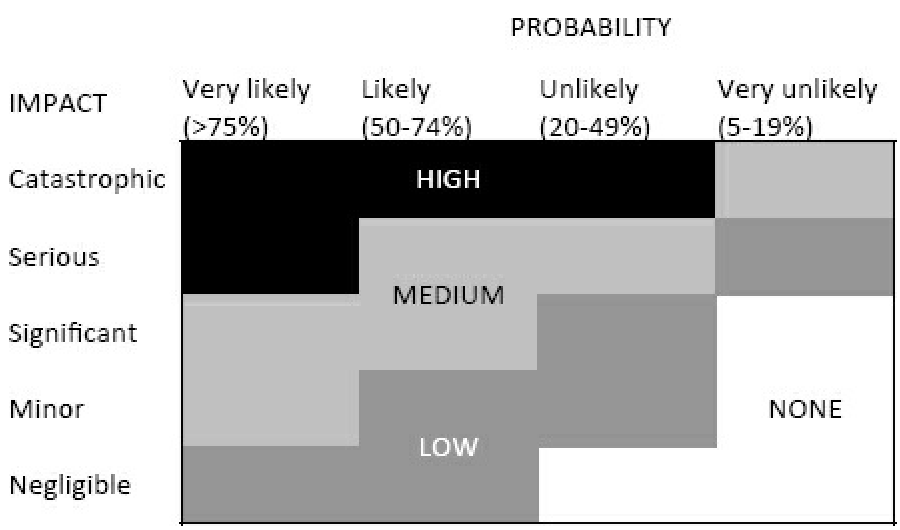


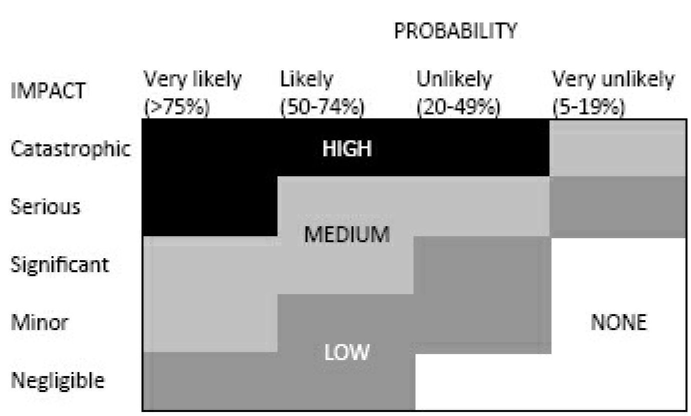
Exhibit 4-3 Rating Scale

Scale (Probability and Impact): 1 (lowest) to 5 (highest)
Risk Score: Probability × Impact = 1 (1 × 1, lowest) to 25 (5 × 5, highest)
High risks: scores of 3 to 5 in both probability and impact

Medium risks: scores of 3 to 5 in either probability or impact, but not both
Low risks: scores under 3 for both probability and impact
Risk Ranking: From highest risk score to lowest risk score

Risk	Probability	Impact	Risk Score (P × I)	Risk Ranking
1. If too many other projects schedule manufacturing time to coincide with ours, the plant production schedule may not be able to support our deadline.	3	5	15	1 HIGH
2. If the manual is more than six weeks late, the customer will not be able to take over maintenance and repair of the equipment at the end of our warranty period.	2	3	6	3 MEDIUM
3. If customer emergencies require us to make a special shipment during the inventory process, we may need to work overtime to meet the original deadline.	1	2	2	5 LOW
4. If any members of the project team are unavailable, we will either recruit replacements from other departments or pay overtime to the remaining team members to meet the original deadline.	2	2	4	4* (tie) LOW
5. If the DigiWigit® prototype is not properly packaged, it is likely to be damaged in transit.	2	5	10	2 MEDIUM
6. If the manual contains significant errors, the customer may not be able to maintain and repair the equipment correctly; in extreme cases, a customer could suffer significant losses as a result of our errors.	1	4	4	4* (tie) MEDIUM

Exercise 4.2
Ranking Risks



Use the risks you identified in Exercise 1-1 and rank them using the two methods illustrated in Exhibits 4-2 and 4-3.

Risk	Probability	Impact	Risk Rating
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			
15.			

Risk Number	Probability Score	Impact Score	Risk Score	Risk Ranking
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				

Are there any significant differences in how you rated the same risk in the two parts of Exercise 4-2? Describe the difference and why you think you chose different ratings. Which score do you think more accurately describes the value of the risk?

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Developing a Risk Ranking for a Project

Valuing and scoring individual risks is obviously important, but what about the overall risk ranking of a project? often, that's what customers and senior management really want to know.

Total risk exposure can be measured in several different ways, and each of these ways may provide you with a different answer. One simple method is to determine the overall risk exposure. To do that, add up the risk scores. In Exhibit 4-4, we've done that using the information from Exhibit 4-3. Notice that the answer (41) doesn't tell us anything unless we compare it to the numbers for other projects. If total risk exposure for most projects were in the range of 30-50, we'd call this a moderately risky project. If the number for most projects were, say, 10, we'd call this high risk. And if the average score were closer to 100, the same project would be low risk.

An organization could also measure project risk by determining the maximum possible loss (or gain) or by the presence or absence of risks that are above the risk threshold levels in a given category.

Risks can also be measured by category and phase using a risk table approach. One such approach is illustrated in Exhibit 4-5. Again, the number produced by this process is only meaningful when you compare it to the number for other projects.

Exhibit 4-4 Total Risk Exposure

Risk	Score
1	15
2	6
3	2
4	4
5	10
6	4
TOTAL	41

Exhibit 4-5 Measuring Total Project Risk

In creating the following spreadsheet, we used a scale of 1 (lowest) to 5 (highest) for the total risk in each category for each phase of the project. The maximum possible score (risk of 5 in every category and phase) is 350. Here, the actual score is 162.

Project Phase	Risk Category							
	Schedule	**Cost**	**Business**	**Security**	**Quality**	**Safety**	**Legal**	**TOTALS**
Conceptual	3	1	1	3	1	2	1	12
Preliminary Design	3	2	2	3	2	1	1	14
Final Drawings	3	2	3	3	4	3	3	21
Prototype Development	2	4	3	3	3	4	2	21
Initial Testing	1	2	2	3	5	5	3	21
Production	2	5	4	2	4	4	2	23
Shipping	1	2	2	2	2	2	2	13
Documentation	2	1	3	1	3	3	3	16
Training	1	2	3	1	2	1	2	12
Closeout	1	1	1	1	1	1	3	9
TOTALS	19	22	24	22	27	26	22	162

HIGHEST POSSIBLE SCORE	350
ACTUAL SCORE	162
RISK RATIO	162/350, or 46%

Updating the Risk Register and Developing a Risk Information Sheet

At the end of this process, you've reviewed the risks in each of the risk triage categories, assessed probability and impact, rated the risks more fully, and estimated the total risk exposure for the project.

Now update the risk register you started preparing during the risk identification phase (Exhibit 2-1) by adding the disposition of each risk: accept it, transfer it, or act on it. For risks you accept, you're done—for now. The risk register serves as a "parking lot" for identified but accepted risks. From time to time, it's a good idea to review the risk register to see if there are any risks that ought to be revisited because of changes in knowledge or circumstances.

For risks you transfer, the question becomes how much involvement do you still need to have with the risk? If it's entirely out of your hands, and you neither have to help manage the risk nor furnish information, then you just need to make a note on the updated risk register. If you will be involved with the risk, or need to manage responses to the risk, then treat it as a risk you are going to act on.

For all risks you are going to act on, you need more space than the risk register provides. A risk information sheet allows you to document a risk in more detail and helps you manage it actively.

Exhibit 4-6 provides an example of a Risk Information sheet.

The top section of the risk information sheet repeats information from the risk register: risk ID, probability, impact, risk rating, and risk description. Simply copy what you've already written elsewhere.

The second section captures information from both qualitative and quantitative risk analysis and provides background and understanding of the risk and its wider context. The risk response section (which we'll get to later) is the detailed description of what you plan to do about the risk. As the project moves forward, you'll update the risk information sheet when its status changes, and end up with a final disposition for the risk.

If you get past the point in which it's possible for the risk to occur, and it doesn't, the risk is closed. For example, if there's a risk the product won't pass testing, and it does indeed pass testing, that particular risk no longer exists. If, on the other hand, the project does fail testing, then you have to do whatever is necessary to respond to that failure. When you have done everything you can do, and the risk has done all the damage (or benefit, if it's an opportunity) it's capable of doing, the risk is also closed.

In Exercise 4-3, you'll prepare a risk information sheet of your own.

Exhibit 4-6 Risk Information Sheet

RISK INFORMATION SHEET	
RISK ID	RISK DESCRIPTION
RATING	
PROBABILITY	
IMPACT	
RISK ANALYSIS	
RISK RESPONSE (ACTIONS AND DISPOSITION)	
STATUS OF RISK (INCLUDING FINAL OUTCOME)	

Exercise 4-2 Prepare a Risk Information Sheet

Using one of the risks you originally identified in Exercise 2-1 and developed in subsequent exercises, prepare a risk information sheet using the form provided.

RISK INFORMATION SHEET	
RISK ID	RISK DESCRIPTION
RATING	
PROBABILITY	
IMPACT	
RISK ANALYSIS	
RISK RESPONSE (ACTIONS AND DISPOSITION)	
STATUS OF RISK (INCLUDING FINAL OUTCOME)	

recap

How much do you know about the risk? Levels of knowledge range from certainty to completely unknown. The information you have at the outset, however, is not the same as the information you will have after you do research.

Establish ranges for probability and impact when you don't have actual numerical values. Establish risk thresholds—the maximum level of allowable risk in a given category (financial, safety, image, and so forth). You can calculate risk scores and rate the risks with words or with numbers.

To determine the overall risk ranking for an entire project (as opposed to an individual risk), you can use the total risk exposure (sum of the risk scores), the maximum possible loss or gain, the presence or absence of risks above the threshold level in any category, or use a spreadsheet to compare risks in each category to each phase of the project.

Update the risk register with the final disposition of each risk (whether you accept it, transfer it, or decide to act on it). For risks that require significant action, prepare a risk information sheet. Keep the risk register and review the risks on it from time to time in case circumstances or new knowledge cause you to reassess the potential seriousness of a given risk. You'll update the risk register with risk response information and updated risk status as the project moves forward. At the end, you will close risks, either because they did not occur (and can no longer occur) or because they did occur and all the outcomes of the risk and risk response have happened.

Review Questions

1. You should close a risk under the following conditions.
(a) When the risk exceeds an allowable risk threshold
(b) When you have decided to accept the risk and take no further action
(c) When the risk register has been successfully updated
(d) When the project has reached the point the risk can no longer happen, or when all its effects are finished

1. (d)

2. You need to establish a risk threshold when:
(a) there are a large number of risks in a given category.
(b) the potential cost of the risk exceeds the budget of the project.
(c) there is a maximum level of risk exposure that the organization is willing to accept in that category.
(d) the risk involves legal exposure or safety.

2. (c)

3. When it comes to determining the level of knowledge available about a given risk, you should:
(a) use exact figures for impact and ranges for probability.
(b) establish levels based on the preponderance of the evidence, rated as low, medium, or high.
(c) wait until quantitative risk analysis results are available before documenting any risk.
(d) put down what you know right now, even if it’s little or nothing, and research more later if necessary.

3. (d)

4. To assess total risk exposure, you should:
(a) review all risks that exceed risk thresholds.
(b) count the total number of risks.
(c) add up the individual risk scores.
(d) determine the maximum potential amount that can be gained or lost.

4. (c)

5. If there is a 25% chance that a given event will cost the project $100,000, what can you conclude?
(a) If the cost of eliminating the risk is less than $25,000, it’s probably wise to do so.
(b) If the cost of eliminating the risk is greater than $25,000, you should not take any action.
(c) The risk exceeds the risk threshold for the project category.
(d) The risk requires development of a risk information sheet.

5. (a)

5

Statistical Foundations of Quantitative Risk and Cost Analysis

focus

Learning Objectives

By the end of this chapter, you will be able to:

- Define the Law of Large Numbers and the concepts of statistics and probability that derive from it.
- Explain the difference between probability and odds, and understand the roles each plays in risk decision-making.
- Apply basic rules of probability, including joint probability and union.
- Prepare a distribution of outcomes and recognize types of normal distributions (wide, narrow) and when a distribution is not normal.
- Define the three measures of central tendency (mean, median, and mode) and calculate the standard deviation of a normal distribution.
- Estimate the probability of a given outcome based on its distance from the mean as measured in standard deviations.
- Recognize that a range of distributions may apply to a given risk analysis situation.

Estimated timing for this chapter:

Reading	55 minutes
Exercises	40 minutes
Review Questions	10 minutes
Total Time	1 hour 45 minutes

Quantitative Risk and Cost Analysis Fundamentals

Quantitative risk analysis, as previously noted, is the process of numerically analyzing the effect of identified risks on overall project objectives. As the name "quantitative" implies, the key word in this definition is "numerically." Quantitative risk analysis is classical risk analysis, the probability-based tools developed to assess risk in financial instruments such as insurance. As such, it's a fundamental part of cost analysis under conditions of uncertainty.

Quantitative risk analysis tools are normally applied to risks that our previous risk analysis has shown to be significant. Quantitative risk analysis can also be used to provide a probabilistic analysis of the likelihood of the project meeting its cost and time objectives.

The "numerical" aspect of quantitative risk analysis rests on a foundation of probability and statistics. Not everyone who has responsibility for risk and cost analysis has a background in the mathematical disciplines of probability and statistics, but some of the basic ideas from those disciplines are essential knowledge for moving ahead in this course. In this chapter, we will explain the basic concepts of statistics and probability as they apply to our topic.

If this is something you already know well, feel free to skim this chapter and move forward. If statistics wasn't your best subject in school, or it's been a long time since you studied it, this chapter is for you. The more serious you want to be about formal risk management, the more knowledge of these subjects you will need, so we strongly encourage further study. If you decided to skip our review on your first reading and subsequently discovered that some of the later concepts in this book don't quite compute, welcome back.

A Statistic

There's no evidence that the Soviet leader Joseph Stalin actually ever made a statement frequently attributed to him: "One death is a tragedy; a million deaths is a statistic." In discussing classical risk management, the reported stalin quotation does, however, reveal an essential truth: you can't divine a trend or tendency from a single incident.

Stalin, for example, died at the age of 74 of (apparently) natural causes. What does that tell us about the average life span (or common causes of death) in the Soviet Union at that time? Obviously, not much. What if instead we gather information on the age at death and cause of death for a million people living in the Soviet Union at that time? Well, now we really *do* have a statistic—sort of. Actually, it's just a big pile of information, but it can be analyzed. The mathematical tools we use to organize and interpret the data are known as *statistics*.

Depending on the amount and quality of data and the depth of our analysis, there's all sort of information to be gleaned here. If we measure the age at death of those who die next year (and know the cause of death), we can see if there's been a change, and if so, how big it is, whether it's a trend, and in which categories and in which directions the trend seems to be moving.

The same tools measure what we do about it. If we implement a Five-year Plan and want to know how well it's working, we can compare the actual outcomes to the previous trend. Are we doing significantly better than we would have otherwise? The same? Worse?

As our pile of statistics grows and the quality and depth of our analysis improves, we can give answers with greater confidence. What statistics *can't* tell us is the individual case: how long is Soviet citizen imya Rek going to live?

The Law of Large Numbers

The *Law of Large Numbers* (LLN) is a principle of probability theory. It argues that the larger the sample population or number of trials, the more likely that the actual probability will converge with the theoretical one. Roll a die a single time, and you don't get a distribution, but an absolute value. Roll the die six times, and the actual results could be all over the map, with three of one number and one of another. Roll the die 100 times, and the likelihood increases that the resulting distribution will look like the theoretical one. (In this case, it wouldn't be a normal distribution, but a completely flat one, because the probability of getting each individual answer is exactly the same, 1/6.)

Roll the die 1,000,000 times, and the chance the actual distribution will look like the theoretical one approaches certainty. That still doesn't mean you'll get identical results for each number rolled, of course. In 1,000,000 trials, a 1/6 probability you should get 166,666.667 rolls of one, but of course that's impossible. You can roll a one 166,666 times or 166,667 times, but you can't roll a fractional result. And, as we learned in the last chapter, we still expect some random variation. If the final results only diverge 0.1% from theoretical probability, a difference of 300 between the number of rolls of one and the number of rolls of two would be utterly insignificant.

Probability, Odds, and Throwing Dice

So far, we've assessed the probability of a risk event using qualitative methods—which is to say, we've made educated guesses, but haven't done the math. Now, let's look at the mathematical discipline of probability.

A science of probability didn't get started until relatively recently in human history, and it's arguably one of the foundations of our modern economic civilization. As we've seen, just about any possible decision carries with it some degree of risk. Being able to quantify the risk is fundamental to deciding to price and respond to it.

We owe the beginnings of our understanding of the mechanics of probability to a 16th century physician and compulsive gambler named Girolamo Cardano, who first articulated the basic concepts of probability in a book titled *Liber de Ludo Aleae*, or *A Book on Games of Chance*. (Benjamin, 533-544) He first conceived of expressing probability as a fraction.

This self-study course follows a long tradition of illustrating probability through gambling. Gambling provides us with an untainted theoretical environment with which to study risk. We know the odds; we know the rules; we understand the mechanics of the game. We can measure our expected loss before we put the first coin in a slot machine.

Of course, some people consistently win at gambling. These people are known as casino owners. They are able to win consistently because they apply the rules of probability with great precision to design games that provide a constant, measurable edge to the house.

Theoretical versus Actual

It's important to keep in mind that outside a casino, it's different.

- You often don't know the real probability, certainty not with any precision.
- You may not know all the rules of the game, or all the factors that might affect the outcome.
- You don't necessarily know that everyone is honest. Casinos seldom cheat because they don't need to; the power to set the odds is more than enough. This is not always the case.

- Some situations have a likelihood and impact of an upside that is far greater than any downside risk: they are risks worth taking.
- Risks are often linked to each other in ways that aren't obvious. Variables aren't always independent.
- Your choices matter. Approximately 80% of small businesses fail within five years of opening. A small number of known causes account for the vast majority of failures; if you avoid those mistakes, your odds of success are dramatically higher.

For all these reasons, theoretical probability doesn't always line up with actual probability.

Probability

A *probability* is expressed as a fraction: the number of desired outcomes divided by the number of possible outcomes.

There are six possible outcomes if your throw a six-sided die: one, two, three, four, five, or six. If you want to know the probability of rolling a three, three is one outcome out of six possible outcomes. Therefore, the probability of rolling a three is 1/6 (0.167, or a little less than 17%).

By the same token, in a deck of 52 cards with four aces, the chance of drawing an ace at random is 4/52 (1/13, 0.077, or a little less than 8%).

Odds

Odds measure the ratio of desired to undesired outcomes, as opposed to total outcomes. The probability of rolling a three on a six-sided die is 1/6, but the odds of rolling a three are only 1/5: one desired outcome compared to five undesired outcomes.

Imagine a game in which Player A will win $6 whenever a one is rolled, and Player B will win $6 whenever any number *except* a one is rolled. To balance the game so that both Player A and Player B have an equal chance of victory, you can adjust the financial stakes according to the odds: Player A bets $1 each round and Player B bets $5 each round (making up the total pot of $6). Over time, both players should end up with the same amount of money.

Exhibit 5-1 Basic Probabilities with One Six-Sided Die

Roll	Probability	Odds
1	1/6	1/5
2	1/6	1/5
3	1/6	1/5
4	1/6	1/5
5	1/6	1/5
6	1/6	1/5

Basic Rules of Probability

We now have two definitions: the probability of an event is the ratio of the number of times a given result occurs divided by the total number of possibilities. There is one chance in six of rolling a three on a six-sided die.

The odds of an event is the ratio of the number of times a given result occurs divided by the number of times the event does not occur. The odds of rolling a three on a six-sided die are one in five.

Exhibit 5-1 lists probabilities and odds for rolling a single die.

If you roll a six-sided die twice in a row, the outcome range becomes more complex. What is the probability and odds of rolling two threes in a row? Exhibit 5-2 lists the possible outcomes from rolling twice.

Exhibit 5-2 Basic Probabilities Rolling One Die Twice

First Roll	Second Roll
1	1
1	2
1	3
1	4
1	5
1	6
2	1
2	2
2	3
2	4
2	5
2	6
3	1
3	2
3	3
3	4
3	5
3	6
4	1
4	2
4	3

4	4
4	5
4	6
5	1
5	2
5	3
5	4
5	5
5	6
6	1
6	2
6	3
6	4
6	5
6	6

Rolling two threes in a row, as you can see, comes up one time out of 36 possibilities. The probability is 1/36; the odds, accordingly, are 1/35.

Of course, listing every possible outcome quickly gets tedious, so mathematicians quickly found an easier way to do it. As we already know, the probability of rolling a three on a single die roll is 1/6. The probability of doing it a second time is also 1/6. Multiply the numbers together and you get 1/36, the same answer as if you had counted them by hand. This is one of the rules of mathematical probability.

Like other branches of mathematics, probability has its own symbols and terms. Exhibit 5-3 lists common examples.

Exercise 5-1 Probability Practice

Imagine you are rolling a single six-sided die. Write your answers as fractions. What are the probability and the odds that you will:

		Probability	Odds
a.	Roll a 4?	________	________
b.	Roll a 2?	________	________
c.	Not roll a 4 or a 2?	________	________

Now imagine that you roll two six-sided dice. What are the probability and odds that you will:

a. Roll two 4s? ________ ________

b. Roll a 4 and then a 2? ________ ________
c. Roll a 4 after having already rolled a 2? ________ ________
d. Roll a 4 on at least one die? ________ ________
e. Not roll a 4 on at least one die? ________ ________

Exhibit 5-3 Mathematical Descriptions of Probability

Symbol	What It Means
p(A)	The probability of Event A, represented as a number between 0 (impossible) and 1 (certain). The probability of rolling a three on a six-sided die is approximately 0.17.
p(not A)	The probability that Event A will *not* occur, also represented as a number between 0 and 1. This is also known as the *opposite* or *complement* of an event. The probability of *not* rolling a three is approximately 0.83.
p(A)=1-p(not A)	The chance that Event A will happen is equal to one minus the chance that it will *not* happen. The chance of rolling a three is one minus 0.83, or 0.17.
∩	Joint probability or intersection. The probability that multiple events will happen.
p(A ∩ B)	The joint probability that both Event A and Event B will happen. If the events are independent of one another, then the joint probability is found by multiplying p(A) times p(B). The chance of rolling two threes is 1/6 × 1/6, or approximately 0.03.
∪	Union. The probability that at least one event will happen.
p(A ∪ B)	The probability that Event A or Event B will happen. If the events are independent of one another, the probability of at least one happening is the sum of the chances, or p(A)+p(B). The chance of rolling at least one three on two rolls is 1/6 + 1/6, or 2/6, approximately 0.33. (Yes, the case of double threes does count as a situation in which at least one three is rolled.)
p(A|B)	The probability that Event A *will* happen if Event B happens. Imagine a gambling game in which rolling double threes entitles you to another throw. If you get double threes again, you win a large sum of money. If you have not yet thrown the dice, the probability is 1/36 × 1/36, or 1 in 1296, or approximately 0.00077. If, however, you've already thrown double threes once, the probability of doing it again rises back to 1/36. The formula is p(A|B)= p(A ∩ B)/p(B)

Distribution

In our dice example, probabilities are distributed equally. The chance of rolling a three is equal to the chance of rolling a four, or indeed of any other number. If we roll two dice and add the numbers together, however, the picture changes, as shown in Exhibit 5-4.

Exhibit 5-4 Sum of Two Dice

First Roll	Second Roll	Total
1	1	2
1	2	3
1	3	4
1	4	5
1	5	6
1	6	7
2	1	3
2	2	4
2	3	5
2	4	6
2	5	7
2	6	8
3	1	4
3	2	5
3	3	6
3	4	7
3	5	8
3	6	9
4	1	5
4	2	6
4	3	7
4	4	8
4	5	9
4	6	10
5	1	6
5	2	7
5	3	8
5	4	9
5	5	10
5	6	11
6	1	7
6	2	8
R	3	9
6	4	10
6	5	11

6	6	12

Exhibit 5-5 Distribution of Outcomes Rolling Two Dice

Number	Times It Occurs	Probability	Odds
2	1	1/36	1/35
3	2	2/36 (1/18)	2/34 (1/17)
4	3	3/36 (1/12)	3/33 (1/11)
5	4	4/36 (1/9)	4/32 (1/8)
6	5	5/36	5/31
7	6	6/36 (1/6)	6/30 (1/5)
8	5	5/36	5/31
9	4	4/36 (1/9)	4/32 (1/8)
10	3	3/36 (1/12)	3/33 (1/11)
11	2	2/36 (1/18)	2/34 (1/17)
12	1	1/36	1/35

As before, there are 36 possible outcomes for rolling two dice. Notice some numbers appear more than once, and some more than others. The probability of a given roll varies, as shown in Exhibit 5-5.

Notice that a roll of 7 has the greatest likelihood (6/36, or 1/6), and rolls of 2 or 12 are least likely (1/36). Of course, the odds of *not* rolling a seven are still 30 in 36 (5/6), so "most likely" doesn't automatically imply that it is in fact likely to happen. It's simply more likely than the other possible outcomes.

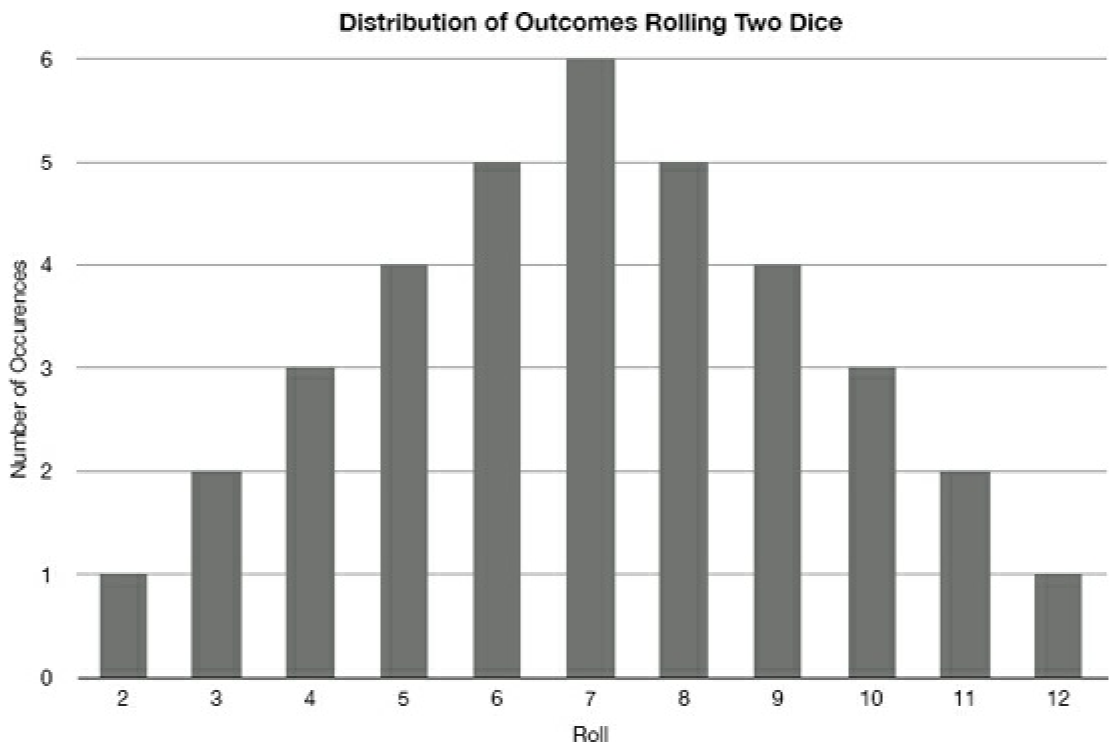
We can visualize the information by displaying it as a graph, shown in Exhibit 5-6.

Normal Distribution

Exhibit 5-6 is an example of a *triangular distribution*, with the highest value as the mean, and a steady march downward at both ends.

As the number of data points grows larger, this kind of figure often becomes curve-shaped, the famous "bell curve" known as the *normal distribution*. It's called the normal distribution not because it's superior to other distributions, but because it occurs very often in practice. (There's a mathematical concept known as the *central limit theorem* that explains why. The entry in the glossary provides a link to more information if you're interested, but it's not necessary for the course.)

Exhibit 5-6 Normal Distribution



As we've established, theoretical probability doesn't automatically equal real-world probability. Let's imagine we roll the dice 108 (36 × 3) times. Exhibit 5-6 suggests that we should expect 18 (6 × 3) rolls of seven. If the actual tally listed 19 occurrences of seven, however, we wouldn't be surprised, or think the dice were loaded. In a different set of 108 rolls, the actual number of sevens might be 16, or 21, and no one would think of this as strange.

Occasionally, less probable outcomes will show up. If we keep rolling long enough, we may encounter a case in which the number of sevens rolled jumps to a large number like 30, or another case in which seven shows up only 11 times.

The more extreme the result, the more we start to suspect that non-random factors are at work. Our basic probability rules say that if we have already rolled sevens 107 times in a row, the probability of rolling a seven on the 108^{th} try would be the same as it ever was: 6/36, or one chance in six. But the chance that will happen honestly is a little less than one chance in ten *followed by 85 zeros*. Far more probable is that you're playing with loaded dice. In that case, of course, the probability of rolling a seven on the 108th roll is what it's been all along: 100%.

In other words, if the actual number is pretty close to the theoretical number, we are inclined to think the variation is random. If the actual number varies a lot, we start to regard the difference as *significant*. There's usually a reason for a significant difference. Finding and managing reasons for such differences is a lot of what risk management and cost analysis is all about.

Common sense is often enough to identify significant differences, but it can also be misleading. A host of cognitive biases (Dobson, *Random Jottings 6*, 2011) distort our understanding and judgment when it comes to risk. Probability and statistics provide tools to help you measure and define significance in objective ways. In a normal distribution, we are interested in *measures of central tendency*, which provide information about the data at hand.

Measures of Central Tendency: Mean, Median, and Mode

Two statisticians shot at a target. One missed to the right, the other to the left. "On average," the first statistician said, "we hit it." Of course, a statistician knows that the average is not necessarily the most meaningful measure.

The average, or *mean*, of a group of numbers is easy to find. You add up the numbers and divide by the number of entries. To find the average of $1, $5, $7, and $9, start by adding $1+$5+$6+$9=$20, and divide the result by four, the number of items in the list: $20/4=$5. The average is $5. If we say, "They have about $5 apiece," that gives a reasonable picture of the relative wealth of the group.

As in the case of the target-shooting statisticians, the average is not always the most useful number. If an imaginary country has three citizens, one of whom makes $1 million and the other two make $1 apiece, the average per capita income is $333,334. If we say, "They make about $333,334 a year," however, we're obscuring the fact that two-thirds of the citizens are starving. The high average income number doesn't help us see the full picture.

We can add the *median* to the discussion. The median splits the range in the middle, so that half the values are above it and half below it. In the case of $1, $5, $7, and $9, the median is $6, because two numbers are below the median and two are above it. The mean is $5; the median is $6. When the median and mean are this close, either number reflects the relative wealth in a useful fashion.

In the case of $1, $1, and $1,000,000, the median is $1. There's one number above and one number below. In the case of $1, $1, and $1,000,000, notice that the mean is dramatically greater than the median. The median income reveals the extreme poverty in our imaginary country, but now it obscures the fact that there is an extreme wealth difference on the right side of the income scale. Identifying both mean and median provides a more complete insight into the data.

The *mode* is the number that occurs most often. In the first instance, each number only occurs once. But in the second example, the mode is $1: it occurs twice, whereas $1,000,000 only occurs once. When the mode is close to the mean and median, any of the numbers convey a similar impression. If the mode is somewhere else, then there may be a reason for the unusual spike.

These three are known as *measures of central tendency*. In other words, they tell us what the middle of the distribution looks like. In some cases, the three measures are close together or identical; in other cases, the three measures can be dramatically different.

Normal and Other Distributions

In a normal distribution, values tend to cluster around the center, with fewer incidents at the extremes of the range. If you're trying to find out if an observed difference is actually significant, you want to analyze its distribution.

Let's imagine we have a big pile of six-sided dice, and we suspect—but don't actually know—that some of them are loaded so that sevens will always result. Testing the dice with physical means will break them, which we don't want. Fortunately, we can also test them using probability.

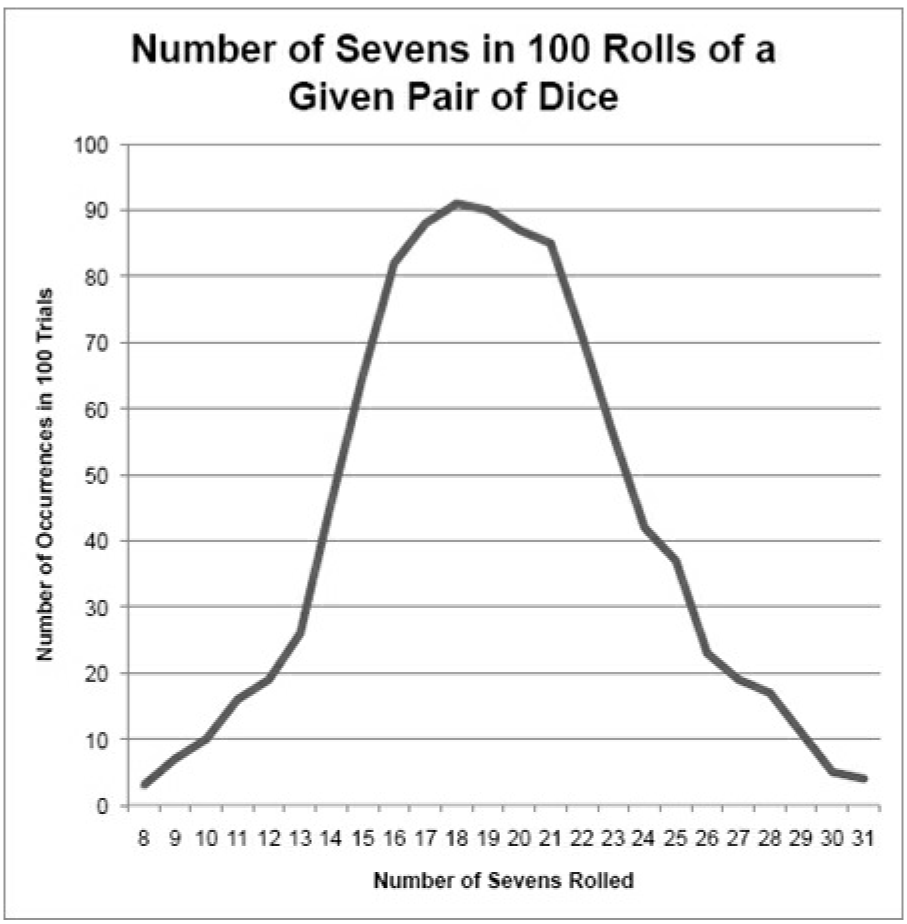
So, we design a dice-rolling machine, and feed the dice in two at a time. The machine rolls each pair 100 times, and counts the number of times a seven comes up. By the time we finish, we record data on 1000 different pairs. Let's first imagine that we get the results shown in Exhibit 5-7.

In analyzing the distribution in Exhibit 5-7, the number of sevens rolled goes from a low of 8 to a high of 31. The majority of times the results appear pretty close to 18, which is, as you'll recall, the expected outcome for 108 rolls, and there are only a few cases of extreme results on both ends. It's not perfectly textbook smooth, but that's because it's actual probability rather than theoretical. The slight irregularities in the shape don't provide a reason to suggest anything fishy about the dice.

Now let's imagine that we got very different results instead, as shown in Exhibit 5-8.

How should we interpret this distribution? For one thing, the range of outcomes is now dramatically skewed to the right. That is, there are more out-liers on the right side of the range—including one case of 100 sevens. We know immediately that at least two dice are loaded, and we want to look at the other pairs that are implicated in extremely large numbers of sevens.

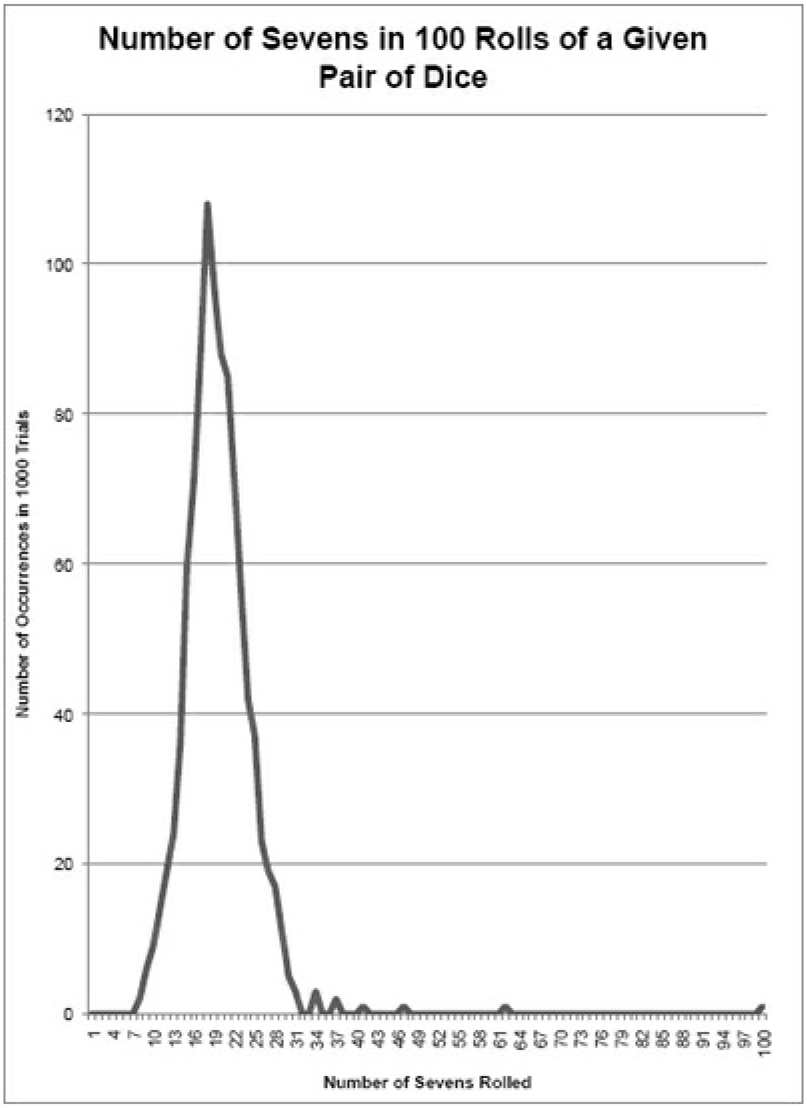
Exhibit 5-7 Analyzing a Normal Distribution



But did we catch them all? We could rerun the test to find out. Does the new distribution look more like Exhibit 5-7 or Exhibit 5-8? if we see the normal distribution emerge, we suspect that we got them all. If the distribution continues to be lopsided, we need to keep looking.

In our thought experiment, the differences were so obvious that common sense was sufficient to tell the difference. But sometimes common sense can mislead, or the differences between distributions are subtle. Here's how to do it with math.

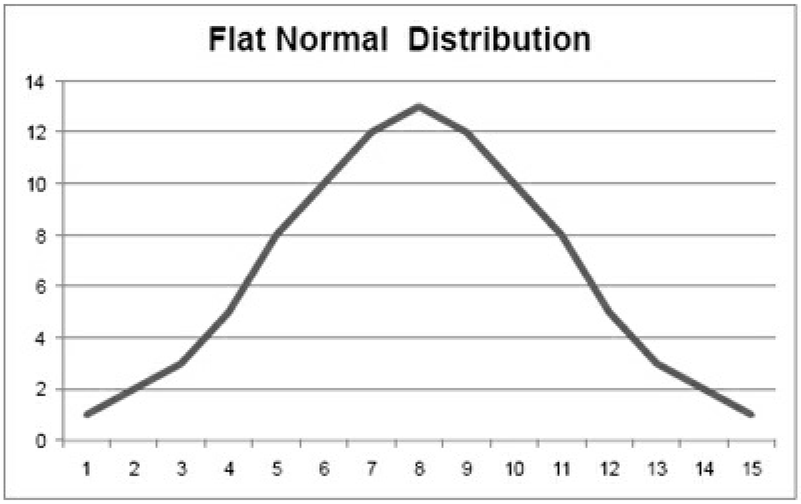
Exhibit 5.8 Analyzing a Skewed Distribution

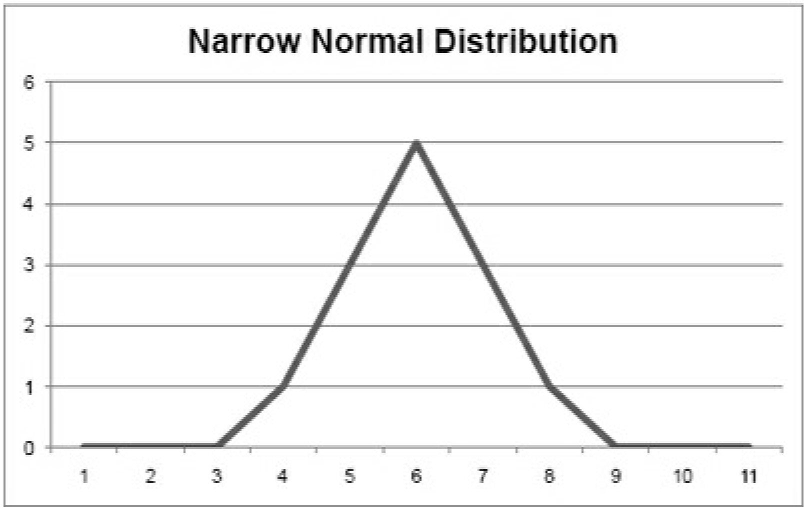


Standard Deviation

The *standard deviation* is the mathematical measurement of the variance in a given normal distribution. It tells us whether the range is spread out or bunched up, and it tells us whether an observed difference is within the normal wobble or whether it rises to the level of *statistical significance*.

Exhibit 5.9 Flat and Narrow Normal Distributions





The standard deviation is represented by the Greek character σ, the little sigma. (The big sigma, ∑, normally represents "sum.") Standard deviation measures the degree to which a normal distribution is bunched up or spread out. Let's look at two more normal distributions. Exhibit 5-9 shows two normal distributions. The top one is a "flat" normal distribution, meaning the numbers are spread out over a wide range. On the right is a "narrow" normal distribution, meaning the numbers are bunched together in a comparatively narrow range. (As you can see from its shape, this particular example may be better described as a *triangular distribution.*)

Exhibit 5-10 Standard Deviation

$$\sigma = \sqrt{\frac{\Sigma d^2}{N}}$$

σ = Standard Deviation
∑ = Sum total of what follows
d^2 = The square of the deviation from the mean for each case
N = Total number of cases
√ = Square root

Exhibit 5-11 Calculating Standard Deviations

Flat Normal Distribution Mean = 8				
Result	Number of Times	Distance from the Mean	Total d (column 2 x column 3)	d^2
1	1	7.00	7.00	49.00
2	2	6.00	12.00	144.00
3	3	5.00	15.00	225.00
4	5	4.00	20.00	400.00
5	8	3.00	24.00	576.00
6	10	2.00	20.00	400.00
7	12	1.00	12.00	144.00
8	13	0.00	0.00	0.00
9	12	-1.00	-12.00	144.00
10	10	-2.00	-20.00	400.00
11	8	-3.00	-24.00	576.00
12	5	-4.00	-20.00	400.00
13	3	-5.00	-15.00	225.00
14	2	-6.00	-12.00	144.00
15	1	-7.00	-7.00	49.00
Sum	95			3876.00

$$\sigma = \sqrt{(3876/95)} = 6.39$$

Flat Normal Distribution Mean = 8				
Result	Number of Times	Distance from the Mean	Total d (column 2 x column 3)	d^2
1	0	5.00	0.00	0.00
2	0	4.00	0.00	0.00
3	0	3.00	0.00	0.00
4	1	2.00	2.00	4.00
5	3	1.00	3.00	9.00
6	5	0.00	0.00	0.00
7	3	-1.00	-3.00	9.00
8	1	-2.00	-2.00	4.00
9	0	-3.00	0.00	0.00
10	0	-4.00	0.00	0.00
11	0	-5.00	0.00	0.00
Sum	13			2.00

$$\sigma = \sqrt{(26/13)} = 1.41$$

The standard deviation calculates how far away a number has to be from the median before it becomes *significant*, suggesting a real difference as opposed to natural random variation. Exhibit 5-

10 provides the formula.

Now, let’s compare the standard deviations of the two figures. We’ll create a spreadsheet to make the math easier, as shown in Exhibit 5-11.

Exercise 5-2 Calculate a Standard Deviation

In this exercise, you’ll calculate the standard deviation of the normal distribution from Exhibit 5-7. While you can do it by hand or with a calculator if you wish, we recommend using a spreadsheet program for speed and accuracy.

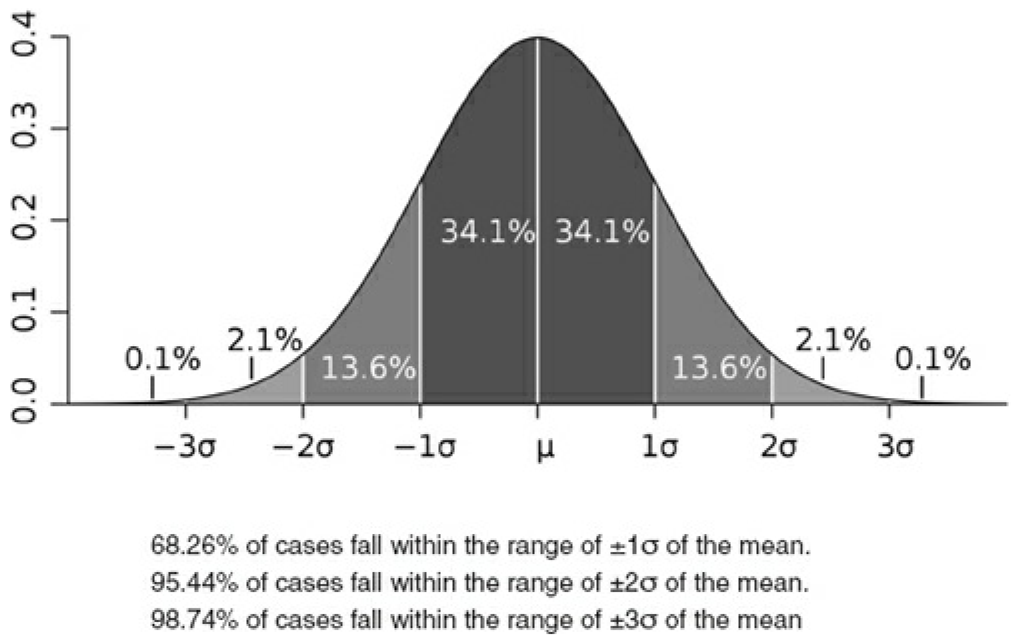
Number of Sevens Rolled in 100 Rolls of Two Given Dice Mean = ________				
Result	**Number of Times**	**Distance from the Mean**	**Total d**	**d^2**
8	3			
9	7			
10	10			
11	16			
12	19			
13	26			
14	46			
15	65			
16	82			
17	88			
18	91			
19	90			
20	87			
21	85			
22	71			
23	56			
24	42			
25	37			
26	23			
27	19			
28	17			
29	11			
30	5			
31	4			
Sum	1000			

σ = ________

What’s the value of knowing the standard deviation? Well, if the difference between the actual probability and the theoretical probability is within a standard deviation (plus or minus) of the mean, then it’s not considered statistically significant.

Imagine that the sales in your department increase by $25,000 over the previous month. The question is whether that $25,000 is significant or if it's just random. If the standard deviation is, say, $10,000, then $25,000 is a real increase in sales. But if instead the standard deviation is $100,000, then a given month's variation of $25,000 is within the expected normal range—nothing to write home about.

Exhibit 5-12: Percent of Cases within 1, 2, and 3 Standard Deviations in a Normal Distribution



CREDIT: Standard deviation diagram, based on an original graph by Jeremy Kemp, 2005. Licensed under the Creative Commons Attribution 2.5 Generic license; downloaded from Wikimedia Commons on 11 January 2011.

We divide the range into thirds, covering one, two, and three standard deviations from the mean. Each range has an associated probability, shown in Exhibit 5-12.

In any normal distribution the farther the distance from the mean of any given variable *as measured in standard deviations*, the more significant.

This, by the way, is where the name "Six Sigma," referring to the quality discipline, comes from. If errors are so rare they happen only with 6σ frequency, then they're very rare indeed, working out to somewhere around one error per one million operations.

Other Types of Distributions

Normal distributions are commonly found in nature, but they're far from the only kind. An exhaustive list is beyond our scope, but some other distributions include:

- Bernoulli distribution
- Binomial distribution

- Degenerate distribution
- Discrete uniform distribution
- Hypergeometric distribution
- Extended negative binomial distribution
- Geometric distribution
- Logarithmic distribution
- Parabolic fractal distribution
- Continuous uniform distribution
- Triangular distribution
- Chi-square distribution
- Pareto distribution

You can find a list of probability distribution functions and illustrations of what they look like by searching "list of probability distributions" on Wikipedia.

Different types of distributions suggest different ideas about how to interpret the data. Although normal distributions are very common, it's not a good idea to assume that any distribution of outcomes will automatically fall into that pattern.

Many standard tools of risk management apply concepts from probability and statistics. Probability rests on the idea of the *Law of Large Numbers*, the idea that the larger the sample population or number of trials, the more likely that actual probability will converge with theoretical probability. We often cannot predict the outcome of one single case, but the Law of Large Numbers allows us to predict the range of likely outcomes of many cases.

If the measure of a risk is the probability of its occurrence times the impact if it does occur, how do you figure out the probability? Probability is defined as the ratio of the number of desired outcomes to the number of total outcomes. The odds are slightly different: the ratio of the number of desired outcomes to the number of undesired outcomes. Theoretical probability is different from real probability. Flipping a coin 100 times will probably not result in exactly 50 heads and exactly 50 tails. If the number of heads is slightly greater or less, it's no big deal. If, however, you've just flipped 99 heads in a row, at some point you're likely to start assuming the coin is rigged.

The chance that both Event A *and* Event B will happen is measured by multiplying the probability of Event A times the probability of Event B. The probability that Event A *or* Event B will happen is measured by adding the probability of Event A to the probability of Event B. The probability that Event A will happen *if* Event B happens is measured by multiplying the probabilities of Events A and B and dividing the result by the probability of Event B.

When you combine multiple independent variables (for example, by rolling two dice instead of one), you get a distribution of outcomes. Measures of central tendency help illustrate the nature of a particular distribution. The most common measures are the mean, the median, and the mode. In a normal distribution, all three values tend to be close to the center.

Normal distributions can be wide or narrow, depending on the range. The standard deviation measures the width of the distribution, and thus helps reveal whether a particular result is merely random variation or potentially significant. Most results (roughly two-thirds) tend to fall within one standard deviation (plus or minus) of the mean of a normal distribution. The greater the distance from the mean, as measured in standard deviations, the more likely it is that a given event is statistically significant.

In addition to normal distributions, there are many other sorts of distributions. Each provides the opportunity for insight, which is why it is such an important topic in risk and cost analysis.

Review Questions

1. What are the odds of getting three heads in a row on three flips of a coin?
(a) 1/7
(b) 1/6
(c) 1/8
(d) 1/3

1. (a)

2. If a particular result is three standard deviations from the mean in a normal distribution, it should be considered:
(a) proof that something's wrong.
(b) statistically significant.
(c) normal.
(d) evidence that the distribution is not normal.

2. (b)

3. In a normal distribution, what percent of the results tend to fall within one standard deviation from the mean?
(a) over 95%
(b) 50%
(c) All of them
(d) About 2/3

3. (d)

4. Three measures of central tendency are the mean, the median, and the mode. The mode is defined as the:
(a) arithmetic average.
(b) square of the distance from the mean.
(c) most commonly occurring number.
(d) point that divides the range evenly.

4. (c)

5. The probability of rolling two sixes in a row with a single six-sided die is:
(a) 1/36.
(b) 1/35.
(c) 2/6.
(d) 6/36.

5. (a)

6

Risk Cost Analysis

Learning Objectives

By the end of this chapter, you will be able to:

- Apply the fundamental risk formula of R = P × I to an actual risk situation.
- Define risk cost analysis, contingency allowance and reserve, and risk premium.
- Identify whether a given risk has a high or low degree of variation and apply the appropriate strategy in preparing to manage it.
- Conduct a risk cost analysis and extrapolate the effect of different risk outcomes, using concepts of standard deviation, secondary risk, residual risk, and black swan events.
- Apply exclusion, capping, and reinsurance as strategies for managing black swan risk and extreme risk fluctuations.

Estimated timing for this chapter:

Reading	1 hour
Exercises	1 hour
Review Questions	10 minutes
Total Time	2 hours 10 minutes

Introduction to Cost Risk Analysis

The last chapter covered basic concepts in probability and statistics, the foundation for classical risk analysis. Statistics allows you to analyze large amounts of existing data and identify pattern. Probability gives you a glimpse into the uncertainties of the future. It is hard to overestimate the impact of classical risk analysis and risk management in the development of our modern economy. Classical risk analysis provides a rational process for taking—or avoiding—risks.

Risk and cost analysis were joined together at birth. It's hard to imagine a modern economic civilization without the ability to quantify and price risk. Insurance, for example, is risk management in action. So is safety engineering, as the *Titanic* designers unwittingly demonstrated.

Risk historian Peter Bernstein is emphatic: "Without a command of probability theory and other instruments of risk management, engineers could never have designed the great bridges that span our widest rivers, homes would still be heated by fireplaces or parlor stoves, electric power utilities would not exist, polio would still be maiming children, no airplanes would fly, and space travel would just be a dream. Without insurance in its many varieties, the death of the breadwinner would reduce young families to starvation or charity, even more people would be denied health care, and only the wealthiest could afford to own a home." (Bernstein, 63-73)

Classical Risk

To decide what, if anything, should be done about a given risk, you have to figure out what the risk is worth. As we've learned, the fundamental formula is $R = P \times I$: the value of a risk is the probability of its occurrence times the impact if it does occur. When the probability is known and the impact can be quantified financially, valuing a risk is rather straightforward: if there's a 10% chance of losing $10,000, the value of the risk is $1,000. If the cost of doing away with the risk is less than $1,000, there's a presumption that this would be a good investment. (Your mileage, as we'll see, may vary.)

In our gambling thought experiments (and assuming honest dice), we were able to calculate odds and payoffs well enough to estimate the likely return on our playing investment. Classical risk analysis emphasizes the statistical and probability mechanics of large numbers.

As we've noted, real life isn't always cooperative when it comes to providing good data. While we may sometimes know the potential impact of a risk quite precisely (if our new product fails, we will lose the money we have invested in it), in real life measuring its probability (how likely is it that our new product will be a hit?) is not so simple.

We could look at rates of general market acceptance of new products; we could look at our own history of new product introduction; we could look at indicators of economic growth; we could compile consumer survey data; we could look at the quality of our product and marketing plans. All this information could help us develop an estimate of probability. The resulting number might be useful, but it's hardly solid. We don't—we can't—*know* until the market renders its verdict.

Even worse, if it's a project we haven't done before, we may not have any historical data on which to base an estimate in the first place. In addition, there's unquantifiable uncertainty, the "unknown unknowns," made famous by former Secretary of Defense Donald Rumsfeld. There are indeed things that we do not know that we do not know. Of course, that's not nearly the same thing as being helpless to do anything about it.

Risk Cost Analysis

For our purposes, *risk cost analysis* is the process of analyzing the range of potential costs and benefits of particular risks, and using the analysis to calculate a value for that risk. The purpose of risk cost analysis is twofold: to incorporate risk-related costs into estimates and budgets, and to evaluate the financial impact of various strategies to accept or mitigate them. In short, to cost analyze a risk, we have to understand it, decide how much it's worth, and compare that to the cost of doing something about it. Risk cost analysis doesn't automatically turn into a decision, but it's important input.

This discipline has elements of both science and art. The science part consists of the mathematical tools we've been studying. The art part is deciding how much weight to give various factors in reaching your decision. If you're doing the risk cost analysis, it doesn't automatically mean you'll be making (or even recommending) the decision; that may belong to someone above you in the organization.

Let's learn how it's done. In this chapter, we'll deconstruct the steps in a risk cost analysis using the tools of classical risk management.

Insurance as a Model for Risk Cost Analysis

In the same way that gambling serves as a useful model to illustrate basic probability, insurance provides a model for the process of risk cost analysis. No matter what your field or what kind of risk you need to analyze, you'll apply some of the same principles and concepts that an insurance company would use to set its premiums.

We think of insurance as a specific category of financial product, but in a broader sense, insurance describes any money we spend to insulate ourselves from some of the impact of experiencing a particular risk. If we buy insurance against a particular risk, we're protecting ourselves against part of the impact of the risk—in this case, the financial impact. If we spend money on a safer car, we're also protecting ourselves against the impact of an accident—this time literally; we are reducing the amount of damage suffered by the occupants of the car. If we spend money to send our children (or ourselves) to driver's education classes, we are lowering the probability of an accident—which is why your insurance premiums are often lower if you have taken driver's education classes.

We build insurance into many different kinds of financial transactions. For example, when you borrow money, the price of that money (the interest rate) includes a provision for the risk that you'll default and not pay at all. If you're seen as having excellent credit, the risk is lowered, and the interest rate normally reflects that. If, on the other hand, your credit scores are poor, the risk that you won't pay back your loan increases, and so does your interest rate. You won't see that number broken out as "insurance," but in effect, that's what it is.

Risk, remember, measures uncertainty. Most people with poor credit do in fact pay their bills, and even people with great credit sometimes don't. The insurance part of your interest rate isn't about you personally: it's the law of large numbers. What is the expected default among people whose characteristics are similar to yours? If the pool you're in has a higher default rate, you get assessed your share of the total risk, no matter how virtuous your own personal attitude toward your obligations.

If groups are not carefully and thoughtfully defined, you can make important mistakes. You may be looking at a secondary factor rather than the actual risk, or failing to see a root common cause.

Contingency Allowance and Contingency Reserve

In project management, an equivalent to insurance is often expressed as a *contingency allowance*, extra money (or extra time) to compensate for *known risks*. If the price of raw materials normally fluctuates within an expected range, you may pay more or less depending on what day you place the order. If neither the day you make the purchase nor the price you will have to pay are under your control, you need to build extra money into the cost estimate in case the price that day is on the high side of the expected range.

Some authorities distinguish between a contingency allowance and a *contingency reserve*, which is money or time set aside for *unknown risks*. If supplies of the needed material suddenly quadruple in price because a war has broken out where most of the stocks come from, that's far outside the normal fluctuation. In practice, the terms are often used interchangeably.

Whether your organization distinguishes between the two types or not, it's a valuable distinction for you to make. Many organizations resist providing a formal contingency allowance, fearing that it will become the project manager's private slush fund. If you estimate materials costs using a number at the higher end of the normal range of fluctuation, however, it's more likely to be perceived as a legitimate response to risk.

Pricing Insurance Risk

When it comes to insurance, both buyers and sellers have an interest in getting the numbers right. The cost of any insurance includes the following:

- The value of the risk itself (probability times impact)
- The cost of doing business (overhead, cost of marketing and sales, financing costs, salaries)
- The profit the insurer hopes to make
- The value of any investment income the insurer receives from its reserves of cash

Insurance companies each have their own ways of measuring and valuing their risks. There are different sets of data available and different ways to segment a population. One insurance company may be willing to accept more or less risk for itself, or to price more or less aggressively to win business.

If the insurer values the risk incorrectly, there are potential consequences to both parties. If the pricing of the risk is too high, you may go elsewhere for your insurance. If the price is too low, the insurer could end up unable to pay legitimate claims and even go out of business. This does neither the insurer nor the insured any favors.

The professional who prices the risk is known as an *actuary*, and the discipline of doing so is known as *actuarial science*. no matter what your discipline, if risk is part of your environment, knowing a little something about actuarial science is important.

Risk Premiums

Because the cost of the risk itself is only one element in establishing the price of insurance, someone who buys insurance always pays a *risk premium*. The risk premium is the difference between the price of the policy and the underlying value of the risk itself.

Depending on the seriousness of a given risk, it's not inappropriate to pay a risk premium, but a good risk manager and cost analyst always wants to know how much that premium is going to be. A particular insurance policy may be a very good value, but you don't know unless you check the loss ratio—how much the insurer pays out in claims for each dollar it takes in. If the loss ratio is too high, the insurer may not be healthy—but if it's too low, you're overpaying.

Insurance Risk with Low Variation

Let's analyze the risk process and risk decision for an insurance company, using the data and assumptions in Exhibit 6-1. For now, we're only concerned with the base value of the risk, not the additional costs or profit the insurance company will use in calculating the final premium charged to customers.

The accident figures in Exhibit 6-1 are per 100,000 policyholders. With one million policyholders, we expect ten times as many accidents. Our mean, therefore, changes to 1,000. The base value of the risk is the probability (1000/1,000,000) times the impact ($10,000), which works out to 0.1% × $10,000, or $10. To pay the cost of claims (1,000 × $10,000 = $10,000,000), that implies the insurer needs to collect $10 from each policyholder to pay for the risk it is assuming. The base value of the risk is therefore $10.

As Exhibit 6-1 shows (and as our understanding of probability would lead us to expect), the number of actual covered incidents varies each year. In some years, the insurer's payouts will be higher than expected, and in some years lower. Random fluctuation suggests you may from time to time go through several years in a row with above average payouts.

If you're the insurer, how do you manage this uncertainty? If it's small enough, perhaps the ordinary cash flow of your business is enough to cover it. You may have other money you can draw on temporarily. This money may be capital, whether investor-furnished or retained from previous profits; it may be a line of credit, in which you draw money out or pay it down as a way of dampening out the effect of the fluctuation; or you may choose to change the price of the risk.

Exhibit 6-1 Assumptions for Insurance Case Study

Risky Business Insurance Company

Policy Holders:	1,000,000
Payout:	$10,000 benefit for each covered occurrence
Actuarial Data:	

Risky Business Insurance Company Historical Numbers of Covered Accidents Per 100,000 Policyholders, 2000-2010 Mean: 100			
Year	Number of Accidents	Distance from the Mean	d^2
2000	105	-5.00	25.00
2001	91	9.00	81.00
2002	98	2.00	4.00
2003	102	-2.00	4.00
2004	110	-10.00	100.00
2005	109	-9.00	81.00
2006	90	10.00	100.00
2007	103	-3.00	9.00
2008	96	4.00	16.00
2009	97	3.00	9.00
2010	99	1.00	1.00
Sum	1100		430.00

$$\sigma = \sqrt{(430/1100)} = 0.63$$

In our example, the standard deviation is very small: 0.63. The total range goes from 90 to 110 events per 100,000, which would affect your payout by a maximum of $100,000, which amounts to only 1% of the total pot. Still, you could easily have two or three down years in a row, meaning you'd have to pay out $300,000 more from your risk pool than you're collecting in premiums.

Where will you get the money if that happens? If the variance is small related to the company (1% in this case), your cash flow may allow you to pay your claims with no problems. The larger the potential variance compared to your total revenue, the bigger a problem you have.

Insurance companies raise investment capital, obtain lines of credit, and keep reserves on hand. Some categories of insurance companies are regulated, meaning that they are required by law to meet certain conditions to ensure they can pay their claims. Other categories of insurance are not regulated, and the company's leadership has to decide the desired balance between risk and prudence.

Insurance Risk with High Variation

Now let's imagine what would happen if the range were wider. Instead of a range of 90-110 accidents per 100,000 insured, let's say we have a range of 50-150. In Exercise 6-1, you'll refigure the base value of the risk based on changed assumptions. In Exercise 6-2, you'll use that information to calculate the impact of the wider range on the company's financial position.

Exercise 6-1 Greater Accident Variation

Calculate the mean and standard deviation based on the changed data from Exhibit 6-1 as provided.

Risky Business Insurance Company Historical Numbers of Covered Accidents Per 100,000 Policyholders, 2000-2010 Mean: ________			
Year	Number of Accidents	Distance from the Mean	d^2
2000	150		
2001	50		
2002	75		
2003	125		
2004	100		
2005	110		
2006	90		
2007	50		
2008	150		
2009	90		
2010	110		
Sum	1100		

$\sigma =$ ____________________

Exercise 6-12 Premium Income and Claims Outlays

Calculate the net income or loss by comparing premiums charged by the insurance company to claims paid by the insurance company.

Risky Business Insurance Company Premium Income and Claims Outlays Per Year 2000-2010				
Year	Number of Accidents	Premiums Charged ($10 x 1 million)	Claims Paid ($10,000 per covered accident)	Net Income (Loss)
2000	1500			
2001	500			
2002	750			
2003	1250			
2004	1000			
2005	1100			
2006	900			
2007	500			
2008	1500			
2009	900			
2010	1100			
TOTALS				

In doing these exercises, we notice the following. First, the mean (100) is unchanged from Exhibit 6-1, but in a bad year for accidents, the insurer could be on the hook for as much as $15,000,000, with only $10,000,000 in premiums to pay for it! A few years of losing $5,000,000/year could be seriously damaging to your financial health.

In planning for costs and risks, you have to account for this much higher degree of variation. Somehow, you have to make sure you have the cash on hand. You could use capital, either investors or retained profits. You could establish a line of credit. And, of course, you can increase the premium your policyholders need to pay.

Adding Standard Deviation to the Price of a Risk

When the potential range of outcomes is wide, risk managers can add safety margin to a project. The greatest safety would be to charge the maximum value of the risk. In this case, that would mean we use the highest number, 150 per 100,000, in the R = P × I equation. The value of the risk becomes (150/100,000) × $10,000, which reduces to 0.15% × $10,000, or $15.00. You should always be able to pay your bills, and usually make a healthy profit, but you may find your market share eroded by people whose risk premium is less steep than yours.

Alternately, you can use the standard deviation as a framework for determining an appropriate safety margin. As you found in the exercise, changing the range of accidents also increased the standard deviation fivefold, from 0.63 to 3.25.

As noted earlier, there's about a 68% chance the real number of accidents will be no greater than 1σ above the mean and a 95% chance it will be no greater than 2σ. (Yes, the standard deviation is plus-or-minus, not just plus. In this case, we're only interested in the higher side, because we can't afford the risk of paying out an extra $5,000,000 in a bad year.)

Let's look at adding 1σ to the base value of the risk. This means you would now value the risk on 103.25 accidents per 100,000 rather than 100, and that changes your premium by 32.5¢. Rounding up, that means a premium of $10.33. That looks much better to the customer than $15. The question becomes, what happens to our expected outcomes?

Exhibit 6-2 updates the information you calculated in Exercise 6-2 showing the effect of the change in pricing. As you can see, this change in risk pricing adds $3.6 million to the bottom line over eleven years and reduces the net impact of bad years. You're ahead six years out of eleven, and in two of the four losing years, the loss is less than 10%. This corresponds reasonably well to our theoretical value of 68% for 1σ.

Is that good enough? Well, you don't necessarily have to stop at 1σ. If, say, human life were at stake, you might decide that safety considerations warranted adding margins of 2σ, 3σ, or even 6σ, until you decided that you had done everything appropriate for the specific situation.

Your choices are limited, of course, by the money you have or can get, or the nature and competitive demands of the marketplace in which you operate. To compensate, there's the benefit you and customers might gain from higher degrees of safety. One size never fits all when it comes to deciding how much safety margin is appropriate. Risk cost analysis merely measures the amount it's going to cost.

Additional Factors in Risk Decisions

So far, the risks we have discussed are *primary risks*. The primary risk is the risk that is the subject of our initial concern. What we choose to do about that risk may itself be risky. The risk in our proposed solution is called *secondary risk.* If we aren't able to get rid of all the primary risk, what's left over is known as *residual risk.*

Exhibit 6-2 Effect of Premium Change on Net Income (Loss)

Risky Business Insurance Company Net Income and Loss Statement 2000-2010				
Year	Number of Accidents	Premiums Charged ($10.33 x 1 million)	Claims Paid ($10,000 per covered accident)	Net Income (Loss)
2000	1500	$10,330,000	$15,000,000	$(4,670,000)
2001	500	$10,330,000	$5,000,000	$5,330,000
2002	750	$10,330,000	$7,500,000	$2,830,000
2003	1250	$10,330,000	$12,500,000	$(2,170,000)
2004	1000	$10,330,000	$10,000,000	$330,000
2005	1100	$10,330,000	$11,000,000	$(670,000)
2006	900	$10,330,000	$9,000,000	$1,330,000
2007	500	$10,330,000	$5,000,000	$5,330,000
2008	1500	$10,330,000	$15,000,000	$(4,670,000)
2009	900	$10,330,000	$9,000,000	$1,330,000
2010	1100	$10,330,000	$11,000,000	$(670,000)
TOTALS	11000	$113,630,000	$110,000,000	$3,630,000

Secondary Risks

A *secondary risk* is a risk that comes into existence as a result of your attempt to solve the original risk. The purpose of buying insurance is to transfer some portion of financial risk associated with an event to someone else. But what happens if the insurance company goes bankrupt? That's a secondary risk, because the harm of the insurer going bankrupt only affects you if you bought insurance in the first place.

Here's another secondary risk. The insurer, as we've mentioned, may invest some part of the pool of insurance premiums in the hope of making additional money. If the investments are successful, the company can lower prices to be more competitive or it can pocket the money as profit, or (often) some combination. On the other hand, if the insurance company loses money on those investments, the company has less money for claims and expenses, and may also be unable to meet its obligations. (This is why insurance companies often have regulatory restrictions on the type of investments they are allowed to make with their cash reserves.)

Like primary risks, secondary risks can be managed. If you're shopping for insurance, you might look at an independent rating agency like A. M. Best for measures of the risk that an insurer might be at risk of bankruptcy. For the risk that an insurer might make poor investments, governments often regulate and restrict what insurers may invest in, and how much cash they must keep on hand to meet their obligations.

Sometimes, the proposed solution can be worse than the original risk. Unless you pay attention to the secondary risk of your proposed solution, you can make things worse.

Residual Risks

The *residual risk* is what's left over after you have taken action on the primary risk. For example, many times when you buy insurance, you select a deductible. The deductible is the part of a covered event the insurer won't pay for. Because the number of small accidents is often greater than the number of big accidents, the insurer is often willing to provide you with a discount for choosing a higher deductible, because they save money in two ways, by not paying (or paying less) for some events, and by avoiding the cost of processing the claim, which can be considerable.

If you have a deductible, it's still insured—by you. You are retaining the *residual risk.* If you do nothing, all the risk is residual risk. If you are able to eliminate the risk altogether, you have no residual risk. Usually, you end up somewhere in between.

Black Swan Events

In Exhibit 6-2, we identified that the fewest number of accidents in any year was 50 in 100,000, and the greatest number of accidents in any year was 150 in 100,000. In 11 years of measurement, no value has gone outside that range—but that doesn't mean it's not possible. If there's a "100 Year Event," there's a good chance it won't appear at all in the records we have.

Imagine what would happen if in a given year, our hypothetical insurance company was confronted with not 150, but 1,500 accidents per 100,000? No one expects it; it's highly improbable—but for all we know, it *could* happen. That's known as a *black swan event.*

As it applies to risk, the term originates with financier-philosopher Nassim Nicholas Taleb in his book of the same name (Taleb, 2010), and refers to events that are high-impact, hard to predict, or rare. The term "black swan" goes back to the Roman poet Juvenal, referring to something that does not exist, because in the Western world, all known swans were white. In 1697, much to the surprise of European ornithologists, Dutch explorer Willem de Vlamingh discovered black swans in western Australia. From that point on, "black swan" no longer meant "impossible," but suggested that perceived impossibility might turn out to be true.

One kind of black swan event, then, involves a flaw in our knowledge. Other black swan events involve things that are known to happen, but are extremely rare. There's not much chance *you'll* win the lottery, but it's certain *someone* will.

A third category of black swan events include those that are completely unexpected, but were not considered impossible. On September 12, 2001, one of the authors of this book was scheduled to speak at a project management conference in Chicago. In the aftermath of the 9/11 attacks, there was of course no way the conference could go forward, at no doubt great expense to its organizers. Of course, no one in the management of that conference would have put "terrorist attack" on its list of risks to be managed, and even with 20-20 hindsight, no one would suggest that was somehow a failure to exercise due diligence. Unfortunately, that didn't save them from the consequences. In planning for risk, you can't afford to ignore the possibility of something completely upsetting all your assumptions.

Three basic strategies for managing black swan risks are exclusion, capping and reinsurance.

Excluding Risks

Under what circumstances would we see a tenfold increase in accidents? We might think of natural disasters, wars, or other circumstances that would dramatically change our risk landscape.

Because of the magnitude of such events, insurance companies often exclude them. Categories of exclusion often include natural disasters, terrorist attacks, or wars. In a legal sense, an "act of God" is something so overwhelming and uncontrollable that it excuses one or both parties from an obligation they otherwise would have to fulfill. In effect, the policyholder is now self-insuring that extreme risk, because he or she will have to pay the cost of loss personally.

Contract negotiation often involves substantial risk management because many important contract issues involve allocation of risks. What if the customer wants to change something in the statement of work? What if the product doesn't perform as expected? What if unexpected problems crop up?

Capping Risks

Another strategy is capping risks. In the conditions of an insurance policy, the insurer agrees to pay $10,000 per covered event. Perhaps an individual policyholder's losses are greater; perhaps they are less. Either way, however, the policyholder gets $10,000. By limiting the amount the policy is going to pay, the insurer caps its risk exposure on an individual claim. The policyholder, by definition, self-insures any excess risk.

If you ask an insurer for a $1 million policy rather than a $10,000 policy, the insurer may be unwilling to write the policy for fear of not being able to pay the potential losses. Instead, the insurer might accept the premium and share it with other investors, each assuming one piece of the risk (known as *treaty insurance*). If the insurer has to pay the claim, it will collect from all the other investors. (The originator of the treaty usually pockets an extra share of the money for the work involved in selling and managing the treaty.)

When you *buy* insurance, you're also capping your risk. If you have a $500 deductible on your car insurance, you are capping your personal out-of-pocket costs at $500 per occurrence.

Reinsurance

Insurance companies almost always buy insurance themselves. The practice is known as *reinsurance,* and it's a way to offset risk. Treaty insurance—offsetting your risk by bringing in additional insurers—is one kind of reinsurance.

Adding 1s to the value of the risk lowers the probability of negative years and the cost of negative years by a slight amount, and increases the probability that over time, the company's profits will increase. That still may not be enough to cope with the potential loss of $4.7 million in a given year, and it's definitely not enough to cope with a black swan event disaster.

Depending on our cash reserves and the cost of the reinsurance, we might offset some or all of that risk. For example, if we felt we could handle losses of up to $750,000 (a bit less than 8%) ourselves, we could buy reinsurance that paid the difference whenever claims in a given year exceeded $10,750,000.

What's a fair risk price for the reinsurance? In Exercise 6-3, your job is to figure out the base price of the risk for the reinsurer.

Exercise 6.3
Pricing Risk

Use the estimates from the table to answer the questions.

Llewellyns of Los Angeles Reinsurance Estimate for Risky Business Insurance				
Year	Risky Business Net Income (Loss)	Reinsurer's Exposure	Base Cost of Risk Per Year	Cost Per Policyholder
2000	$(4,670,000)			
2001	$5,330,000			
2002	$2,830,000			
2003	$(2,170,000)			
2004	$330,000			
2005	$(670,000)			
2006	$1,330,000			
2007	$5,330,000			
2008	$(4,670,000)			
2009	$1,330,000			
2010	$(670,000)			
SUM				

a. Reinsurer will pay the excess if total outlays for any given year exceed $10,750,000, with a maximum payout of $5,000,000 in any year. What will the reinsurer need to charge to cover the base value of the risk according to the information we have about the last 11 years?

b. What additional factors can you think of that the reinsurer would need to consider in establishing a fair value for the risk it is taking on?

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

c. If we want a policy in which the reinsurer covered losses up to $10,000,000 rather than $5,000,000, how would you price the excess risk?

____

____

____

____

d. If the reinsurer's overhead and sales costs equal 25% of the value of the risk, and the reinsurer has a profit target of 15%, how would you estimate the premium for the $5,000,000 and the $10,000,000 policies?

Exhibit 6-3 Recommended Risk Price

Risky Business Insurance Company Premium Charge Worksheet	
Base Cost of Risk	$10.00
1σ of Base Risk	$0.33
Cost of Reinsurance ($10 million cap)	$1.32
Overhead (50%)	$5.83
Sales Commissions (15%)	$1.75
Profit Target (15%)	$1.75
Cost of Policy	$20.97

Developing a Final Risk Price

The person doing the cost risk analysis has the responsibility for making a recommendation, but not necessarily for making the decision. The decision of what a risk is worth and what we should do about it are not automatically the same thing.

In Exhibit 6-3, let's develop a recommended price for our insurance policy by rolling together the various considerations to date.

Exhibit 6-4 summarizes the effect of this policy cost on the company's financial position.

Adjusting a Risk Price Based on Market Conditions

A cost of $20.97 keeps the insurer solvent enough to pay all the claims and provides an estimated profit of 14% over eleven years, very close to the 15% target. Here, the company stays profitable each year, but only because of the reinsurance.

As a customer, you should note that you are paying a markup of 110% of the base cost of the risk. The extra $10.97 is, as we noted, the *risk premium.* Whether that's a good price for you depends on what the competition offers, how much the protection against a $10,000 loss is worth to you, and the effect of spending $20.97 on this when you could spend it on something else.

If market conditions don't allow the insurer to charge $20.97, how can you manage the risk? First, look at controllable costs. Overhead in our current example costs 50% of the risk costs. If we can reduce our costs by 10%, the price of the insurance policy drops by 58¢ with no increase in financial risk and no impact on profitability. If we are willing to accept 10% profit rather than 15%, we save another 58¢, and so on. Interestingly, cutting the reinsurance maximum from $10 million to $5 million only saves a dime, so that may not be the best place to cut.

Exhibit 6:4 Financial Results over Eleven Years

Year	Number of Accidents	Premiums Charged	Costs (Overhead, Commission, Reinsurance)	Claims Paid	Reinsurance Income	Net Income (Loss)	% Profit (Loss)
2000	1500	$20,970,000	$8,900,000	$15,000,000	$3,920,000	$990,000	5%
2001	500	$20,970,000	$8,900,000	$5,000,000	$-	$7,070,000	34%
2002	750	$20,970,000	$8,900,000	$7,500,000	$-	$4,570,000	22%
2003	1250	$20,970,000	$8,900,000	$12,500,000	$1,420,000	$990,000	5%
2004	1000	$20,970,000	$8,900,000	$10,000,000	$-	$2,070,000	10%
2005	1100	$20,970,000	$8,900,000	$11,000,000	$-	$1,070,000	5%
2006	900	$20,970,000	$8,900,000	$9,000,000	$-	$3,070,000	15%
2007	500	$20,970,000	$8,900,000	$5,000,000	$-	$7,070,000	34%
2008	1500	$20,970,000	$8,900,000	$15,000,000	$3,920,000	$990,000	5%
2009	900	$20,970,000	$8,900,000	$9,000,000	$-	$3,070,000	15%
2010	1100	$20,970,000	$8,900,000	$11,000,000	$-	$1,070,000	5%
TOTALS	11000	$230,670,000	$97,900,000	$110,000,000	$9,260,000	$32,030,000	14%

In any cost-related risk situation, the same considerations apply: what is the value of the risk and what is the cost of responding to the risk? When the cost of responding is less than the value of the risk itself, you have a powerful financial argument for acting on the risk. If it is the other way around, you have to consider whether other (noneconomic) factors justify paying the necessary risk premium.

recap

To decide what, if anything, should be done about a given risk, you have to figure out what the risk is worth. The fundamental risk formula $R = P \times I$ provides the basis for a risk cost analysis.

While in the theoretical world of gambling, probability and impact are known, in real life you may not have full or accurate information. In addition, “unknown unknowns”—risks you don’t even know you have—can complicate the situation. Risk cost analysis is the process of analyzing the range of potential costs and benefits of particular risks, and using the analysis to calculate a value for that risk. The purpose of risk cost analysis is twofold: to incorporate risk-related costs into estimates and budgets, and to evaluate the financial impact of various strategies to accept or mitigate them.

Risk cost analysis often involves weighting different factors, including market conditions that determine whether costs can be passed through to you own customers. In the same way that gambling serves as a useful model to illustrate probability, insurance serves as a useful model for risk cost analysis. In a practical sense, insurance can be thought of as any money you spend to protect yourself against risk.

In project management, an equivalent to insurance is often expressed as a contingency allowance, extra money (or extra time) to compensate for known risks. A contingency reserve is extra money (or extra time) set aside for unknown risks.

Only by assessing a risk’s proper value can you evaluate the cost-effectiveness and appropriateness of different strategies and options for responding to it. If you value a risk too high or too low, there may be serious consequences to you and to your customers.

Because an insurer has costs, the charge for insurance is normally greater than the base cost of the underlying risk. The difference between the base cost and the charge is known as a risk premium. Depending on the seriousness of the risk and the amount of the premium, it may be a good investment—but not in every case.

When the expected variation is low, normal fluctuation in actual values is not serious. When the expected variation is subject to wild swings, you may require additional layers of protection against risk. You can absorb these swings if your financial condition permits. You can charge a higher premium to cover the risk. Adding one or two standard deviations to the base cost of the risk reduces the risk to the insurer.

In addition to primary risk, you may also need to account for secondary risk (new risks brought on by your proposed response to the primary risk) and residual risk (the risk left over after your proposed response). There are also black swan events, risk events that are high impact, hard to predict, or rare.

Three strategies for managing excess risk, whether black swan, secondary, or residual are:

- *Exclusion.* When you exclude a risk, you refuse responsibility for paying for it. Contract negotiation often involves deciding which risks are outside the contract or require renegotiation and additional payments.
- *Capping.* When you cap a risk, you identify a maximum amount you are willing or able to pay, and

if the actual costs are greater, your responsibility stops at the maximum.
- *Reinsurance.* You can transfer certain of your risks to other entities so that your maximum payout obligation is limited.

The person doing the cost risk analysis has the responsibility for making a recommendation, but not necessarily for making the decision. The decision of what a risk is worth and what we should do about it are not automatically the same thing. Nevertheless, the decision needs to rest on a foundation of good data.

Review Questions

1. The difference between the price charged for covering a risk and the base cost of the risk is known as a:
   (a) risk premium.
   (b) secondary risk.
   (c) black swan risk.
   (d) reinsurance risk.

1. (a)

2. If the standard deviation for occurrences of a particular risk is higher 2. (b) than the standard deviation for occurrences of a different risk, what conclusion can be fairly drawn?
   (a) The first risk is more likely to happen.
   (b) The range of the first risk has a greater variance.
   (c) The second risk is less important.
   (d) The second risk is more expensive to cover.

2. (b)

3. The difference between a contingency allowance and a contingency 3. (d) reserve is that the contingency allowance is a provision for:
   (a) unknown risks
   (b) residual risks.
   (c) black swan risks.
   (d) known risks.

3. (d)

4. If the secondary risk is greater than the primary risk, what should you do? 4. (c)
   (a) Accept a greater amount of residual risk.
   (b) Accept the secondary risk.
   (c) Try to reduce the secondary risk to an acceptable level, and if you can't, consider using a different strategy.
   (d) Purchase reinsurance.

4. (c)

5. How does risk management apply to contract negotiation? 5. (c)
   (a) The seller must accept risks of non-performance.
   (b) The buyer must offer additional money to cover expected risks.
   (c) Ownership of specific risk events may be allocated to buyer or seller.
   (d) The contract requires purchase of insurance or reinsurance.

5. (c)

7

Quantitative Cost Analysis Tools

Learning Objectives

By the end of this chapter, you will be able to:

- Identify whether a particular cost is deterministic or probabilistic.
- Perform a cost-benefit analysis including both deterministic and probabilistic costs.
- Calculate an Expected Monetary Value (EMV) for two or more states of nature.
- Prepare and interpret a decision tree analysis.
- Perform a sensitivity analysis.

Estimated timing for this chapter:

Reading	30 minutes
Exercises	2 hours 40 minutes
Review Questions	15 minutes
Total Time	3 hours 25 minutes

Quantitative Cost Analysis

Quantitative risk analysis tools, as we've noted, exist in many areas of business, from engineering and quality to finance and scheduling. Some are highly specialized, while others are commonly used across many organizations and disciplines. In this chapter, we'll explore some of the more common quantitative tools for cost, and in the next, we'll cover quantitative schedule analysis.

Cost Estimating Under Uncertainty

Cost estimates, because they involve the future, typically involve both qualitative and quantitative risk analysis. In our example of pricing an insurance policy in the previous chapter, we saw some of the complexity a cost estimate can contain. You may not need to go into that level of depth, but it's often important for you to apply the same kind of thinking whenever you have to prepare a cost estimate or budget request.

Cost numbers fall into two rough categories.

- *Deterministic costs* are fixed and known, at least within the time period covered by the project. If the trade show has announced that the cost of renting a 10×10 exhibit booth is $5,000, we can determine the precise cost for whatever booth size we choose to get.
- *Probabilistic costs* have uncertainty. We have to put together a budget for a proposed relocation before we shop for space. The average cost of leasing office space in our city is $150 a square foot, but that's an *average.* What we will actually pay cannot be determined with precision.

From a risk management perspective, we're only concerned with probabilistic costs. Let's take the $150/square foot real estate price. As in the insurance price case, we can present this number several different ways, depending on the safety that's appropriate. How accurate does the estimate need to be, and how much variance exists in the range? If your estimate has to be accurate within 10% (±$15), and prices range from $135 to $165/foot, then the average price is accurate enough.

What if the range of prices goes from $135 to $250? The right answer depends on how the cost estimate will be used. You might want to know the worst-case scenario, in which case $250 might be the right answer. You might want to know that there was no way you could pay less than $135. You might want to start with what you can afford, and cap it—you won't look at anything costing more than $175, so that number becomes the new ceiling.

A risk-based cost estimate should always be expressed as a range ($150/foot ± $15, or $135-170/foot). Always define the scope of what you're estimating (cost of leasing 10,000 square feet of office space in a downtown location close to a subway station), how long the estimate will remain useful (current prices, subject to market change), and any assumptions being made (Class A office space only, no unusual buildout needs).

Cost Risk Analysis Tools

Common tools for quantitative risk analysis of costs are cost-benefit analysis, Expected Monetary Value (EMV), decision tree analysis, and sensitivity analysis.

Cost-Benefit Analysis

Risk contains opportunity and threat. Cost-benefit analysis also has a risk component, because you have to price the uncertainties of both positive and negative outcomes in balancing a business risk.

The phrase "bottom line" comes from the output of cost-benefit analysis. In order to compare costs and benefits, you have to quantify all aspects of the project, both positive and negative, in the same unit (usually, but not always, currency) and at the same point in time (comparing the value of money in the future to money right now). The equations for determining the net present value (NPV) of future money are not specifically about risk management, and they're available in any good finance reference.

What if there are costs and benefits you can't put in dollars? Well, they don't show up in the cost-benefit analysis, and aren't reflected in the bottom line. If the cost-benefit analysis turns out positive anyway, it doesn't matter. If the cost-benefit analysis turns out negative, you still have to put a minimum price on those intangibles—how much it would take to turn the cost benefit results positive.

The Acme Widget Company is having trouble meeting demand for its custom widget designs, and is thinking about buying a new widget maker, which would add 100,000 widgets a year to production. Widget makers run between $100,000 and $250,000. The company makes a gross profit of between $5 and $7 dollars per widget, and has additional overhead costs that consume $4 per widget sold.

If we take everything at face value, then the cost-benefit analysis would look something like Exhibit 7-1. Notice that because our numbers include ranges, our cost-benefit analysis also includes ranges.

Exhibit 7-1. Cost-Benefit Analysis

Cost-Benefit Analysis for New Widget Maker			
	Low	High	Mean
Additional Gross Profit	$500,000	$700,000	$600,000
(less) Cost of Equipment	$100,000	$250,000	$175,000
(less) Additional Overhead	$300,000	$300,000	$300,000
Net Benefit	$100,000	$150,000	$125,000
Benefit Per Month	$8,333.33	$12,500.00	$10,416.67
Number of Months to Amortize Purchase	12	20	17

Of course, not all these numbers may be as fixed and known as they appear. In Exercise 7-1, let's figure out which of these numbers are deterministic and which are probabilistic.

Exercise 7-1. Deterministic or Probabilistic?

Number	Deterministic	Probabilistic
Make 100,000 new widgets per year with the new equipment		
Sell the additional 100,000 widgets to customers		
Buy a widget maker for a price of $100,000 to $250,000		
Make a gross profit of $5 to $7 per widget		

Incur overhead costs of $3 per widget sold		

It turns out that only one of our numbers is deterministic, the rest probabilistic. For each of the probabilistic numbers, we have to figure out what values we want to use. And for that, we have to dig a little deeper into the situation.

Expected Monetary Value (EMV)

Our basic risk formula R = P × I is an example of an *Expected Monetary Value* (EMV) calculation. If there's a 10% chance of a $10,000 problem (or opportunity), the EMV is $1,000. Of course, *you* won't have to pay (or receive) $1,000. *You* will get one of the two outcomes: no penalty (or benefit), or the full $10,000 (plus or minus).

One benefit of the EMV involves the law of large numbers. A given risk will or will not happen, but of all the risks on your project, *some* will happen. Let's imagine we have a project with a base cost of $500,000, and we've found 20 minor risks with an average risk score of $1,000 that we choose to accept. If we add $20,000 (20 x $1,000) in contingency allowance to the project, it doesn't particularly matter to us which of those risks end up consuming the $20,000.

There may be more than one alternative. In that case, the EMV has to add together probabilities and impact for each potential outcome (sometimes referred to as each "state of nature"). Let's say that for an investment of $8,000, you have a 25% chance of losing $3,000 (you get $5,000 back), a 25% chance of making $2,000 (you get $10,000 back), and a 50% chance of earning $12,000 (you get $20,000 back). Exhibit 7-2 shows how to calculate the EMV.

Exhibit 7-2 Expected Monetary Value (EMV)

First possible outcome:	25% × $5,000	=	$1,250
Second possible outcome:	25% × $10,000	=	$2,500
Third possible outcome:	50% × $20,000	=	$10,000
Expected Monetary Value (EMV)		=	$13,750

Or, you can write it this way:

EMV = (0.25 x $5000) + (0.25 x $10,000) + (0.5 x $20,000)

EMV = $13,750

You can compare this EMV to the potential investment to help decide whether it's worth the risk. Ignoring for the moment the time value of money (let's assume it's a short-term investment), the return is $5,750, or 71 percent. Looks good—if you can afford the potential downside of losing $3,000.

In Exercise 7-2, you can try it yourself.

Exercise 7-2 Calculating Expected Monetary Value (EMV)

The Veeblebrox 3000 widget maker produces custom widget designs at a cost of $15 per widget, and produces 1,000 widgets per run. Thirty percent of the time, the widgets are perfect. The rest of the time, there are some defects, shown in the table below. The cost of repairing each defect is $200. What is the EMV cost for 10,000 widgets if you also have $50,000 in fixed costs?

We recommend you use a spreadsheet to solve this problem. If you need help, the formulas are provided separately from the final answer.

Errors	Likelihood
0	30%
1	40%
2	20%
3	10%
5	5%
10	1%

Decision Tree Analysis

If you compare the EMVs of different alternatives, choices, or conditions, you create a *decision tree.* We'll use the investment we developed in our discussion of expected monetary value, and call that Investment A. The EMV, as you remember, was $13,750, representing a gain of $5,750 on our $8,000 investment.

We have another opportunity, Investment B. This one's pricier, costing $12,000. It's also riskier, but it has a very attractive payday. There's a 60% chance you'll lose all your investment, a 30% chance you'll get $20,000, and a 10% chance of making $100,000.

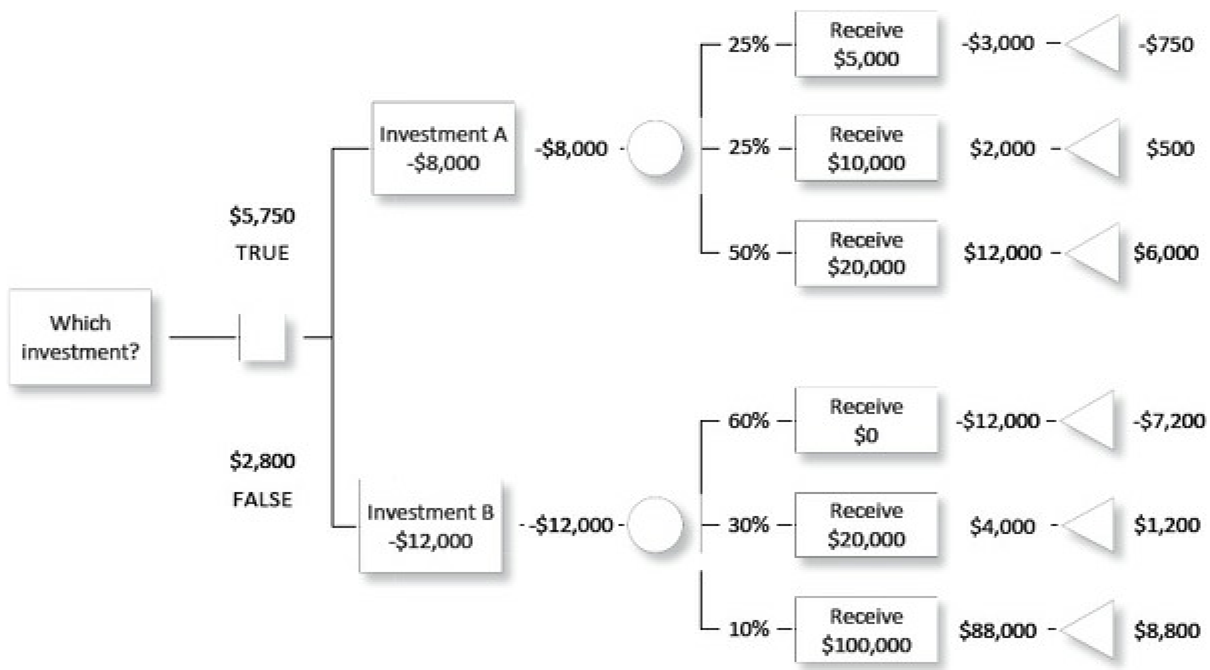
Exhibit 7-3 shows a side-by-side comparison of the two investments using a decision tree.

Here's how to read it. Start with the question at the left: Which investment (shall we make)? The square to the right of the question represents a *decision node.* This decision node has two branches, one leading to Investment A and one leading to Investment B. (Forget the "True/False" values for now. They're added at the very end.)

Investment A has a cost of $8,000. The circle to the right of Investment A is called a *chance node.* Like a decision node, it generates new branches, but as the name implies, the outcome isn't up to you. The probabilities and outcomes for each alternative come next. The first outcome of Investment A is that you get back $5,000. This is a net loss of $3,000. Because there's a 25% chance you'll get that outcome, the EMV for that branch is -$750.

When we finish calculating all three branches for Investment A, we add up the EMVs for each outcome, and get $5,750. We write that above the decision node—in other words, that's the EMV for the decision to choose Investment A

Exhibit 7-3 Decision Tree



Next, we do the same thing for Investment B, and find that its EMV totals $2,800. We write that below the decision node. And the decision tree is clear: $5,750 beats $2,800. The Investment A decision is labeled TRUE, and the other(s) are labeled FALSE.

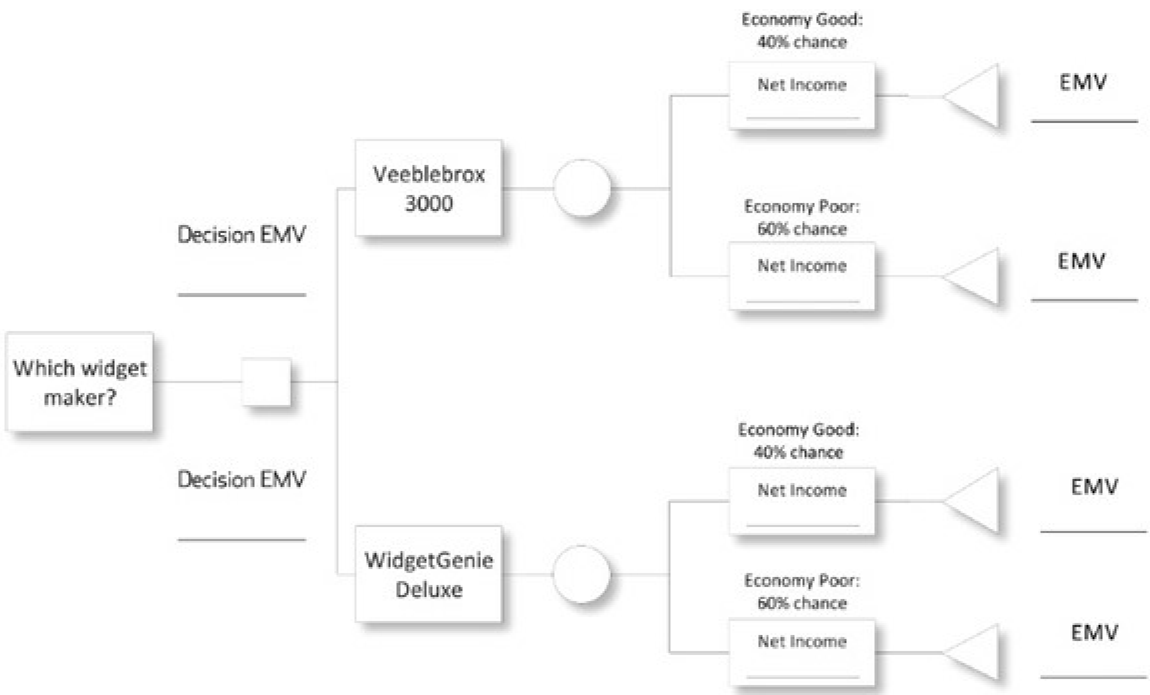
Think About It … (Decision Tree)

What price for Investment B would make it equal in EMV to Investment A?

Exercise 7-3 Decision Tree

You're ready to buy a new widget maker, and you're looking at the Veeblebrox 3000 and the new WidgetGenie Deluxe. The Veeblebrox costs $100,000 and the WidgetGenie costs $75,000. The cost per widget for the Veeblebrox is $15 and for the Widget Genie it's $12. The Veeblebrox has a net error rate of 2% (repairs cost $200 each) and the WidgetGenie has an error rate of 3% (repairs cost $150 each). If the market is good (40%), you can sell 500,000 widgets a year at $20 per widget, but if it's poor (60%), sales will only average 250,000 and you can't get more than $18 per widget.

Which machine is a better buy?



Net Income Worksheet (for Each Outcome)

Gross Revenue	__________
(minus) Manufacturing Cost	__________
(minus) Cost of Errors	__________
(minus) Cost of Equipment	__________
Net Income	__________

Sensitivity Analysis

If you change an assumption, what happens to the outcome? Let's continue with the Veeblebrox vs. WidgetGenie example. The Veeblebrox 3000 produces 2% defective widgets, while the WidgetGenie produces 3% defectives. What if the lower defect rate of Veeblebrox widgets allowed you to charge a 10% price premium?

The process of figuring this out is known as *sensitivity analysis,* the measurement of how a change in a specific assumption or variable affects the bottom line. In this case, the effect is dramatic. Compare the table in Exhibit 7-4 to the answer you developed for Exercise 7-3.

If a 10% price premium changes the decision analysis this drastically, how about some other changes? In Exercise 7-3, use the spreadsheet template you developed in Exercise 7-2 (or copy the one in the answer key), and model the following scenarios. But before you do, make a guess: will this change flip the recommended decision? You may be surprised at which changes make the greatest difference.

Exhibit 7-4 Sensitivity Analysis

Category	Veeblebrox 3000		WidgetGenie Deluxe	
	Good Economy	Poor Economy	Good Economy	Poor Economy
Widgets Sold	500,000	300,000	500,000	300,000
Price Per Widget	$22	$21	$20	$19
Gross Revenue	$11,000,000	$6,270,000	$10,000,000	$5,700,000
Cost Per Widget	$15	$15	$13	$13
Manufacturing Cost	$7,500,000	$4,500,000	$6,500,000	$3,900,000
Error Rate	2%	2%	3%	3%
Number of Errors	10,000	6,000	15,000	9,000
Cost Per Error	$200	$200	$150	$150
Total Cost of Errors	$2,000,000	$1,200,000	$2,250,000	$1,350,000
Cost of Equipment	$100,000	$100,000	$250,000	$250,000
Net Income	$1,400,000	$470,000	$1,000,000	$200,000
Probability	40%	60%	40%	60%
EMV	$560,000	$282,000	$400,000	$120,000
EMV of Decision	$842,000		$520,000	

Exercise 7-4 Sensitivity Analysis

For each scenario, what are the new EMVs for Veeblebrox and WidgetGenie? Does the decision tree analysis change?

- What if Veeblebrox sold a maintenance package that reduced its error rate to only 1%?

- What if the Veeblebrox was so much faster than the WidgetGenie that you could make and sell 600,000 units in a good economy and 500,000 in a poor economy, as opposed to the WidgetGenie projection of 500,000/300,000?

- What if the cost of fixing Veeblebrox errors dropped from $200 to $100?

- What if WidgetGenie doubles the price on their equipment?

recap

Quantitative tools for risk analysis include cost-benefit analysis, expected monetary value (EMV), decision tree analysis, and sensitivity analysis. They address probabilistic costs, costs with uncertainty. Deterministic costs, in contrast, are fixed and known.

Uncertainty is presented different ways, depending on the purpose for a particular cost estimate. If you want the worst-case scenario, you deliberately pick the most negative assumptions. If you want an average or a median, you develop the estimate accordingly. You should always express a risk-based cost estimate as range, and along with the estimate itself you need to define the scope of the estimate, any assumptions being made, and how long the estimate is likely to remain valid.

Cost-benefit analysis often requires you to price the uncertainties in both costs and benefits; to do so, you must always determine which numbers are deterministic and which are probabilistic.

The expected monetary value (EMV) calculation is essentially the formula for pricing a risk: the probability times the impact summed together for each state of nature. Decision-tree analysis compares EMVs side-by-side to evaluate different decisions or scenarios. Sensitivity analysis measures the effect of a specific change in assumptions or other variables on the bottom line.

These tools are only a selection of what is available. Depending on the specific environment and industry in which you work, you may find additional tools you need.

Review Questions

1. If a given investment has a 20% of gaining $10,000 and an 80% chance of losing $4,000, what's the expected monetary value?
   (a) + $5,200
   (b) - $1,200
   (c) - $5,200
   (d) + $1,200

1. (b)

2. The term "bottom line" comes from which financial tool?
   (a) Cost-benefit analysis
   (b) Decision tree analysis
   (c) Expected monetary value analysis
   (d) Sensitivity analysis

2. (a)

3. A circle in a decision tree diagram indicates:
   (a) a decision node from which different outcomes branch.
   (b) a chance node from which different outcomes branch.
   (c) an end node signifying the final outcome of a given branch.
   (d) an EMV calculation of a given risk factor.
4. Using the Veeblebrox/WidgetGenie sensitivity analysis data, what would happen to the buying decision if the cost of repairing defective widgets on the Veeblebrox were the same as for the WidgetGenie?
   (a) Veeblebrox 3000 by $250,000
   (b) Veeblebrox 3000 by $210,000
   (c) WidgetGenie by $270,000
   (d) WidgetGenie by $210,000

4. (b)

5. Consider the cost of an insurance policy and the cost of repairing the car in the event of a fender-bender. Which costs are deterministic and which are probabilistic?
   (a) Policy cost is deterministic; repair cost is probabilistic.
   (b) Policy cost is probabilistic; repair cost is deterministic.
   (c) Both costs are deterministic.
   (d) Both costs are probabilistic.

5. (a)

8

Quantitative Schedule Analysis Tools

Learning Objectives

By the end of this chapter, you will be able to:

- Apply sensitivity analysis to project schedule issues.
- Use the tools of network diagramming and critical path analysis to construct a network diagram from a list of tasks, perform a forward and backward pass on a network diagram, identify the critical path in a network diagram, and calculate total float and free float in noncritical activities.
- Describe the three types of schedule risk.
- Create a three-point estimate for a work package with uncertain duration.
- Calculate a PERT time using a three-point estimate and determine the standard deviation for a work package and for a path using the PERT method.
- Establish a confidence level for achieving a given finish date given a PERT analysis.
- Describe the process used by a Monte Carlo simulation program for project risk management.

Estimated timing for this chapter:

Reading	50 minutes
Exercises	1 hour 45 minutes
Review Questions	10 minutes
Total Time	2 hours 45 minutes

Sensitivity Analysis for Scheduling Issues

Sensitivity analysis works for time as well as for cost. We’ve been talking about cost so far, so let’s use a schedule example. We’re putting a swimming pool in our back yard. We’ve built some safety into our schedule. According to the plan, we are scheduled to finish four days ahead of the pool party.

One task in our project is called “Dig hole.” Another task is “Pour concrete.” Obviously, we can't pour the concrete until after we've dug the hole. If pouring the concrete runs late, the anticipated finish of the project also goes late by the same amount. "Dig hole," clearly, is at risk of taking longer than the scheduled time. What's the effect on the project deadline if it does go late, say by one day? At first glance, the answer appears to be none. We have, after all, four days of total margin. One day isn't a big deal. (At least not for the schedule. It might affect cost, especially if we're paying people by the hour to dig the hole.)

What if we're contracting out the pouring of the concrete? Now, it's a different story. If the concrete truck is scheduled to pull up bright and early Tuesday morning, and the hole is only half-done, our problem suddenly balloons. It's not just one day any more. Depending on how busy the contractor is, that one-day delay in digging the hole might cost us a week or more until we can get that concrete poured—and pretty much everything else will come to a screeching halt.

Earlier, we classified costs as either deterministic or probabilistic, depending on whether they were fixed and known. We can apply the same categories when we think about time. If you sign up for a three-day workshop, the three days are deterministic. You can put them in your schedule. The seminar won't take two days or four days. The time-span is fixed and known.

This self-study sourcebook contains time estimates as well, based on known metrics for reading speed and length of time to complete exercises. But these estimates are probabilistic, because they are based on averages. Your mileage, as they say, may differ.

Schedule Risk Analysis

The technique of network diagramming enables you to display a project schedule graphically. This has numerous advantages, but for our purposes, we are concerned with network diagramming as it applies to risk management.

Time, as we all know, is money. The discipline of quantitative risk analysis must consider schedule issues as well as actual dollar costs. The length of time it takes to do the work often affects the cost, especially when people are paid by the hour. In addition, the consequences of meeting or failing to meet a deadline can be in some cases quite substantial.

The discipline of project management has long wrestled with the problem of managing uncertainty, with the first major breakthrough coming in 1957, when the U.S. Navy's Polaris Special Projects Office and consultants from (then) Booz Allen Hamilton developed a special statistical approach to scheduling when the durations of activities were probabilistic.

The Polaris Evaluation and Review Technique helped manage what was at the time the most complex engineering project ever attempted. The "Polaris" gave way to "Program," and the *Program Evaluation and Review Technique* became known as PERT. More or less at the same time, the DuPont Corporation, working with Remington Rand, developed the *Critical Path Method,* commonly called CPM. Both tools involve a method called *network diagramming* The technique of network diagramming enables you to display a project schedule graphically. This has numerous advantages, but for our purposes, we are concerned with network diagramming and schedule development as it applies to risk management.

Schedule Development

Two scheduling tools are common in project management: the Gantt chart, which is essentially a bar graph over a calendar; and the network diagram, which shows the sequence in which activities will be performed. For small-and medium-sized projects, the Gantt chart is the most common and easiest scheduling tool; for very large projects, the network diagram is more appropriate. Our risk management discussion will focus on network diagramming; for information on Gantt charts, consult a standard project management reference book.

In the 1950s, the preferred technique for network diagramming was the *activity on arrow* method, also known as *arrow diagramming*. Today, virtually all project management practitioners use the *precedence diagramming method* (PDM), also called *activity on node,* which we will use throughout this section. Exhibit 8-1 shows the difference between the two techniques.

Network Diagramming and Critical Path Analysis

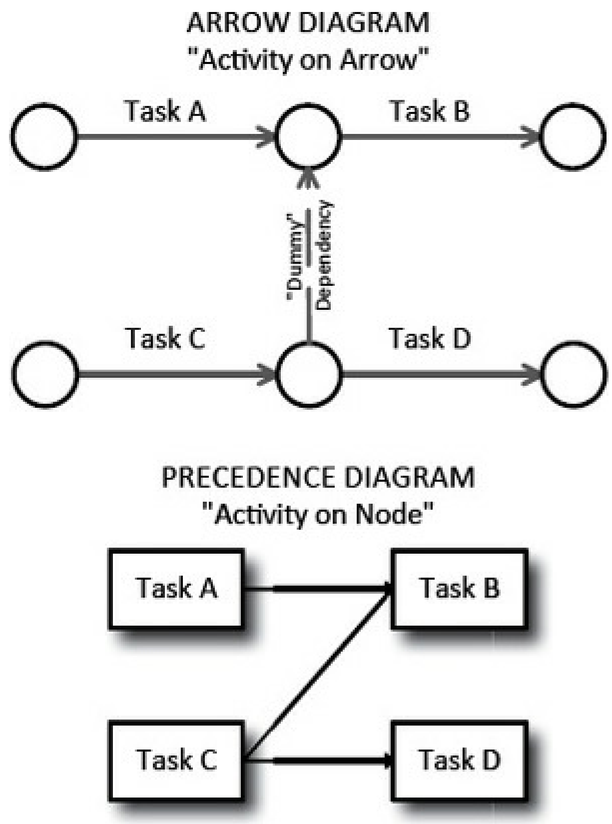
A network diagram resembles a computer flow chart. For our purposes, the easiest way to build a network diagram is to use sticky notes. Each note will list one of the work packages or tasks to be performed. We'll put the notes in the order in which we'll do the work, and draw connecting arrows to show the workflow. Exhibit 8-2 shows a formal example created by computer software, but ours will be a bit more casual.

The first step is to create a "Start" milestone for your project. A milestone is a work package that has zero duration and no associated work or resource consumption. In other words, a milestone is simply a signpost. Traditionally, a milestone on a Gantt chart (but not a network diagram) is represented by a diamond. Sometimes it makes it easier to read if you turn a sticky note 45° to indicate that a given work package is a milestone.

Next, lay out the subsequent work packages in the order they are to be performed. Activities can be dependent (following a predecessor activity) or parallel (performed at the same time as other project activities. Dependent activities are sometimes required by the logic of the work (i.e., you can't conduct a beta test of the training unless the training materials have been developed), and are sometimes driven by available resources or other factors (for example, the same person can develop the workbook and the exercises, but not at the same time. If no particular order is demanded by logic, you can choose whichever order you prefer).

Exhibit 8-1. Arrow vs. Node

Both diagrams represent the same relationships: Task B is dependent on Tasks A and C; Task D is dependent only on Task C. The "dummy" dependency in the arrow diagram shows the extra dependency relationship.



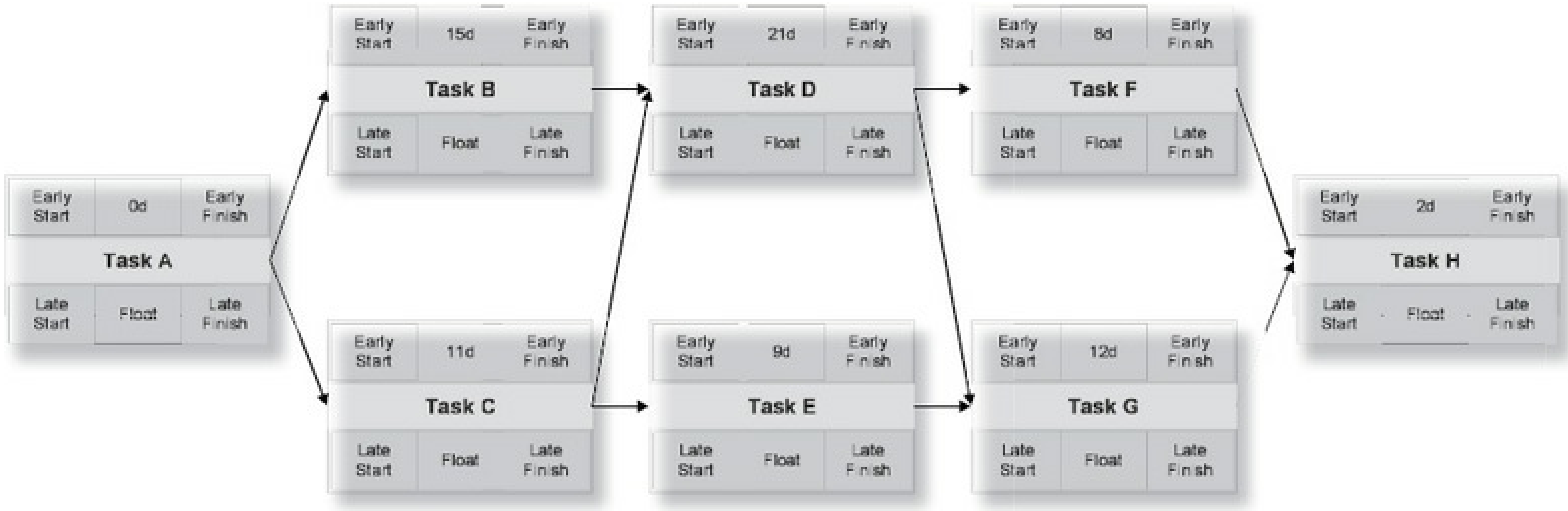
When all activities have been placed and connecting lines drawn, create a “Finish” milestone. Connect all unlinked activities to Finish so that every work package has at least one predecessor and at least one dependent activity—don’t leave any orphaned work packages.

Normally, more than one sequence of activities is possible. The correct order for your project is the one that represents how you and your team plan to approach this project. Exhibit 8-2 shows a sample network diagram.

Here’s how to read the network diagram in Exhibit 8-2. Task A is a milestone and serves as the start of the project. Both tasks B and C are dependent on the start milestone. Task D is dependent on both tasks B and C; task E is dependent only on task C. Task F is dependent on task D; task G is dependent on both tasks D and E. Task H, the finish milestone, is dependent on both tasks F and G.

Exhibit 8-2 Network Diagram

This network diagram reflects the order in which work packages will be performed. Note that estimated durations have been assigned to each activity.



Forward and Backward Pass

So, how long will the project take? With dependency relationships crossing from top to bottom and back again, the answer takes a little bit of calculation. You need to find the longest path (called the *critical path*) through the project network to determine the length of the project. If you use project management software, it will determine the critical path for you automatically. To calculate the critical path manually, you must perform a forward pass followed by a backward pass.

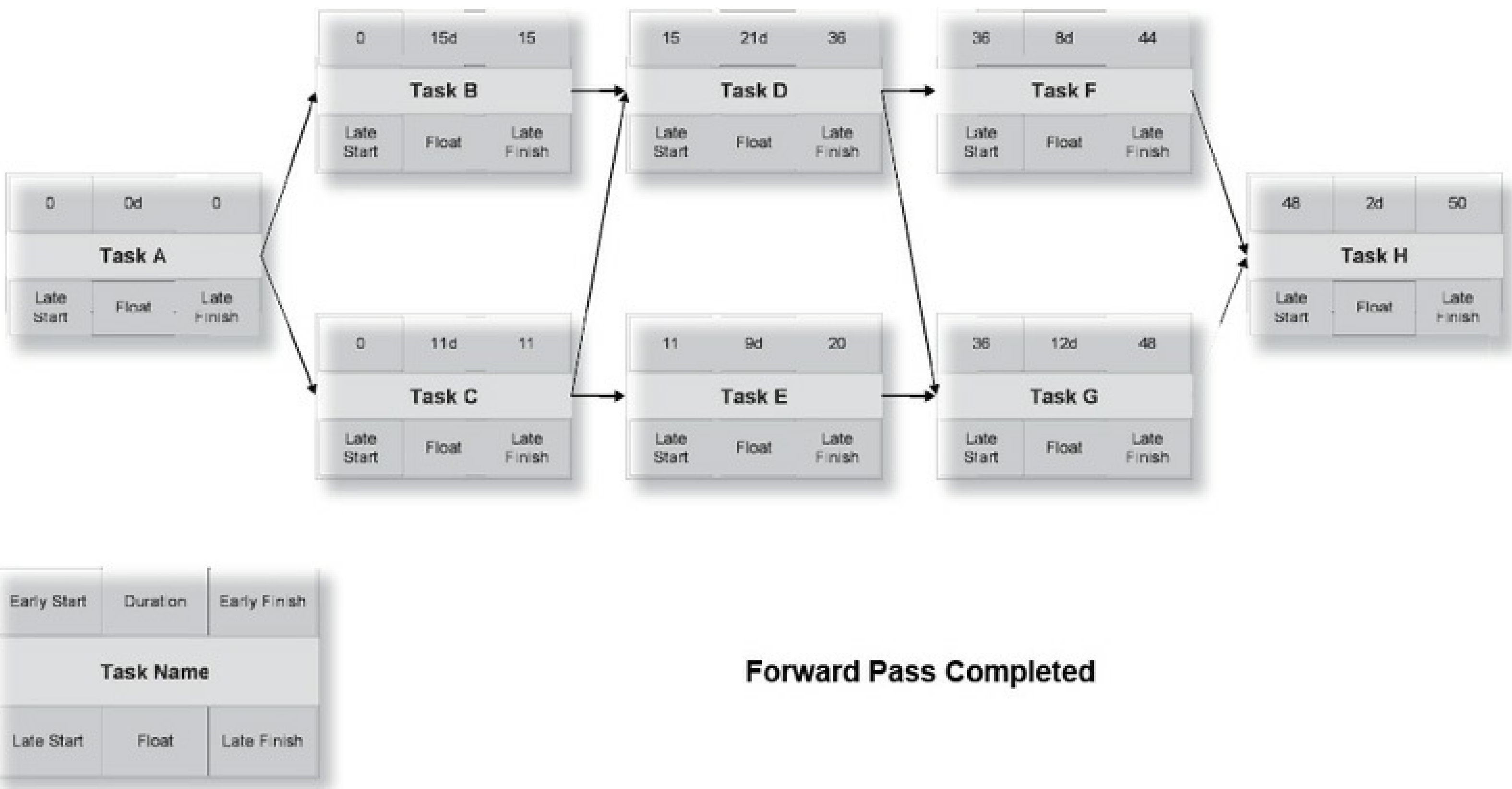
Forward Pass

The forward pass calculates the early start and early finish for each activity. The final number in the forward pass calculation is the planned duration of the project. Exhibit 8-3 shows the forward pass.

Starting in the upper-left corner of the first work package, you enter a zero, which represents the start of business of the first day of the project. Add the task duration to the start, and write that number in the upper-right corner. In task A, the early start (0) is added to the duration (0) to get the early finish (0+0=0). Copy the early finish number into the connected Tasks B and C, and add the respective durations (0+15=15 and 0+11=11).

Task E, you'll note, is dependent only on Task C, and can start on day 11. Task D, however, is dependent on both Tasks B and C. Because Task D cannot begin until both predecessor tasks are complete, it takes the larger of the two early finish dates, or day 15. Similarly, Task G takes the larger of the early finish dates of its two predecessors, Tasks D and E. At the end of the forward pass you know the duration of the project. However, you aren't done yet.

Exhibit 8-3 Forward Pass



Backward Pass

If we want the project to finish within its allotted 50 days, we will now calculate the late finish and late start of each activity, shown in Exhibit 8-4. The late finish is the latest an activity can be completed while still achieving the overall deadline. The late start is the late finish minus the task duration.

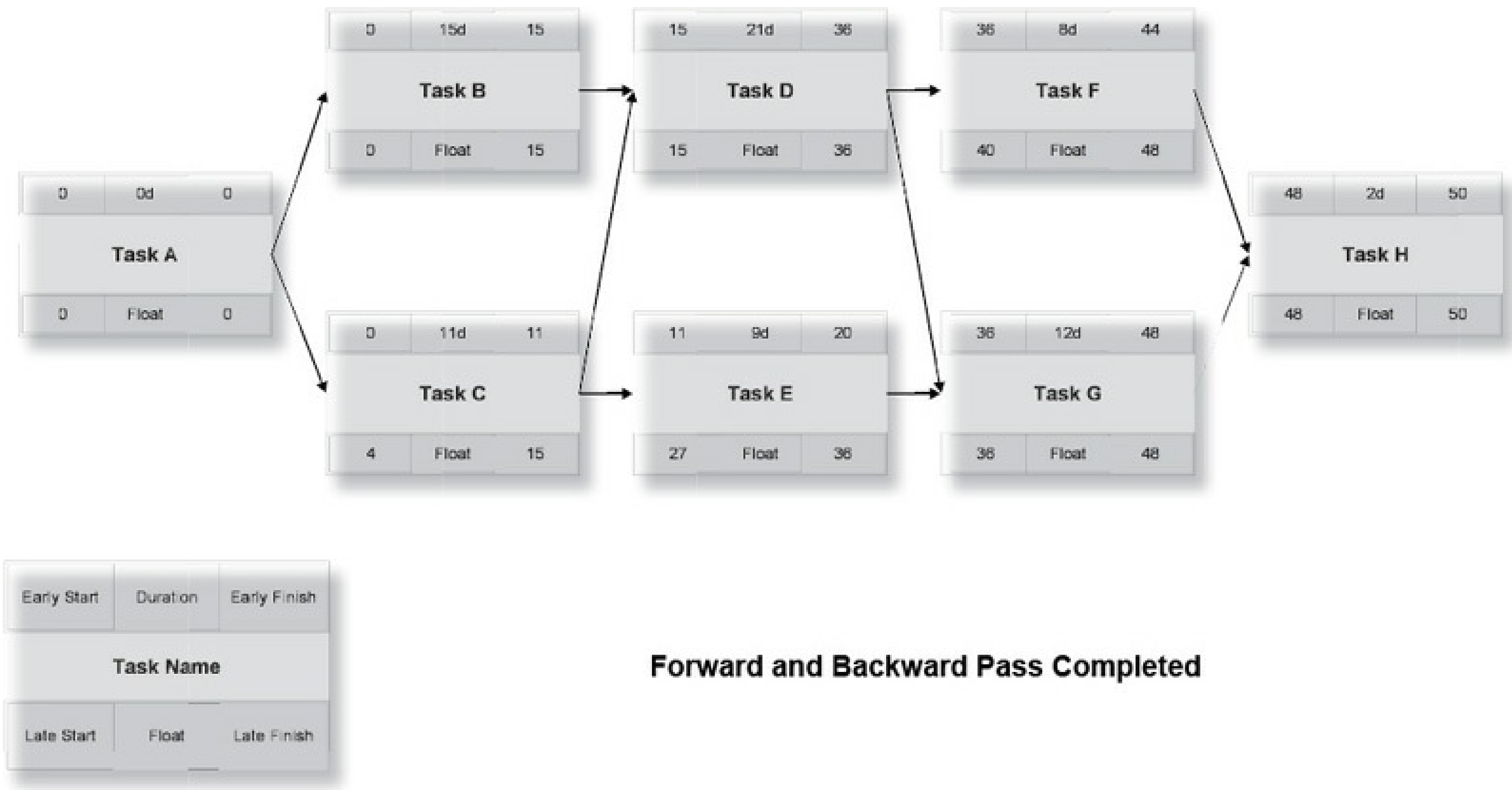
Tasks F and G can both finish as late as day 48. Task F can therefore begin as late as day 40, while Task G cannot begin any later than day 36. Task D must finish in time to allow both Tasks F and G to finish no later than day 50. This means that the lower of the two late start numbers (36 in this case) is the late finish of Task D. The backward pass must end in zero when you reach the beginning of the project.

Critical Path and Float

Earlier, we said that the purpose of the forward and backward pass was to find the longest path through the project, which we call the *critical path.*

In our swimming pool example we differentiated between what happens if we pour the concrete ourselves (the delay is day-for-day) and if we have a scheduled date with a contractor (the delay is until the next available date in the contractor's schedule, which could potentially be weeks).

Exhibit 8-4
Backward Pass



The backward pass calculates the late finish and late start of each activity, showing the latest any activity can be performed while achieving the original deadline.

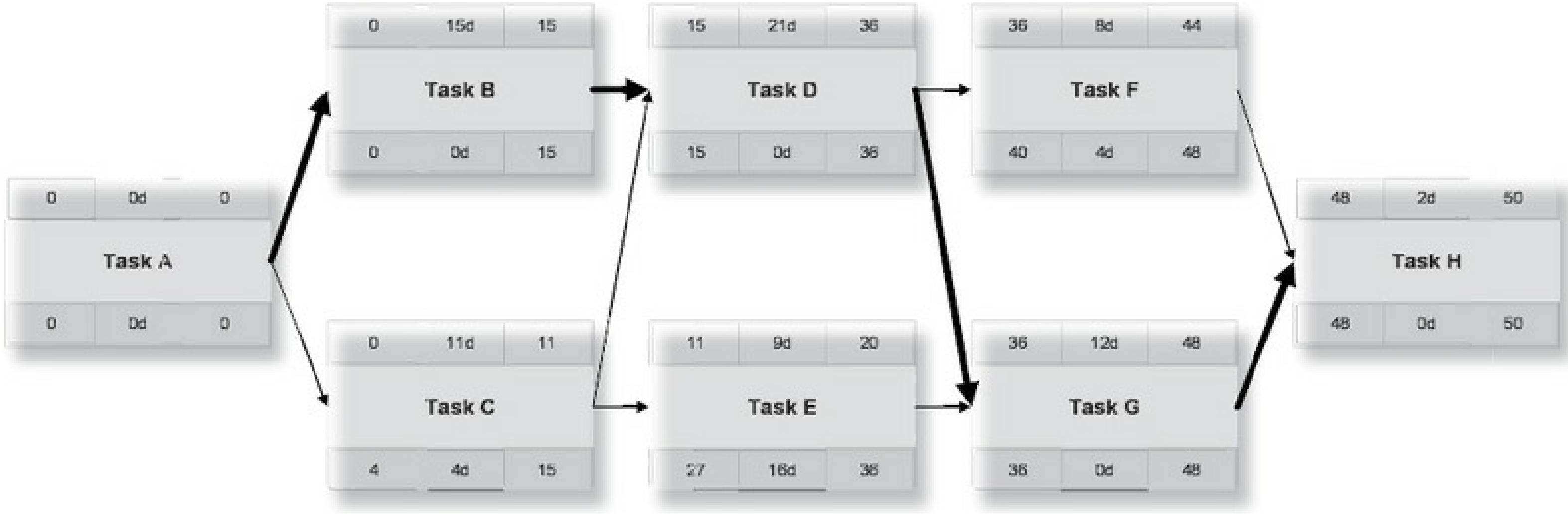
Let's go back to Exhibit 8-4 and take a look at Tasks A, B, C, and D. Notice the following:

1. Tasks B and C can't begin until Task A is complete.
2. Task D can't begin until Tasks B and C are complete.
3. Task B is scheduled to take 15 days.
4. Task C is scheduled to take 11 days.

If Task B takes longer than 15 days, Task D can't start on time. However, if Task C takes longer than 11 days (and no more than 15 days), *Task D's start time is unaffected*. Task C can be as many as four days late with no effect on the project schedule!

In project management, a task that can't be late without affecting the deadline is called *critical*. If there's extra time, as in the case of Task C, it's *noncritical*. The extra time is called *float* or *slack*. (We'll use "float" in this book, but either term is acceptable.) To understand and manage schedule risk, you have to manage the critical path and the available float.

Exhibit 8-5
Critical Path and Float



Final Network Diagram Showing Critical Path and Available Float

---

The *critical path,* as shown in Exhibit 8-5, is the longest path through the network. On the critical path, there is no difference between the early start (or finish) and the late start (or finish) of each activity. In other words, any delay of a critical path activity immediately introduces the danger of a late project. If a task is *noncritical,* it has *float* (also called *slack*), the amount of time the task can be late before the deadline is affected.

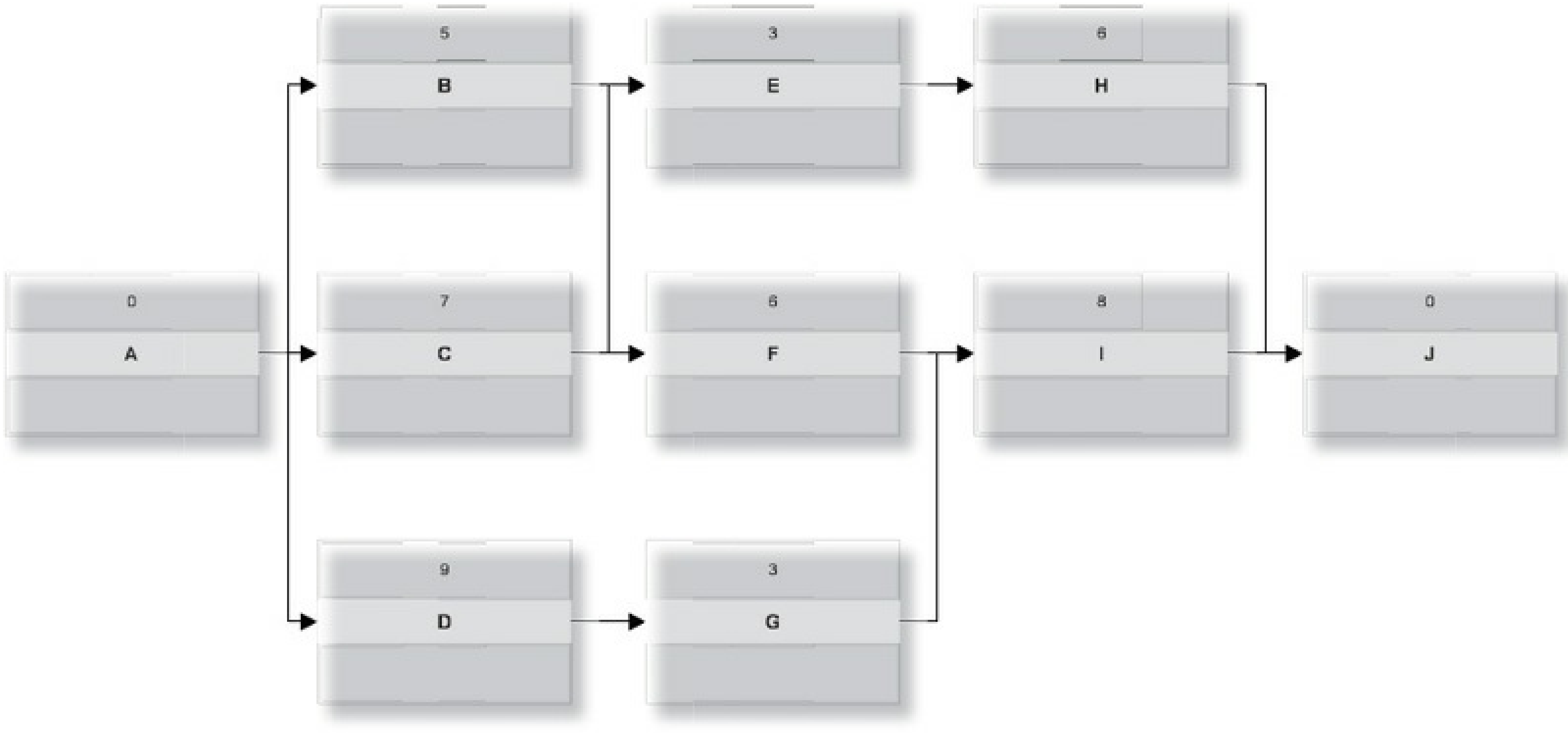
Mathematically, a task is critical if there is no difference between the early start (or finish) and the late start (or finish). If the late start (or finish) is greater than the early start (or finish), the difference is called *total float.* A task can have delay equal to its total float without affecting the project's deadline. *Free float* is the amount of delay before the task forces a delay in any subsequent activity (whether or not it's critical); float that is not free is shared with other activities.

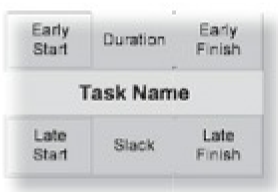
Exhibit 8-5 shows the critical path and available total float.

Notice that task C can start as early as day 0 or as late as day 4. It has four days of total float (extra time before lateness jeopardizes the project deadline). However, if Task C uses any of its float, the float available for Task E is reduced because Task E will no longer start on Day 11. The float is shared, not free. The float in Tasks E and F, however, is free float, because no other task is affected if those activities use their available float.

Exercise 8-1

Identify Critical Path and Float





Perform a forward and backward pass on the figure above. Determine the Critical Path and identify available float.

Types of Schedule Risk

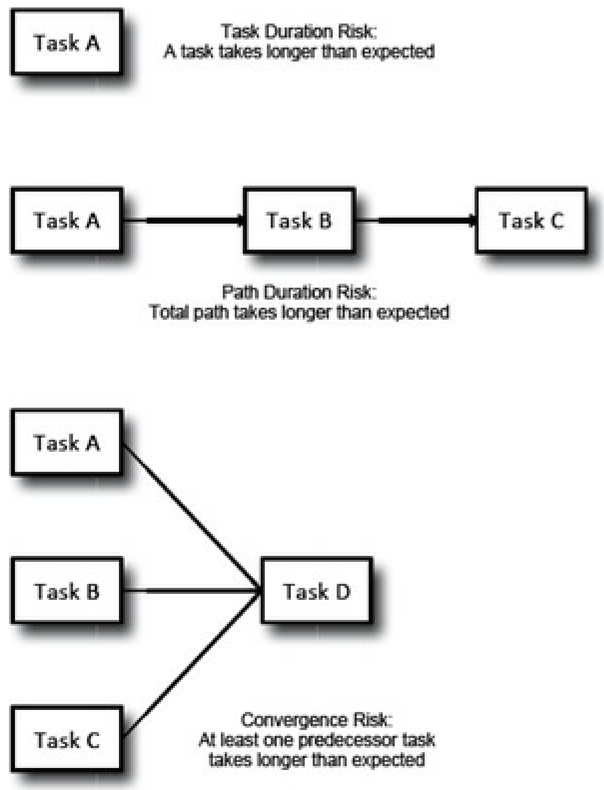
Risk to the schedule comes in three forms, illustrated in Exhibit 8-6.

- *Task Duration Risk.* The risk a task will take longer than the time scheduled.
- *Path Duration Risk.* The risk that a sequence of dependent tasks will take longer than the total time scheduled.
- *Convergence Risk.* The risk that at least one predecessor of a task with multiple predecessors will take longer than the time scheduled.

If there's a specific risk to the schedule, then you normally develop a specific response. If being late digging the hole could lead to project disaster, then it makes sense to allow more time for digging the hole, or to acquire more resources with which to do it quickly.

Sometimes, the problem is simply uncertainty. When tasks involve creativity and judgment, it's often not possible to assign an exact time in a meaningful way. You know how long it will take to teach a three-day class, but when it comes to writing the course for that three-day class, you'll be a lot less precise. "It'll take three or four weeks" is often about as honest an estimate as you're able to provide. Throwing extra people at the job won't necessarily help. Occasionally, it'll make things worse.

Exhibit 8-6 Types of Schedule Risk



If you have unavoidable uncertainty about how long individual activities in your project will take (task duration risk), you automatically end up with path duration risk for any path that includes those tasks, and you have convergence risk whenever one of those paths links up with any other path in your project.

How can you figure out how long the project will take when you can't be sure how long key tasks will take? Once again, you're into the realm of probability.

Three-Point Estimating Techniques

We have to dig a hole every time we put in a new swimming pool, but yards are different. Weather interferes. Equipment breaks down. The time it takes to dig a hole varies. Over time, we would naturally expect the hole-digging times to form a distribution, whether normal, triangular, or some other type, just as we've seen in cost analysis.

Exhibit 8-7 Historical Times for a Common Task

Hole	
1	

2	
3	
4	
5	
6	
7	
8	
9	
10	
Optimistic (Best Case)	
Most Likely (Median)	
Pessimistic (Worst Case)	

We can define the schedule distribution with a *three-point estimate.* Instead of using a single number as our estimate, we use three: the optimistic (best case) time, the pessimistic (worst case) time, and the most likely estimate (either the mean or the median). Figure 8-7 provides some historical times for digging that hole that we can use in creating a three-point estimate.

The range is between 2 and 5 days, and the median is 3 days, and now we have our three estimates.

You can create three estimates even if you don't have historical records to draw on. In fact, a lot of people find that it's actually easier to create three estimates than one, because you can use different assumptions to make them.

Exhibit 8-8 PERT Formulas

$$T_{(e)} = (T_{(o)} + 4\,T_{(m)} + T_{(p)}) / 6$$
$$\sigma = (T_{(p)} - T_{(o)}) / 6$$

where:

$T_{(e)}$ = PERT Estimate
$T_{(o)}$ = Optimistic Estimate
$T_{(m)}$ = Most Likely Estimate
$T_{(p)}$ = Pessimistic Estimate
σ = Standard Deviation of $T_{(e)}$ for a Single Task

Program Evaluation and Review Technique (PERT)

Three-point estimating was developed as part of the PERT method. PERT is a comprehensive approach to project management, but we're only concerned here with a particular portion of PERT that applies to risk analysis.

Let's say we have a large network diagram with hundreds (or thousands) of tasks, many of which have a high level of uncertainty in the estimates, so we've created a three-point estimate for each of those tasks. The question now is what to do with those three numbers. Clearly, it's unwise to plan as if we'll get the optimistic time on every task, and it's excessive to believe that all tasks will have a pessimistic outcome. We could use the most likely numbers, but that can be quite misleading as well.

PERT applies two formulas to those numbers, both shown in Exhibit 8-8. The first formula creates the PERT estimate, a weighted average of the three numbers. The second formula is how PERT calculates the standard deviation. In this context, the standard deviation is a measure of the degree of schedule risk (uncertainty) in the particular estimate.

By this measure, the PERT estimate ($T_{(e)}$) for our "dig hole" activity is (2 + (4 × 3) + 5) / 6 = 19 / 6 = 3.16 days, and the standard deviation (σ) is (5 – 2) / 6 = 0.5 days. In Exercise 8-2, create the other PERT estimates for the tasks in our swimming pool project and enter them in the network diagram provided.

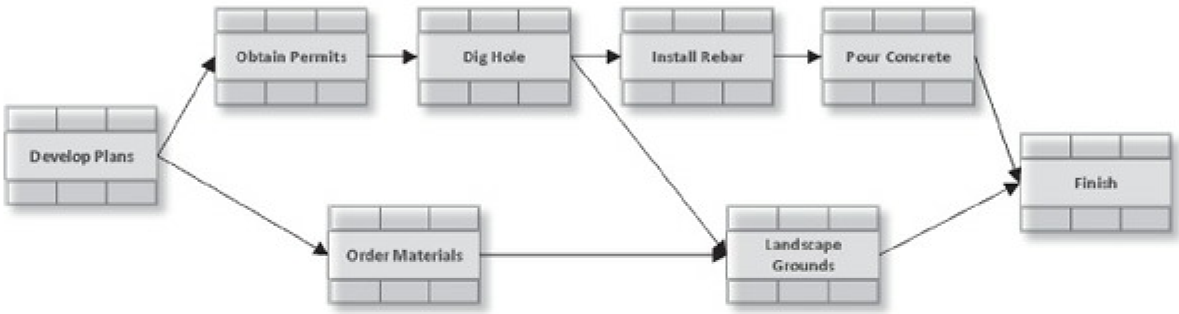
Exercise 8-2 Scheduling With PERT Estimates

Step 1. Calculate the PERT estimate ($T_{(e)}$) and standard deviation (σ) for each of the tasks in the swimming pool project using the information below. Round PERT estimates to the nearest whole day.

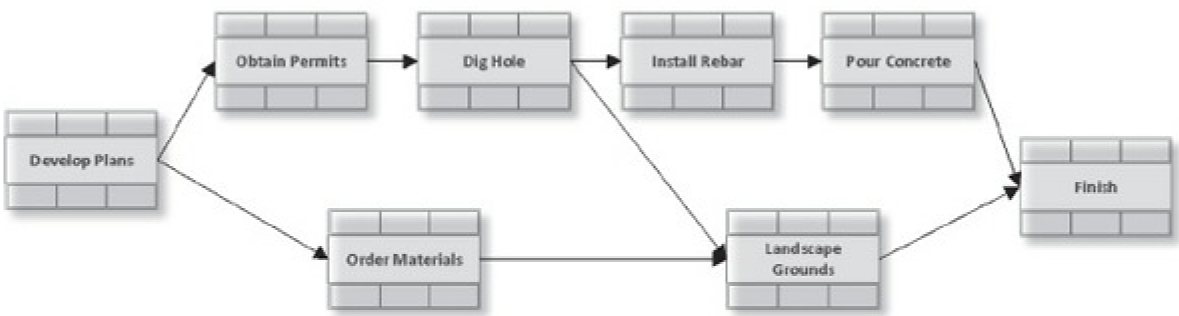
	Optimistic	Most Likely	Pessimistic	PERT Estimate	Standard Deviation
Develop Plans	6	12	24		
Obtain Permits	10	15	40		
Order Materials	10	12	15		
Dig Hole	2	3	5		
Install Rebar	5	7	9		
Pour Concrete	1	1	2		
Landscape Grounds	10	12	14		
Finish	1	1	1		

Step 2. Complete the network diagrams below. In the first diagram, use the PERT estimates for each task. For comparison, use the "most likely" estimates in the second diagram.

Swimming Pool Schedule
with PERT Estimates



Swimming Pool Schedule
with "Most Likely" Estimates



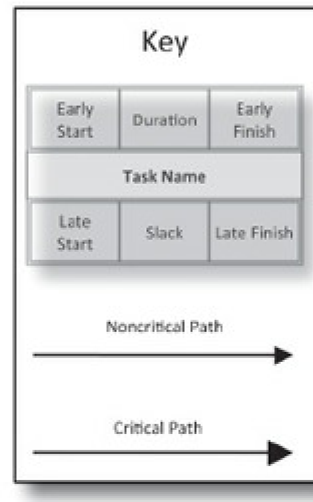


Exhibit 8.9 Confidence Levels

Standard Deviation	Confide
0σ	5
1σ	68.
1.28σ	8
1.64σ	9
1.96σ	9
2σ	95.
2.58σ	99.
2.81σ	99.
3σ	99.
3.29σ	99.
4σ	99.

Confidence Levels and the Standard Deviation

When we priced the risk for our insurance policy, we added a standard deviation to the base price of the risk to increase safety. Similarly, the standard deviation serves as a tool for what we might call "scientific padding"—risk-adjusting your schedule by allowing extra time to compensate for known uncertainty.

Using the standard deviation, we can determine a *confidence level* for the schedule, a measurement of how likely it is that the project will finish on or before a given date. Exhibit 8-9 provides a table showing the confidence levels associated with specific standard deviations.

In Exercise 8-2, we found that the "most likely" schedule took 43 days, and the PERT estimated schedule took 47. The confidence level for the 47-day estimate is 50%—that is, there's only a 50% chance that the project will finish on or before Day 47. What if we wanted to be 80% certain the project would finish on time? According to Exhibit 8-9, we need to add 1.28 σ to the estimate.

Now all we have to do is find the standard deviation for the project. To do that, take the standard deviations for each of the tasks on the critical path. Square them, add up the numbers, and take the square root of the sum (also called the *root sum square*). The answer is the standard deviation for the project. Multiply that by the confidence level desired, and that's how much extra time you need to allow.

Exercise 8-3 Calculating Standard Deviation for a Path or Network

Using the table from Step 1 of Exercise 8-2, square the standard deviations of the tasks on the critical path, sum them, and take the square root of the sum. Now, using the information in Exhibit 8-9, calculate the project duration at the following levels of confidence:

80% confidence	=	____________
90% confidence	=	____________
95% confidence	=	____________

Advantages and Disadvantages of PERT

As you may have noticed, the PERT formula for calculating the standard deviation doesn't resemble the formula you learned in Chapter 5. In fact, from a statistics perspective, there are a lot of problems with PERT.

There's a reason for this. When PERT was first developed in the late 1950s, computing horsepower was limited and expensive. It was simply impossible to perform a full analysis of a network containing tens of thousands of work packages in a reasonable timeframe. The brilliant minds behind PERT resorted to shortcuts. They made assumptions about the distribution and standard deviation (known as "back-fitting the curve") and developed formulas that were cheaper and easier to compute based on those assumptions.

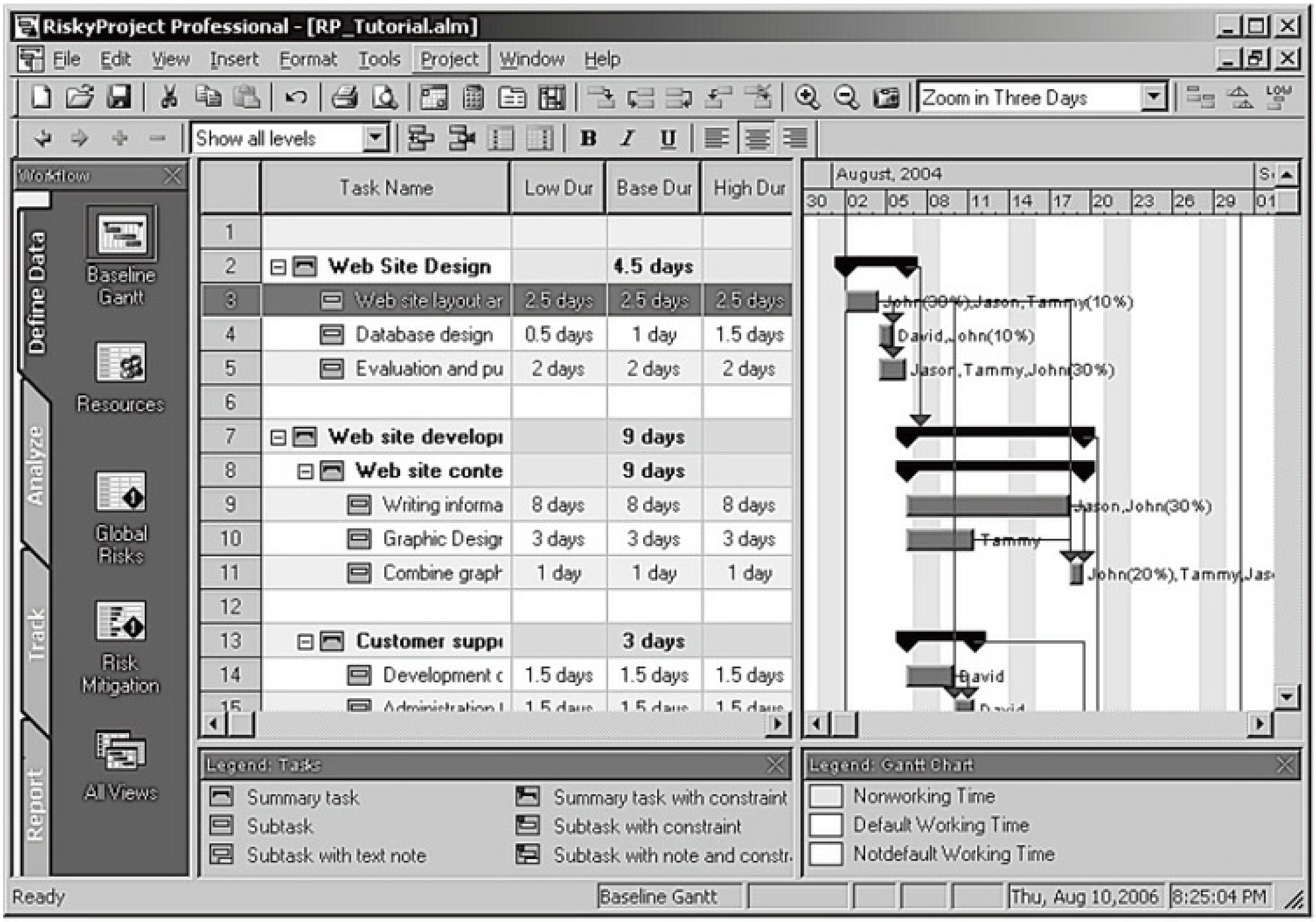
PERT estimates are very useful and have been applied successfully on major projects, but you should always treat a PERT analysis with caution. It provides a useful yardstick to measure schedule risk, but its answer tends to be far from precise. PERT is particularly subject to convergence risk, meaning that the PERT estimate tends to provide an optimistic view of how long the project will take to complete.

PERT works best when the project has a dominant single critical path; it is much less reliable when the relationships among paths and tasks are highly complex. PERT is an important element in the history of project schedule risk management, and the fundamental three-point estimating technique is still used, but most operating project managers who need to perform schedule risk analysis have switched from PERT to the Monte Carlo simulation technique.

Monte Carlo Simulation

While the PERT method attempts to measure schedule risk by calculation, the Monte Carlo simulation measures schedule risk by massive simulation, run by specialized software. Monte Carlo simulation programs for project management are available as plug-ins for common project management programs such as Microsoft Project® as well as in stand-alone versions.

Exhibit 8-10 Monte Carlo Input Screen



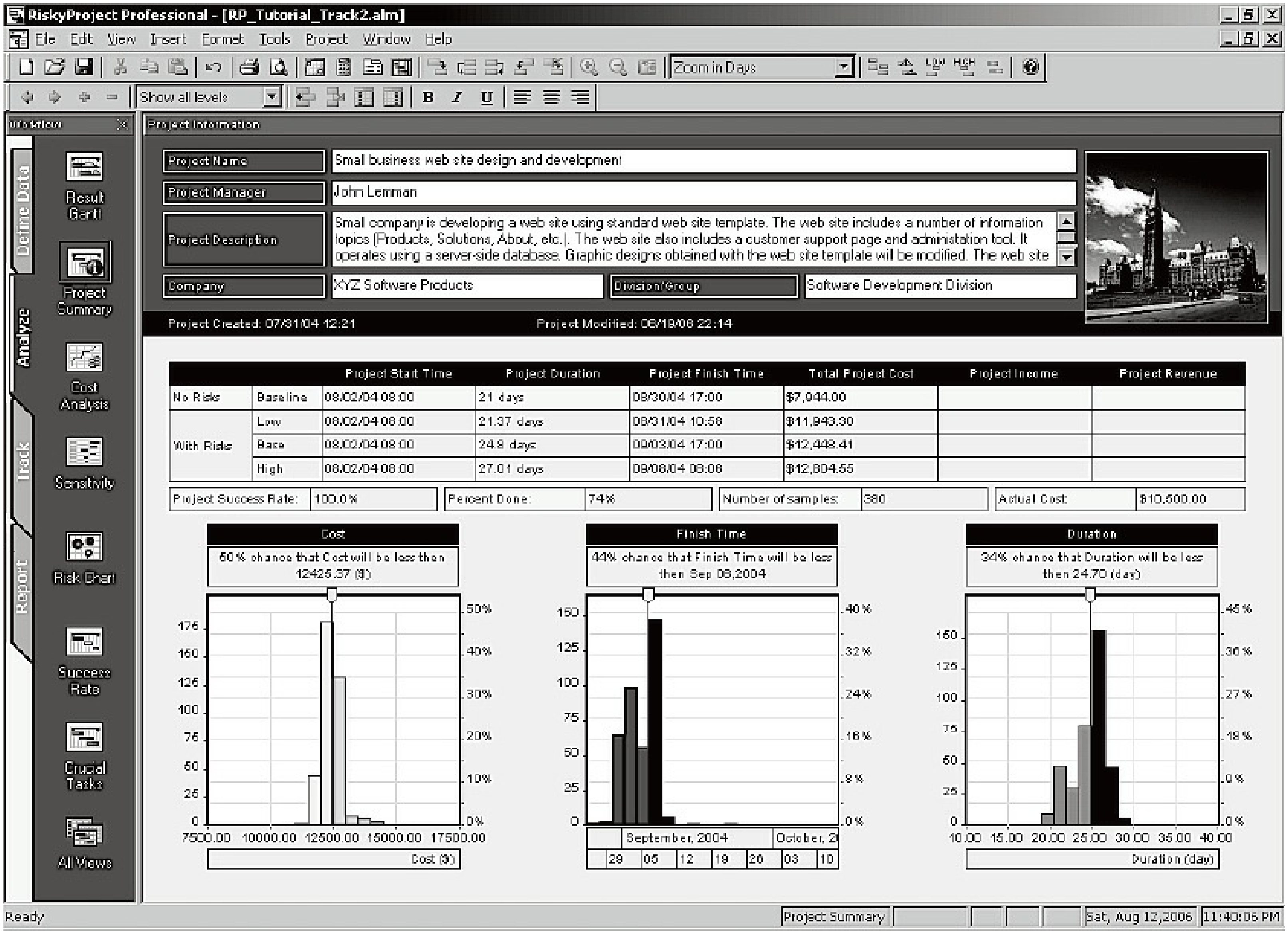
Screenshot taken from RiskyProject by Intaver Institute, Inc.™ and ©Intaver Institute, Inc., used with permission.

To run a Monte Carlo simulation, you first need the same three-point estimates for task durations that you would use in performing a PERT analysis. (You also need the other elements of a completed project schedule, including a list of tasks and their dependency relationships, of course.) While a standard project management software package provides space to enter a single time estimate for a task, a Monte Carlo program provides places to enter all three estimates, as shown in Exhibit 8-10.

In PERT, we used statistical tools to analyze the schedule, but a Monte Carlo simulation uses more of a "brute force" approach. The simulation pretends that we are actually managing the project. It decides how long it takes to accomplish a particular task by selecting a random number from the range provided. For our swimming pool project task "Develop Plans," with an optimistic estimate of 6, most likely 12, and pessimistic 24, the program might choose 15 as the duration of the task for this iteration.

It then checks to see if a finish time of 15 days alters the start dates of any subsequent activities, and adjusts as necessary. Then it goes to the next task ("Order Materials") and selects a number between 10 and 15. Let's say it's 11. Again, it checks to see if any start times have been moved, and then to the next task, and so on until the project ends. Perhaps the answer is 49 days this time. The program stores that number, goes back to the top, and does it again. And again, and again, and so on for 5,000 or 6,000 trials.

Exhibit 8-11 Monte Carlo Simulation Results



Screenshot taken from RiskyProject by Intaver Institute, Inc.™ and ©Intaver Institute, Inc., used with permission.

The output of the program is a distribution showing how often the project ended on a given date. Exhibit 8-11 provides an example. In this particular program, the slider on top of each histogram allows you to see the date or cost associated with any desired confidence level.

While the technique has been understood for a long time, it is only recently that the increase in computer processing speed and reduction in cost has made the technique practical.

A Monte Carlo simulation is much more robust than a PERT analysis, and normally deserves more weight in decision-making. As you can see, a Monte Carlo simulation can simulate cost as well as schedule, as long as you enter the cost data (salary costs and other expenses that vary with time spent) into the program.

Monte Carlo simulation programs are commonly available as add-ins for project management software packages. There's a list available in the "Additional Resources" section of this book, but you should remember that software availability and features change frequently.

recap

The tools of quantitative risk analysis extend to schedule as well as cost. Quantitative schedule analysis requires the development of a *network diagram,* a flow chart of the work packages and activities that make up the project.

Knowing how to develop a network diagram is fundamental to many aspects of project planning. In the most commonly used technique, known as the *precedence diagramming method,* work packages are represented as *nodes* (boxes) and connected by their *dependency relationships* (arrows). Once the work package durations have been estimated, you can perform a *forward and backward pass* (or let project management software do it for you) to reveal the *critical path* (the longest path through the network, equal to the project duration) and the availability of *float,* extra time to perform activities not on the critical path. Critical path analysis identifies which tasks must be completed on time if you are going to meet the desired end date.

Schedule risk comes in three forms:

- *Task Duration Risk.* The risk a task will take longer than the time scheduled.
- *Path Duration Risk.* The risk that a sequence of dependent tasks will take longer than the total time scheduled.
- *Convergence Risk.* The risk that at least one predecessor of a task with multiple predecessors will take longer than the time scheduled.

The seriousness (sensitivity) of a task duration risk is compounded by its effect on path duration risk and convergence risk.

Specific risks to the schedule require specific risk mitigation responses, but some schedule risk is simply the inherent uncertainty in knowing how long it will take to accomplish certain tasks. In that case, where estimates are highly probabilistic, project risk managers can use *three-point estimates* to show the range and distribution of potential outcomes.

The PERT analysis technique uses probability mechanics. The PERT time estimate is a weighted average derived from the three-point estimate. The standard deviation of the PERT estimate serves as a barometer of schedule risk. By taking the root sum square of the standard deviations of the work packages on the critical path, you can determine the confidence level that your project will achieve a given deadline.

More powerful computers have led to the rise of the Monte Carlo simulation technique, which uses a repetitive technique of iterating the schedule many times to create a distribution of completion time, dates, and costs.

Review Questions

1. If Task B has three days of total float, which statement must be true?
   (a) Task B is expected to take three days to complete.
   (b) Task B is a critical task.
   (c) If Task B is delayed no more than three days, the start date of no other task will be affected.
   (d) If Task B is delayed no more than three days, the expected project completion date is not affected.

1. (d)

2. Three-point estimates are used in which risk analysis techniques?
   (a) PERT analysis and Monte Carlo simulation
   (b) Probabilistic analysis and PERT analysis
   (c) Monte Carlo simulation and sensitivity analysis
   (d) Probabilistic analysis and sensitivity analysis

2. (a)

3. What does a network diagram show?
   (a) The sequence in which activities will be performed
   (b) A bar graph of task durations over a calendar grid
   (c) The breakdown and logical organization of the work structure
   (d) The IT infrastructure for your project

3. (a)

4. A skilled machine operator can produce 50 widgets per hour. If the machine breaks down, the same operator can perform the necessary repairs. Which statement is true?
   (a) The time to produce a given number of widgets is probabilistic; the time to fix the machine if it breaks is deterministic.
   (b) The time to produce a given number of widgets is deterministic; the time to fix the machine if it breaks is probabilistic.
   (c) Both times are deterministic.
   (d) Both times are probabilistic.

4. (b)

5. The risk that at least one predecessor of a task with multiple predecessors will take longer than the time scheduled is known as:
   (a) task duration risk.
   (b) convergence risk.
   (c) predecessor risk.
   (d) path duration risk.

5. (b)

9

Risk Response Planning

Learning Objectives

By the end of this chapter, you will be able to:

- Establish a process to conduct risk response planning for your project or organization.
- Analyze a proposed risk response for residual and secondary risk considerations.
- Determine when multi-stage risk responses are desirable or appropriate.
- Define three strategies for managing threat risk.
- Define three strategies for managing opportunity risk.
- Define two strategies for risk acceptance.
- Develop action steps for a risk response and place them in the project plan or in other project documentation.

Estimated timing for this chapter:

Reading	45 minutes
Exercises	45 minutes
Review Questions	10 minutes
Total Time	1 hour 40 minutes

Organizing for Risk Response Planning

Effective risk response planning rests on a foundation of good information:, the output of the risk analysis processes that you decide to use. It’s worth repeating that not all risks (or projects) demand the sort of comprehensive analysis that we’ve been covering, but at least some risks and some projects require that much or even more. You must always adjust the scope and level of your risk analysis based on the actual risk exposure.

Exhibit 9-1 Six Tips for Risk Response Planning

1. Establish teams of more than one person to work out risk solutions. Not every person on your project need be on every team, but each risk deserves more than one point of view.
2. Do not be satisfied with a single risk response; come up with several before choosing the best one.
3. A risk solution is worthless without a plan for its implementation. Define the steps necessary for each risk response and document them on the Risk Information Sheet (see Exhibit 4-6) and elsewhere as necessary.
4. Always examine potential risk responses for side effects (secondary risk) and remaining risk exposure (residual risk) before settling on a strategy.
5. There's no rule that limits you to one solution per risk. If you can't find a single solution, consider multiple strategies to nibble away at the total risk.
6. Consider opportunities as well as threats in building risk responses. Making a good outcome more likely or better can be as desirable as making a bad outcome less likely or less bad.
7. Keep a file of risks and responses for use on future projects. Recycling isn't only good for the environment, it can be a great risk management tool as well.

When you have completed your analysis, you're ready to take appropriate action. Consider the best practices in Exhibit 9-1 in organizing your risk response planning efforts.

Exercise 9-1 Risk Response Planning

Identify five risks, either ones you have used in previous chapters of this book, or ones relating to a project you are managing or have managed in the past. For each risk, list a proposed risk response: what you will do to manage the risk.

1. Risk:

   Response:

2. Risk:

Response:

3. Risk:

Response:

4. Risk:

Response:

5. Risk:

Response:

Residual and Secondary Risk

Proposed solutions to risks are seldom perfect. Whether we're discussing opportunity or threat, our risk responses are subject to two additional factors: residual risk and secondary risk. If these are not taken into consideration, the response to the primary risk may not deliver the desired outcome.

Residual Risk

Residual risk is the risk left over after your proposed solution has been implemented. Automobile insurance, for example, protects you against the financial impact of being in an accident—but not against all of it. If you have, say, a $500 deductible, you carry the residual risk of having to pay up to $500 in the event of an accident. That amount is residual risk.

There's more residual risk: the policy normally excludes certain events from its coverage. If your accident falls into a non-covered category, you have no insurance protection. In addition, there is the risk that the insurer may go out of business or otherwise be unable to pay the claim.

If the residual risk is small enough, you may decide to accept it. If the risk is large, you may want to modify your proposed solution, add additional risk responses to address the residual risk, or in some cases throw out that solution and move to a different one.

Secondary Risk

Secondary risk is new risk created by your proposed response to the original risk. Smoking is extremely hazardous to your health, but obesity is even worse—and giving up smoking in some cases promotes weight gain. That doesn't mean you shouldn't give up smoking, but it does imply that you need to be prepared to deal with potential weight gain as a secondary risk.

During the incident at the Three Mile Island nuclear plant, safety systems reported problems—110 separate alarms with flashing lights and sounds all going off at the same time. The resulting cacophony made it difficult to sort out the potentially catastrophic factors from minor ones, caused confusion in the relaying of orders and directives, and generally made the problem harder to solve, not easier—the opposite of what the alarms were supposed to provide. (Chiles, 58)

Managing secondary risk doesn't mean throwing out the primary risk. Clearly, we want our nuclear reactors equipped with alarms that tell us when something has gone wrong. However, one of the responses to the Three Mile Island incident was to deal aggressively with the issue of control room design, making it easier for operators to receive, interpret, and act on information in an emergency.

As with residual risk, if the secondary risk is small enough, you may decide to accept it. If the risk is large, you may want to modify your proposed solution, add additional risk responses to address the secondary risk, or in some cases throw out that solution and move to a different one.

Exercise 9-2 Residual and Secondary Risk

For the risk responses you developed in Exercise 9-1, are there important considerations of residual or secondary risk that need to be addressed? What will you do about these?

1. ______________________________

2.

3.

4.

5.

Multi-Stage Solutions

One particularly tough category of risks contains those that are low in probability but potentially catastrophic in outcome.

Thousands of small meteors hit the earth every day. Most are the size of grains of sand, and we know them only from the streak of bright light that marks their passing. Slightly larger meteors (5-10 meters in diameter) hit us about once a year, releasing as much energy as the Hiroshima atomic bomb. These generally go unnoticed because they tend to go off at high altitude and thus do little damage. However, there were observed events in South Africa (2009), Peru (2007), Norway (2006), and the Yukon (2000).

Every thousand years or so, a larger one (over 50 meters in diameter) hits with an energy release equivalent to 1,000 Hiroshima bombs. The last such, the Tunguska event in 1908, flattened 80 million trees over 830 square miles. Larger impacts, of course, also happen. Approximately 65 million years ago, an asteroid at least 10 kilometers in diameter struck the Yucatán Peninsula, triggering the Cretaceous–Paleogene (or K–Pg) mass extinction event.

Clearly, a big asteroid impact would be a very bad thing, but the probability appears to be approximately 1/65,000,000. What, if anything, should we do?

We could do nothing at all and bet that we'll stay lucky as a species. We could spend trillions of dollars to put a nuclear-armed space armada into orbit to shoot down any marauding asteroids that happened to come by.

We can also consider a multi-stage solution. In the case of the hypothetical killer asteroid, we can divide the risk into two questions. First, is a killer asteroid actually on its way? Second, what should we do if it is?

The first question is relatively inexpensive to answer, and has a dramatic bearing on the second question. A comprehensive survey of near-Earth asteroids (known as Spaceguard) is at the time of writing about 80 percent complete. Using known equations of orbital mechanics, the future positions of these objects can be charted, and eventually we'll know exactly what might hit us and when.

Changes in knowledge change our understanding of probability. A generic 1/65,000,000 probability may look a lot different when we consider a given asteroid. The 99942 Apophis asteroid, for example, has a chance of colliding with the Earth in the year 2036. NASA's Near-Earth Object Program Office estimates the probability as 1/250,000. In absolute terms, the risk is still small, but it's a lot greater than 1/65,000,000.

A 1/250,000 chance of impact probably doesn't warrant building that space armada, but it does justify continued study. As more accurate measurements are made, the probability of collision will change—it will either appear increasingly probable that a collision will happen, or it will appear increasingly improbable. At some point, if the degree of confidence is high enough, expensive action may be warranted. If the decision to act is made early enough, a slight shove may be all that's needed to adjust the asteroid orbit enough to avert a collision. If the decision is made too late, that space armada may not be enough to accomplish the job.

"Watch and wait" is a perfectly legitimate risk response in many situation involving low probability/high impact events. The potential action is a backup strategy, to be implemented if and only if indicators warrant.

Managing Threats

Whether the risk response is a single-stage or multi-stage action, you still have to develop it. Different strategies exist for both threats and opportunities. Be sure to consider multiple possibilities before settling on a response, and remember that you can combine solutions if necessary. In the case of a business risk, it's important to consider both sides of the risk equation (threat and opportunity) in developing your strategy.

The three basic strategies for managing a threat are avoidance (changing the project so the risk event cannot happen or the project is completely protected from its effects), transference (moving the ownership and impact of the risk to another entity), and mitigation (reducing some combination of probability and impact, but not eliminating the risk altogether).

Avoidance

Avoiding a risk completely often requires a change in the way you do things. If a project has a high risk of failure, you can avoid the failure by cancelling the project. This may be entirely sensible.

You can potentially change many other factors that involve risk, from deadline to budget to performance criteria. You can change the process with which you do the work, the tools you use, whether you do the work in-house or out-of-house, whether you provide a specific functionality or hit a specific numerical target.

An avoidance strategy by its very definition means that there is no residual risk. However, secondary risk is almost certainly present. If the risk of doing it is so high that it's not a good idea, we still have the reason we thought about doing the project in the first place. If we change deadline or budget or performance criteria, we may be swapping one set of risks for another.

Occasionally, the secondary risk can provide opportunity as well as threat. Whatever we think of to replace the project as originally conceived might turn out to be better for us. The cost of contracting out the work (and some of the risk) may turn out to be less than the cost of doing it in-house. Check all possibilities.

Transfer

Risk transference moves the ownership of a risk from one party to another. We've already seen several ways this can be done. In qualitative risk analysis, we classified some risks as owned by someone else. When we move the risk to its proper owner, we've transferred at least some of it.

Insurance is another common method of risk transfer. Some people make their money by taking over other peoples' risks for a fee. Every contract involves some risk transfer. If a vendor charges a firm, fixed price for products or services, the vendor owns the risk of cost overruns. If a vendor charges by the hour or on a cost-plus basis, the buyer owns the risk of cost overruns. Contract details often spell out who has the financial liability for specific risks.

Risk transfer often leaves residual risk and can create secondary risk as well. Earlier in this chapter, we identified residual risks in buying insurance, for example. When transferring risks administratively, the risk may have a new owner, but residual risks often remain.

Mitigation

A mitigation strategy reduces some combination of probability and impact, lowering the risk but leaving at least some residual risk. Mitigation strategies may also create secondary risk.

Examples of mitigation strategies include:

- *Testing.* Tests identify problems in performance and quality before they reach the customer.
- *Redundancy.* Having more than is necessary helps ensure you'll have at least enough.
- *Additional resources.* Adding cost, time, and personnel can reduce the risk of failing to meet one or more key objective.
- *Skill or process improvements.* Improving the skills of team members or the way in which the work is done reduces risk.

Managing Opportunities

Opportunities can be found in stand-alone form and in the form of business risk, and are often matched with corresponding threats. The three basic strategies are to exploit the opportunity (cash in the benefit and use it), enhance the opportunity (make it better or more probable), and share the opportunity (give the benefit to someone else either for goodwill or in trade).

Exploit

The obvious thing to do with an opportunity is to take advantage of it, and that may indeed be the best thing to do. If your stock market investment increases in value, you can sell it. If your successful management of the current project makes you the front-runner for the next job, grab it.

As in the case of threat risks, opportunity risks carry the possibility of residual and secondary risk. If you sell the stock too soon, you may make less of a profit than you would make if you held on to it a bit longer—the residual risk is the value of what you're leaving on the table. At the same time, the secondary risk is a threat: that the stock will tank, leaving you worse off than you would have been had you sold it on time.

When you choose to take business risk in managing your project, exploitation of the potential benefits is, after all, the usual reason for undertaking it.

Enhance

In the case of the stock market investment, we exploit the opportunity if we cash it in: sell the stock, pay the capital gains tax, and pocket the rest. If we choose to keep the stock because we believe it is likely to increase in value, we are pursuing an enhancement strategy instead.

If your outstanding work on the current project positions you well for new business, you could enhance the opportunity by raising your rates. The benefit is greater profit; the secondary risk is losing the business. The residual risk, again, is the potential amount you're leaving on the table.

Share

Although exploitation is the obvious strategy, sharing may often represent the best available response. The benefit from a particular opportunity may not apply to you, and giving (or trading) the benefit to someone who would truly find it valuable can pay tremendous dividends in goodwill and support.

A powerful and frequently overlooked technique to improve project and organizational effectiveness is to look at your project for ways it can incidentally provide benefit to others. For example, your project budget might not support buying the latest and greatest equipment, but if the equipment could benefit enough other projects and activities, the combined result might make it profitable.

If you solve a problem, can you solve it for everyone and not merely for your own project? If your project success makes it easier for another part of your company to win business, can you help move that opportunity to the appropriate department or group? Can what you do benefit the customer in ways over and above the contract? Can the work of the project provide extra benefits to team members, such as improved education and skills that may help them in years to come?

Managing Acceptance

Acceptance strategies basically involve doing nothing—at least not until the problem appears imminent. We normally identify a number of project risks not worth the time, effort, or expense to mitigate. We accept those risks, perhaps allowing some contingency reserve to cover them. For risks that have high cost solutions, we may develop a different kind of contingency—a contingency plan or response.

Contingent Responses

Unlike other risk management strategies, a contingent risk response is not implemented until the risk has actually occurred or has passed some threshold or event point that makes us believe that has become extremely likely to occur. In our asteroid example, it makes no sense to spend a huge amount of money on a response unless we have reason to believe that the collision is likely to happen in the near future. We make the response *contingent* on actual evidence that an asteroid is indeed heading our way. So far, our risk has jumped from 1/65,000,000 to 1/250,000, but that's not yet enough to activate a *risk trigger,* a threshold at which a decision is necessary.

Some contingent responses need to be worked out well in advance. With others, it's sufficient to have a general idea of what we might do, and make the detailed plan if the risk is triggered.

Acceptance

For risks with a minor impact, simple acceptance—we won't do anything, and will cope with the effects as best we can if the risk occurs—is often sufficient. Some risks are accepted because they are subsumed by larger programs. For example, a shop safety program is aimed not at a single risk nor at a single project, but rather at a category of risks.

"Watch and wait" strategies, as in our Spaceguard example, are another subdivision of acceptance. We spend a small amount of time, effort, and resources on monitoring, and defer any substantial action until—or unless—the risk event appears imminent or grows so much in probability that action is warranted.

Exercise 9-3 Types of Risk Response

Look at the risk responses you developed in Exercise 9-1 and classify them according to the categories mentioned in this chapter. Are there any alternate solutions you want to consider instead?

1.

2.

3.

4.

5.

Implementing Risk Response Strategies

Risk responses require actions. If you need insurance, you have to go buy insurance. If you need safety goggles, you need to stop in the shop office and pick up a pair. If you need to test components, you need a testing plan. The effort involved in turning a risk response strategy from an idea into action can in some cases be substantial.

It is important to document what you decide to do about a risk. The Risk Information Sheet (Exhibit 4-6) has a space in which to write the risk response, but the real work may be done elsewhere. In many cases, the best place to put a risk response is into the project plan itself, either as a work package or as requirements. If, for example, testing is part of your risk response to potential lapses in quality, you probably want to have a work package labeled "Testing." Depending on the level and sophistication of the tests, there may be multiple steps involved. Tests have testing requirements. Which tests should be run? What constitutes a satisfactory outcome? What defines failure?

Exhibit 9-2 contains a list of questions to consider in developing and implementing your risk response. Space is provided for you to consider how these questions apply to the risk responses you have worked on in this chapter.

Exhibit 9-2 Questions That Shape Risk Responses

For each proposed response to a given risk, consider the following questions.

Appropriateness

1. Is the risk response proportional?
2. Is the risk response actionable?
3. How does this risk response compare to doing nothing at all?

These questions establish whether the potential risk response can be considered further. If the solution is not proportional to the risk (that is, substantially higher than the risk score and not justified by other reasons), or if we can't actually do what's required, then the solution is a non-starter.

If none of the risk responses are particularly attractive, do consider the potential consequences of doing nothing. They may be greater—or less—than you imagine.

Residual Risk

4. How much and what kind of residual risk will remain?

5. Is the remaining level of residual risk acceptable?

6. Can we reduce the residual risk any further?

7. Is any of the residual risk positive in nature?

We not only need to define the level and nature of any residual risk, but also need to establish whether the residual risk is still too high. If it is, we need a better solution or an additional solution—which gets run through this same process as a new risk response.

Secondary Risk

8. Will the risk response create any secondary risks, either threats or opportunities?

9. Are the secondary risks acceptable?

10. If not, can we modify them so they are acceptable?

11. Are the secondary risks greater than the risks of doing nothing at all?

Secondary threats and opportunities are frequently overlooked in risk response planning. Be sure to consider indirect benefits to the organization, customers, or end users along with benefits to you and your project in evaluating these options.

Staged Response

12. Must we act now, or can this response wait on further information?

13. Will the risk response be better if it is implemented early, or if it is implemented closer to

the risk event?

14. Are secondary and residual risks affected by the timing of the response?

Acting early isn't always or necessarily the best thing to do. Strategic delay can be a very effective part of risk response planning.

Action Steps

15. What are the action steps, tasks, or work packages we have to perform in order to implement this risk response?

16. Can these action steps be placed into the regular project workflow?

17. What resources must be allocated to make these action steps happen?

18. Are any action steps contingent on other project events?

The best place for risk response activities is in the project plan itself. If the risk response is contingent (depending on other events), this may not be possible. In that case, where will you put the information? How will you make sure the risk responses is triggered if necessary?

Metrics

19. What circumstances, events, or measurements will tell you that the risk has occurred or is about to occur?

20. How and when will you know if your risk response is working as anticipated?

21. How will you know if the risk is not going to happen?

22. What will tell you if you need to modify or change your planned risk response?

Without risk metrics—some way to measure what's going on—it's very difficult to figure out whether a risk has occurred or whether your proposed solution is working as intended. Establishing metrics is a valuable tool in almost every project management situation.

Backup Strategy

23. What will you do if the planned risk response is not working adequately?

24. How will you document and record the backup strategy, if any?

25. How will you measure the success or failure of the backup strategy?

Backup strategies and contingency plans aren't necessary in all cases, but it's usually worthwhile to ask the question: Is there a chance the response won't work, and if so, what are you going to do about it?

Closing Criteria

26. How will we decide when this risk is no longer active and should be closed?

27. How will we record the outcome of this risk event?

28. What can we learn from this risk event (whether it happened or not) and how will that knowledge be used?

There's usually a point at which a risk can no longer happen, or a point at which a risk that has happened has done all the damage (or provided all the benefit) it's able to do. Closing a risk moves it from the active list to the inactive list, and should always be done consciously and deliberately.

Risk response planning is the process of deciding what to do about specific project risks. Establish a formal process for developing risk responses as a team, consider more than one potential solution before settling on an answer, and document the risk response on the Risk Information Sheet, in the project plan, and elsewhere as appropriate.

Consider residual risk and secondary risk issues before deciding on a risk response. If residual and secondary risk levels are excessive, modify the risk response or abandon it and choose a different one. If the risk response is expensive, consider multi-stage solutions that defer expensive action unless absolutely necessary.

The three basic strategies for managing a threat are avoidance (changing the project so the risk event cannot happen or the project is completely protected from its effects), transference (moving the ownership and impact of the risk to another entity), and mitigation (reducing some combination of probability and impact, but not eliminating the risk altogether).

Opportunities can be found in stand-alone form and in the form of business risk, and are often matched with corresponding threats. The three basic strategies are to exploit the opportunity (cash in the benefit and use it), enhance the opportunity (make it better or more probable), and share the opportunity (give the benefit to someone else either for goodwill or in trade).

Risk acceptance has two categories: passive acceptance (we do nothing unless the risk occurs, then we cope with it as best as we can) and contingency planning (we create a backup plan but do nothing unless the risk is triggered).

Risk response strategies must be implemented. You need to develop action steps and put them in the project plan or elsewhere. You need to establish metrics that tell you when the action is necessary and whether it's working. You also need to establish criteria for closing a risk, either because it can no longer happen or because all the consequences of the risk have happened.

Review Questions

1. A proposed risk response must always be:
   (a) free of secondary or residual risk.
   (b) structured as a multi-stage solution.
   (c) proportional and actionable.
   (d) paired with a backup strategy.

1. (c)

2. In managing opportunity, which strategy is most appropriate if the benefit is not usable by you or your team?
   (a) Sharing
   (b) Mitigation
   (c) Enhancement
   (d) Acceptance

2. (a)

3. Which of the following is a strategy for managing threat risk?
   (a) Exploitation
   (b) Sharing
   (c) Mitigation
   (d) Enhancement

3. (c)

4. If the proposed risk response will not eliminate all the consequences of the risk, the part that is not eliminated is known as:
   (a) secondary risk.
   (b) residual risk.
   (c) contingency risk.
   (d) multi-stage solution risk.

4. (b)

5. If a proposed risk response has an unacceptable secondary risk, you should:
   (a) modify the proposed response or select a different one.
   (b) change the project so that the initial risk cannot occur.
   (c) provide contingency allowance for the additional risk.
   (d) establish a multi-stage solution.

5. (a)

10

Risk Monitoring and Control

Learning Objectives

By the end of this chapter, you will be able to:

- Define key elements in a risk management plan and a risk management policy.
- Implement a variety of project risk monitoring and control tools, including monitoring and control metrics; early warning indicators; common concepts of Earned Value Project Management (EV or EVM) including planned value, earned value, and actual cost; and schedule and cost performance indices based on earned value metrics.
- Identify the elements in a change management system.
- Explain why risk identification and risk analysis must continue throughout the project life cycle.
- Assess risk management effectiveness during project "lessons learned."

Estimated timing for this chapter:

Reading	50 minutes
Exercises	50 minutes
Review Questions	10 minutes
Total Time	1 hour 50 minutes

Risk Management Processes in Project Execution, Monitoring and Control, and Closeout

We've now analyzed a single risk, but projects rarely have just one risk. Projects have a portfolio of risk, usually including both upside and downside risks. Some of the risks are known (or at least knowable); some of the risks are at least initially unknown.

While the topic of this course is project risk and cost analysis, the job isn't complete until the risk response plan is in place and the risks are managed properly. In this chapter, we'll provide an overview of the aftermath of the risk analysis process.

Risk Management Plans and Policies

A *risk management plan* is part of any well-prepared project management plan. It identifies and describes the risks, rates their relative seriousness by considering their probability and impact, lists any planned responses or actions intended to reduce downside risks or improve upside risks, and explains how the project team will monitor risks and responses for effectiveness.

A *risk management policy* is a document that applies to an entire organization or category of projects. It describes how the organization wants risk management to be performed, which projects and activities are covered by the policy, the definitions and steps involved in the process, the types of reports and documents that need to be prepared and disseminated, who must be consulted or who must approve risk responses, and similar matters.

Your organization either has or doesn't have a formal risk management policy in place. If it does, then your risk management planning activities must conform to it. If it doesn't, you may want to prepare one for your own projects simply to avoid the need to start from scratch each time.

Risk Management Policy Development

A formal risk management policy can be a valuable asset when projects and operations carry with them the possibility of serious organizational consequences. In our judgment, a risk management policy should be considered an organizational best practice when it comes to risk management.

There is little advantage in creating a risk management policy from scratch, because there are numerous templates and guidelines available to help you. Many of them are specific to certain industries or occupation, but by and large they follow the same format. You will find links to a sampling of risk management templates in the Additional Resources section of this book, and more are being added all the time.

Regardless of the organization or category of risk, all risk management policies must address certain questions and issues. The following guidelines are designed to help your organization in preparing a risk management policy.

Philosophy, Approach, Scope

The more explicit and clear the organization's attitude toward risk, the easier it will be for individual projects and operations to behave in accordance with it. A statement of purpose, scope, and commitment helps readers make sense of and apply what is to follow. Consider the following questions:

What kinds of risks are most important?

If you manage a white-water rafting business, for example, there's an inherent level of physical danger to participants. A risk management policy might emphasize the importance of safety precautions, safety training, and emergency medicine. If your business manages investment portfolios for customers, the danger is to financial wealth rather than physical health, and the risk management policy adjusts accordingly.

Defining the areas of greatest concern helps focus attention where you most need it. This doesn't mean you won't address risks outside the areas of primary concern, of course, but they normally have to rise to a higher level for you to take them as seriously.

Think About It …

What kinds, categories, or areas of risk are most important to your organization, group, or type of project?

____

____

____

____

____

What kinds of risks do you want people to take?

Business risk, as we've discussed, combines upside risk and downside risk in the same decision. Avoiding pure risk (at the right price) is clearly prudent, but avoiding business risk eliminates the chance of gain along with the chance of loss.

To avoid any possibility of an accident in white-water rafting, the obvious solution is to avoid white-water rafting, but you also avoid the exhilaration and fun from the activity. To avoid any chance of financial loss, you can keep your money in the safest possible investments, but in doing so you may miss out on valuable returns.

Think About It …

What kinds, categories, or areas of risks should be encouraged? What kinds of risks are potentially beneficial to the project, the organization, or the customers?

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What kinds of risks do you want people to avoid?

Some risks are unacceptable as a matter of policy, and those need to be spelled out. For example, a company might express a strong unwillingness to accept risks in ethical matters, risks involving the potential for injury, or other categories.

Notice that being unwilling to accept risk in a particular area may simply shift the impact of the risk to another area. If you're unwilling to accept the possibility of physical injury from your products, you'll usually end up paying for additional safety measures. The risk switches from physical harm to financial impact.

Think About It …

What kinds of risks should be avoided as a matter of policy? What is the threshold of acceptability on these risks?

What projects and risks are covered?

Failing to perform adequate risk management can be catastrophic. At the same time, risk management costs money and takes away resources that could be employed elsewhere. In order to strike a balance between the cost of risk management and its benefits a number of different questions should be considered, as outlined in Exhibit 10-1. We've provided space for your issues and considerations.

Exhibit 10-1 Organizational Considerations for Risk Management Policy

Consideration	Description	Metric	Your Issues
Size of the Project	The failure of a large-dollar project, all other things being equal, has a greater impact on the organization as a whole.	Metric: Budget or cost estimate	
Importance of the Project	The more important the project to the goals of the organization, the more value in managing its risks properly.	Metric: Forecast or strategic objective	
Legal and Regulatory Requirements	Many organizations are subject to legal, regulatory, or other mandatory standards regarding risk and safety, including hazardous materials and environmental controls, OSHA compliance, required insurance or bonding, and so forth.	Metric: Codes that apply; requirements for action and documentation	
Public Perception	If a project will have significant public visibility or has passionate opposition, the risk exposure increases dramatically even when few dollars are at stake.	Metric: Amount and tone of publicity	
Maximum Downside Risk	Another valid risk ranking criteria is the potential downside of the project, especially when the downside begins to exceed the total cost of the project.	Metric: Identification of downside risk scenario	

We do *not* recommend that projects below the threshold of formal risk management planning be exempt from risk management altogether, of course. However, the degree of rigor and detail appropriate for smaller projects may be far lower than is appropriate for larger or more inherently dangerous ones.

Risk Management Methodology and Process

While most risk management methodologies follow the same broad outline (initiation, analysis, response planning, action), the details of preferred tools, approaches, and steps vary greatly. Even for organizations that use an industry standard, such as the PMBOK®, as a template, there are still numerous details that must be customized for any organization, such as who must be consulted on given risks and how risk data will be integrated with other information. Consider the following:

Definitions. Common vocabulary matters a lot. If a risk is “unlikely,” does that mean a probability lower than 50% or lower than 25%? What constitutes a “significant” risk?

Reporting and Documentation. How will we keep track of risks? What information needs to be archived? Who should be informed of which risks? How will risk management be handled within other project management functions?

Approvals and Authority. Who is responsible for identifying risks and preparing the risk management plan? Who must approve risks in particular categories? Who decides whether the total risk level of a project is acceptable or unacceptable?

Project Risk Monitoring and Control Systems

In project risk analysis and project risk response planning, we identified the risks that required responses, made sure we understood those risks as thoroughly as possible, and developed responses and action steps to implement those responses. Along with our risk responses, we developed metrics: indicators that help us understand what's going on with a particular risk.

How will we make sure these plans and strategies are implemented, and that the things we said we were going to do actually get done? The process of doing this is known as project monitoring and control, the final part of our phased approach to risk management planning.

Managing the Project Risk Environment

Our individual risk response plans form the basis of one aspect of project monitoring and control. In addition, risks are often managed collectively and by category, as in the case of a shop safety program. The safety program doesn't specifically care about the consequence to *your* project, but works to prevent accidents across the board. Project risk monitoring and control has a collective side as well. In addition to managing specific risks, you need to monitor and control the general project environment as part of an effective risk response.

Many of the tools you use to manage the project offer information and insight into the risk environment as well. A weekly report provides status information to check against the plan. If there are discrepancies in, say, the schedule, you've just found evidence of a time risk to the project. If the cost of raw widget stock is higher than the planned number, you know there's a cost issue. If the test report says that the new widget design didn't pass the pressure test, you've uncovered a performance issue.

There are four areas of fundamental concern in your project risk environment:

1. Information that suggests that specific risks have been triggered or that they are not going to occur.
2. Information that suggests that your planned risk responses are working or are not working as intended.
3. Information that suggests project and environmental conditions have changed or not changed from your expectations or history.
4. Information that suggests underlying or structural issues with your project or plan exist or don't exist.

In everything you do to manage, monitor, and control the project for which you are responsible, you need to keep these concerns in mind. As we've pointed out elsewhere, the earlier you learn that you have a problem or an opportunity, the greater your ability to manage it to best effect.

Add a section on "Risks" to any status reporting form you use so that people write about what they see in the near future as well as about what has happened in the recent past. Use part of project staff meetings to discuss the upcoming uncertainties as well as the status of current work.

Establishing Risk Metrics and Early Warning Indicators

In addition to metrics, triggers, and early warning indicators for specific planned risks, you also need to establish general metrics that reveal unusual trends early, and that distinguish between ordinary variation and significant divergence from the expected norm. We are looking for *significant variance from the plan,* in areas of cost, time, and performance.

Often, a project that's within ±5-10% of budget estimates is considered on-budget, especially when we're dealing with large round numbers and uncertainty. If, on the other hand, the variance started out at 1% and it's gone to 8%, it might be sensible to look for any potential underlying problem well before costs get out of hand.

If you work on a large project or in an organization that uses performance measuring software systems, you may have a great deal of specific information available that you can use to monitor and control your risks. Financial data, market performance, test results, and productivity metrics can be of help.

If your project management environment contains a *project management office* (PMO), uses enterprise grade software for project management, or has implemented *Earned Value Project Management* (EV or EVM), you have even more tools at your disposal to monitor and control risks on your project. A PMO often keeps performance data on other projects that you can use to baseline your own effectiveness. Enterprise-grade project management software, capable of handling tens of thousands of activities in tight relationships, provides extensive tools for analyzing and tracing chains of events.

Exhibit 10-2 Earned Value Method (EVM) Performance Index Ratios

Example: Today, the schedule says you should have finished Task A, which was budgeted at $1,000, and half of Task B, which has a total planned cost of $1,000 as well (total of $1,500). You've spent $1,750, but you've accomplished all of Task A and all of Task B as well. How are you doing?

PV = $1,500   AC = $1,750   EV = $2,000
SPI = $2,000 / $1,500 = 1.33 (133%)   CPI = $2,000 / $1,750 = 1.14 (114%)

Example: Today, the schedule says you should have finished Task D ($5,000), Task E ($2,500), and half of Task F (50% of $7,500). You've only finished Tasks D and E, and you've spent $8,250 so far. How are you doing?

PV = $11,250   AC = $8,250   EV = $7,500
SPI = $7,500 / $11,250 = 0.67 (67%)   CPI = $7,500 / $8,250 = 0.91 (91%)

Earned Value Project Management

Earned Value Project Management requires a self-study course in itself, and a full discussion is well outside the scope of this book. If EVM is required for your projects or by your customers, then you will need to become familiar with it if you are not already.

The EV method starts with three numbers: The *planned value* (PV) measures how much work we should have accomplished by a given date and how much we should have spent to accomplish it. To that, we add the *actual cost* (AC), what we actually spent for what we actually did. Finally, we add the *earned value* (EV), which measures what we should have spent for what we actually did.

Earned value allows you to determine the amount of cost or schedule variance, but from a risk point of view, it's valuable to pay particular attention to two ratios that measure performance. The cost performance index (CPI) is the ratio of the earned value to the actual cost (CPI = EV / AC), and the schedule performance index (SPI) is the ratio of the earned value to the planned value (SPI = EV / PV). Exercise 10-1 shows you how to do it.

Exercise 10-1 Earned Value Method (EVM) Performance Index Ratios

Today, the schedule says you should be completely done with Task A ($7,500) and Task B ($5,000), and half done with Task C (total cost of $10,000). You have completed 75% of Task A, spending $6,000 to date; all of Task B at a cost of $6,000; and you are completely done Task C, having spent $12,000. How are you doing?

Task	Planned Value (PV)	Actual Cost (AC)	Earned Value (EV)
A			
B			
C			
Totals	PV =	AC =	EV =

SPI =________________

CPI =________________

What conclusions can you draw about this project?

An SPI or CPI of 1.00 (100%) means you're exactly on track. Small variances (less than 5% or 10% on either side, depending on the type of project and organization) are not usually significant; anything above 10% either way demands investigation.

Implementing and Monitoring Risk Responses

Even if you develop great risk responses, they don't do very much unless they're implemented. We have suggested the best place for many risk responses is in the project plan, and indeed there are always tasks in any project plan that exist solely to address risk. If there were no chance of a failure, there would be no need for inspection or testing. If the design were certain to work, it would not need to be reviewed. Testing, reviews, and many other activities are best treated the same way as any other work package.

A risk response plan can consist of many sorts of actions, as shown in Exhibit 10-3.

Exhibit 10-3 Sample Risk Response Action Plans

Risk: Customer orders may need to be filled during inventory.

Response: Be prepared to work overtime to meet both the needs of the customer and the need for the inventory.

Action Steps:

1. Check with Sales Manager the week before the inventory to see if customer emergencies are expected.
2. Advise team members of the potential for last-minute overtime so they can adjust personal plans as necessary.
3. Recruit two backup team members who will be available to work if needed; include them in training session.
4. If it turns out that overtime or extra staff are needed, prepare authorization requests and timesheets to submit to payroll.

Corrective Actions and Unplanned Responses

Most risk responses are implemented whether or not the risk occurs. If you buy insurance, you may or may not end up having a claim. If you conduct testing, you may or may not find anything wrong. While the risk condition itself may be uncertain, the response is not.

Implementing a contingent response is known as *corrective action.* Responding to an unplanned risk is known as a *workaround.* The difference, of course, is that you have at least a general course of action in mind in the first case, and may be scrambling to find an acceptable solution in the second case.

To make a contingent response effective, you need to establish a *risk trigger,* a set of conditions or circumstances that activate the response. This is particularly important when your risk response requires a head start on the risk event itself.

Watching "Watch and Wait" Risks

We have identified "watch and wait" risks, characterized as having (1) low probability, (2) potentially catastrophic impact, and (3) expensive mitigation. Because of the cost of response, you prefer not to spend the resources unless you have reason to believe the risk event is actually going to occur, or is looking tremendously more likely.

What kind of metrics will you use to observe the risks? Are there leading indicators of potentially adverse trends? Are there particular circumstances that alter the probability or impact of the risk?

Change Management and Risk

It's far from unusual to make changes to the project scope and objectives during the project life cycle. Sometimes new information is received; sometimes circumstances or needs change; and sometimes people simply change their minds. The result is a change order, whether formal or informal. They are part of life for any project manager.

Changes, of course, frequently contain risks—and in the context of our project, they are *new* risks, not yet included in our risk evaluation and response process. While it's not always possible to perform a full risk analysis before deciding what to do about a given change (sometimes the change is a fact whether you like it or not), it's important to perform a risk evaluation as early as practical so that you can respond or adjust as needed.

Planning for Changes

Virtually every authority in project management recommends a formal *change management system,* and it's fairly obvious why this is a good idea. Changes cost money and time, they may affect other parts of the project, and they aren't always communicated effectively. Failing to review and document changes effectively opens your project to huge and unnecessary risk.

There are many right ways to put together a change management system, and they vary by organization and environment. At a minimum, they usually include the following:

- A way to document the change
- A way to allocate any associated costs for the change
- Someone who can approve or reject the change

Risk analysis and risk response planning are necessarily part of all three steps, whether they are done formally or informally. Because changes are a particularly rich source of project risk, we recommend a formal approach in almost all cases. If a change is to be made to an in-progress project, someone (either the project manager, or if the risk is specialized, the particular risk owner) needs to perform a risk analysis and identify issues of potential concern.

Avoid becoming the "boy who cried wolf." Your role is to figure out how to make the change work, rather than to show why it cannot. In some cases, an honest evaluation will reveal risks so serious that they require a reassessment of whether the proposed change is appropriate, but that decision normally belongs to customers or managers at a higher level. Your role is to provide objective data, and when possible to offer solutions or useful alternatives.

Think About It …

Do you have a formal change management plan? Does it do a satisfactory job of evaluating new risks associated with changes? How would you improve it?

Managing Unplanned Change

Problem solving and crisis management are all too frequently a fact of organizational and project life. The goal of risk management is to reduce the number and scope of problems and crises, but it's unrealistic to expect that even the finest risk management will make everything go away.

By their very nature, problems tend to be specific, unexpected, and unique. Risk management can't provide individual answers in advance. We do get advantages from risk management even for the most unplanned and unexpected events, however. By establishing our monitoring system, we're more likely to get an early warning. If we have resources available to address planned risks, they can be repurposed to manage unplanned ones as well.

Revisiting Risk Identification and Risk Analysis

Time—and therefore risk—marches on. When we perform our initial risk identification during the early planning stages of the project, we see a great deal of uncertainty. As the project moves forward in time, however, the future slowly becomes the present, and then quickly turns into the past. Risks turn into problems, or they don't happen at all.

The events on our project change the risk picture for the future. If we suddenly get a huge influx of customer orders in the weeks leading up to our inventory date, and more of them than usual are emergencies, the chance that our inventory will be interrupted by the need to ship goes up dramatically. Instead of waiting for the actual order to work overtime, maybe it makes more sense to put the extra manpower on the job from the beginning to get it done as quickly as possible.

New risks appear with little or no warning. Two of the employees we planned to use on the inventory project have just quit, and they were the only two who had experience doing our inventory in previous years. To address the new set of risks, consider doing two things:

1. Add an item to your regular status meeting agenda to talk about new risks that should be added to the risk management plan. Assess those risks using qualitative risk analysis filtering, and conduct risk analysis and response planning for those you consider serious.
2. If the project will take months to complete, conduct a monthly risk review. Take the plan, existing risks, new risks, and performance data, and update the overall risk management plan.

Update the risk register and risk information sheets for new risks and for existing risks that have changed in nature, probability, or impact.

Closing Risks

At some point in the project, every risk reaches its expiration date—a point after which if the risk has not occurred, it can no longer occur. Before the test is run, the widget has a risk of failing the test. After the test has been run, the widget either passed or failed. Either way, there's no longer a risk, but rather a non-event (it passed) or a problem (it failed).

When you decide that a risk needs to be monitored, managed, controlled, or watched, you should *close* the risk. Close a risk under the following circumstances:

1. The risk did not happen and it is no longer possible for it to happen.
2. The risk happened, and all of its consequences have played out, for better or worse.
3. The residual level of the risk is no longer worth the time and expense to monitor it.

When the project is complete, all the risks associated with the project are also closed. (Risks in the *product,* which you deliver to the customer or user, still remain, of course.)

Document when a risk is closed, either on the risk register or the risk information sheet, and list briefly why it has been closed. Keep information related to all risks, including closed ones, for two reasons. First, you need to review those risks and responses as part of "lessons learned," and second, you may encounter similar risks on future projects and will be able to reuse risk analysis and response planning that you've already done.

Risk Management and Project "Lessons Learned"

Every well-run project includes a post-mortem, or "lessons learned" exercise, and evaluating risk management and risk response is part of it. Consider the following questions:

- How did your estimates of probability and impact line up with reality?
- What risks occurred that you did not expect?
- What risks did you expect that did not occur?
- What assumptions about the project turned out be incorrect?
- What linkages or connections among the risks were not obvious?
- How well did your risk mitigation efforts and risk response plans operate?
- How effectively were you able to monitor conditions and get early warning of risk events?
- Were the risk management processes that you used cost-effective and appropriate for your project?
- What would you do differently next time?
- What did you learn on this project that will improve your ability to manage risks on future projects?

Keep risk response plans, risk analysis data, and actual project results to use as raw material for managing risks on future projects.

recap

Risk management requires an overall process for implementation during the phases of project execution, monitoring, and control. A risk management plan is for an individual project; a risk management policy covers an entire organization or at least a category of projects.

Risk management policy addresses numerous questions:

- What kinds of risks are most important?
- What kinds of risks do you want people to take?
- What kinds of risks do you want people to avoid?
- What projects and risks are covered?

In addition to implementing specific risk responses, risks are also managed collectively and by category. Project monitoring and control activities, such as status reports or other data, provide raw information about risks, helping you to discover whether particular risks are being triggered, whether planned risk responses are working as intended, or whether environmental conditions have changed.

Project metrics take many forms. In the Earned Value Method (EVM), the planned value, actual cost, and earned value of a project allow you to measure schedule and cost performance on your project.

Risk response plans detailing action steps for a given risk are normally integrated into the overall project plan. In addition, you may need to implement corrective action (contingent responses) or workarounds (unplanned risks). Monitor “watch and wait risks” carefully.

Project changes create new risks and modify existing ones. A formal change management process has many virtues, including providing an opportunity for renewed risk management efforts. Risk identification and risk analysis need to be revisited as the project moves forward over time. Close risks when they can no longer happen, when all their consequences have played out, or when the residual risk is no longer cost-effective to monitor.

Finally, evaluate the effectiveness of risk management as part of lessons learned, and organize risk data on current projects so that it benefits future projects as well.

Review Questions

1. The schedule performance index (SPI) measures the ratio of the:
   (a) earned value to the actual cost.
   (b) actual cost to the planned value.
   (c) planned value to the actual cost.
   (d) earned value to the planned value.

1. (d)

2. A risk management policy includes which of the following elements?
   (a) Risk identification and risk analysis information for the project
   (b) How the organization wants risk management to be performed
   (c) A list of planned risk responses and action steps
   (d) Description of metrics and measurements to be used on the project

2. (b)

3. What is the effect of project change on project risk?
   (a) Changes increase overall project risk.
   (b) Changes only add to the list of risks.
   (c) Changes create new risks and modify existing risks.
   (d) Changes balance new risk with new opportunity.

3. (c)

4. What kinds of risks are most desirable? 4. (c)
   (a) Pure risks
   (b) Uncertain risks
   (c) Business risks
   (d) Nonfinancial risks

4. (c)

5. The cost performance index (CPI) measures the ratio of the:
   (a) planned value to the actual cost.
   (b) actual cost to the planned value.
   (c) earned value to the actual cost.
   (d) earned value to the planned value.

5. (c)

Answers to Exercises and Case Studies

Exercise 1-1. Managing Important Risks

One all-too-common strategy for dealing with risk is denial. We sometimes ignore risks because it can be uncomfortable to think about them, especially when the risks are potentially very serious and our options to do something about the risk are limited.

The purpose of this exercise is to make you more conscious of the risks in your environment—and the fact that you are doing something in response to many (albeit not all) of those risks.

You may find that actually writing down a particular risk and thinking about the best response causes you to take action you might not otherwise have taken, or at least refocus on an action you have already taken. Studies showed that random messages provided to bus drivers suggesting they be more careful on a particular day reduced accidents. It’s not that the drivers were otherwise unsafe, it’s that the reinforcement caused them to pay more attention for a short period.

We don’t judge you for the risk on which you have surrendered on the grounds that our own list of surrenders is embarrassingly long. However, there have been cases in which we postponed action for a long time, but eventually did do something about it. Awareness doesn’t always translate into action, but it’s usually a necessary precursor.

With that in mind, we encourage you to become more conscious of the risks in your environment. Continue the exercise over the next week, adding additional risks as you think about them. Try to add at least one risk each day; more is better. Through practice, this will make it easier for you to see risks in any environment—and to act upon them.

Risk	Likelihood	Impact	Seriousness	What Am I Doing About It?

Exercise 1-2. Your Current Risk Management Process

The purpose of this exercise is not to criticize anything you or your organization may be currently doing with respect to risk management. Depending on the seriousness of the risks, the extent to which you have good information about those risks, and the cost of addressing those risks, some organizations have a very high need for formal risk management while others have a comparatively low need.

When thinking about informal risk management, be aware that risk management activities don't always get labeled as risk management. For example, as authors, we check our spelling and grammar before sending our manuscripts to our editors, and our editors check them again. No one in publishing refers to proofreading as part of a book's risk management plan, but if authors were incapable of error, then there'd be no need for poofraeding…er, proofreading…at all. Editors perform an unlabeled risk management function. So do many other professionals.

The two important questions in the exercise concern what works and what could be improved in your current process. We urge you to keep those ideas uppermost in your mind as you continue to work through this self-study course so that you can identify the most appropriate lessons to apply from these pages.

Exercise 1-3. What You Spend on Risk Management

What's valuable in this exercise is increasing your awareness of risk expenditures currently taking place, not how precise or comprehensive your estimate. As we move forward in this self-study course, consider these estimates as you identify other opportunities and tools to manage project risks. Are you spending the right amount on the right targets? What would be the benefit of additional risk expenditures? Where should they be targeted?

Exercise 2-1. Risk Identification Practice

Depending on your own experience, you may have answered some of these questions in a different way. Your answers are right as long as they correspond to your experience in your own work environment—they don't have to be the same as ours.

Question	First Exercise	Second Exercise	Third Exercise
What is being asked of us? What force or circumstance could affect us?	*Goal*: Inventory 10,000 items in three days.	*Assumption*: No items will be received or shipped from the warehouse during the inventory period.	*Resources*: You have five people (in addition to yourself) to accomplish the project.
Is this difficult, problematic, or uncertain?	Doesn't seem to be. Six people working three 8-hour days gives us 144 person hours. To inventory 10,000 items, we will need to count 70/hour. Even allowing time for paperwork, this does not seem excessive.	Unlikely to be a problem, but we do have emergency customer needs from time to time. If we do have to interrupt the job to ship or receive some items, we can put in overtime if necessary to meet the deadline.	Given the amount of time and number of items, the resources seems adequate to the job. If there is absenteeism, or if people are taken from this work to do other things, we might have a problem.
What are the consequences of failure?	We must get the inventory done each year for tax purposes. If there are problems, we will spend money on overtime or recruit extra help to get it done.	If we should have to do shipping and receiving during inventory, there's an increased risk the results will be inaccurate.	Overtime pay
Are there any circumstances or conditions that would result in failure?	Major absenteeism or problems in the warehouse itself; neither appear likely.	We can't easily predict or control customer emergencies. It's seldom the case that a three-day delay will cause major problems.	Major absenteeism or disgruntled employees. There is no indication that either will be a problem.
Are there any opportunities to do this work better, faster, or cheaper, or to gain additional benefit from the work?	The biggest opportunity to speed things up is to be well prepared. Team members need training and tools. Hand-held barcode scanners and other electronic tools can speed up counting.	We can ask our salesforce if they anticipate any customer issues in this period. If so, we can try to meet their needs before the inventory process starts.	Good training and specific procedures will help make sure the work is done correctly and expeditiously.
Are these risks being managed elsewhere?	No. These risks belong to the project.	No. These risks belong to the project.	No. These risks belong to the project.
Should we add any of these risks to our project risk identification list?	No. We've been doing this for years, and our basic procedures are already in place.	Yes. We know that we'll solve any problems with overtime rather than be late, but we need to make sure the possibility is documented.	Yes. There are two potential ways to get around any staff shortages caused by absenteeism: overtime for remaining staff or recruiting additional help.
Conclusion	No risk.	Low Probability/Low Impact Risk	Low Probability/Low Impact Risk
Statement of Risk	N/A	If customer	If members of the

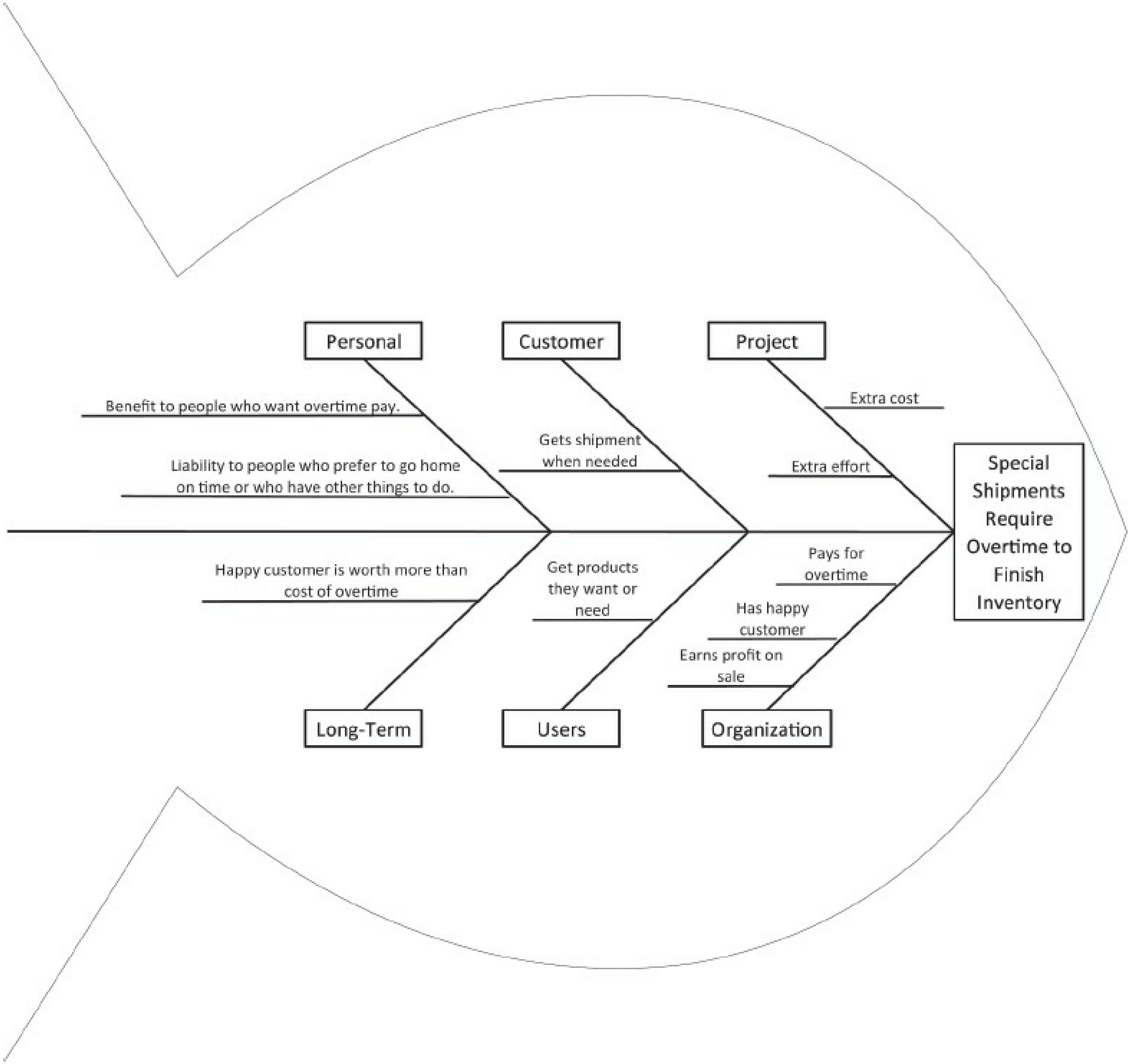
Statement of Risk	N/A	If customer emergencies require us to make a special shipment during the inventory process, we may need to work overtime to meet the original deadline.	If members of the project team are unavailable, we will either recruit replacements from other departments or pay overtime to the remaining team members to meet the original deadline.

Exercise 2-2. Swot Analysis

Depending on your own organizational experience, you may have answers different from ours that are equally correct. Telling helpful from harmful is usually easy; check to make sure you've separated internal from external.

Exercise 3-1. Cause-and-Effect Diagram

Here's one answer for the risk: "If customer emergencies require us to make a special shipment during the inventory process, we may need to work overtime to meet the original deadline" from Exercise 2-1. Notice that in this case, the costs are charged to the project (overtime) but substantial benefits accrue to the organization.



Exercise 4-1. Establishing Risk Thresholds

To provide a comparison guide, we've developed risk thresholds based on the imaginary project from Exercise 2-1. Your thresholds are likely different.

Category	Definition	Threshold	Authority to Make Exceptions
Schedule Risk	Risks that would make the project tend to miss its time constraint	Any risk that would make the project take longer than three days is unacceptable.	Chief Operating Officer
Cost Risk	Risks that would add cost to the project or to the organization	Excessive or unnecessary overtime should be avoided.	Department head
Business Risk	Risks that would cause the organization to be seen less favorably	Emergency customer needs for quick shipping must be accommodated regardless of other factors.	VP/Sales for emergency shipping authority
Security Risk	Risk that sensitive or classified information will be released inappropriately; risk of theft or pilferage	Standard warehouse security practices will be followed.	VP/Operations
Quality Risk	Risk that the product or service will fail to meet its standards	Inventory must be accurate; spot checks should reveal an error no greater than ±3%.	Department head
Safety Risk	Risk that people may be physically harmed as a result of the project or its output	Standard warehouse safety procedures will be followed strictly.	VP/Safety
Legal Risk	Risk of violating laws or regulations; risk of being sued	All applicable laws and regulations will be followed.	General counsel
Hazmat Risk	Risk that hazardous materials will not be handled safely and legally.	All internal policies, regulations, and laws concerning hazmat shall be following to the letter without exception.	General counsel; VP/Safety; VP/Operations
Other			
Other			

Exercise 4-2. Ranking Risks

One reason to consider using more than a single method of ranking risks is what happens when you *do* get different results. If you found that you ranked a risk differently, it may be because of a different scale. In the word exercise, there are four grades of probability (no "in the middle" choice) and in the number scale, there are five (all risks must be rated higher or lower). Sometimes you find yourself putting more emphasis on impact than probability, as opposed to considering both equally.

When this happens, we don't have a bias in favor of one approach over the other. Instead, we view this as a reason to look at a given risk more deeply; based on our greater understanding, sometimes we end up choosing a higher risk rating or a lower one.

Exercise 4-3. Prepare a Risk Information Sheet

This is a risk information sheet for "If customer emergencies require us to make a special shipment during the inventory process, we may need to work overtime to meet the original deadline" from Exercise 2-1 and Exercise 3-1.

In order to provide a complete example, we've filled in the "Status" section of the form. In real life, that won't get filled in until there are actual project events to report. Notice in this case, the risk turned out to be a non-event.

RISK INFORMATION SHEET

RISK ID	RISK DESCRIPTION
R-1	If customer emergencies require us to make a special shipment during the inventory process, we may need to work overtime to meet the original deadline.
RATING Low	
PROBABILITY Unlikely	
IMPACT Minor	

RISK ANALYSIS

Although this is a low priority risk, it's important to specify two things.
1. The three-day window to do inventory is fixed. We cannot exceed three days. Under normal circumstances and with the available team, this is usually ample.
2. Our commitment to meeting customer needs is also fixed. If a customer has an emergency, we will do everything in our power to meet the customer's needs. This is both a key organizational value and good business practice. By establishing our response in advance, we make sure that neither of our goals suffer.

RISK RESPONSE (ACTIONS AND DISPOSITION)

We will do the following things in response to this risk.
1. The sales department will provide as much advance notice as possible of any customer emergencies requiring shipping.
2. If emergency shipping is necessary, overtime is authorized for the inventory team to ensure they meet the three days. The project lead will assign overtime if it is needed and report the information to payroll and to the department head for budget control.
3. If the project lead for any reason feels that the three-day window is in jeopardy, the project lead will immediately notify the department head and VP/Ops to acquire the necessary additional resources.

STATUS OF RISK (INCLUDING FINAL OUTCOME)

No emergency shipping request received during inventory. No actions taken. Risk closed.

Exercise 5-1. Probability Practice

The basic probability of rolling a given number on a six-sided die is 1/6. That's true no matter what number you pick. The probability of *not* rolling a given number is 1 minus the chance of rolling it, or 5/6. The odds, remember, are not the same as the probability, but the ratio of favorable to unfavorable outcomes.

	Probability	Odds
a. Roll a 4	1/6	1/5
b. Roll a 2	1/6	1/5
c. Not roll a 4 or a 2	4/6	4/2

The probability of one event *and* another independent event happening is the product of the two probabilities: 1/6 × 1/6 = 1/36.

It's easier to figure out the probability of *not* rolling a 4 on either die: 5/6 × 5/6 = 25/36. Since the probability of p(A) = 1 – p(not A), figure out the probability of rolling a 4 on at least one die by subtraction: 1 – 25/36 = 11/36. Yes, rolling a double 4 counts as "at least" one die.

a. Roll two 4s	1/36	1/35
b. Roll a 4 and then a 2	1/36	1/35
c. Roll a 4 on at least one die	11/36	11/25
d. Not roll a 4 on at least one die	25/36	25/11

Exercise 5-2. Calculate a Standard Deviation

The answer key to this exercise is in two parts, both assuming you'll use a spreadsheet to develop your answer. The first line contains the formulas that tell you what information should go in each empty cell from the exercise.

To determine the mean, add up the entries in the Result column and divide by the number of entries.

Result	Number of Times	Distance from the Mean	Total d	d²
8	3	= Mean minus Result	= Number of times multiplied by distance from the mean	= Square of total d
9	7			
10	10			
11	16			
12	19			
13	26			
14	46			
15	65			
16	82			
17	88			
18	91			
19	90			

20	87			
21	85			
22	71			
23	56			
24	42			
25	37			
26	23			
27	19			
28	17			
29	11			
30	5			
31	4			
Sum	1000			= sum of all the d^2

To calculate the standard deviation, first divide the sum of the d^2 column by the total number of cases (1,000), then take the square root of your answer.

Armed with that information, let's fill in the rest of the cells.

Mean = 19.5

Result	Number of Times	Distance from the Mean	Total d	d^2
8	3	11.50	34.50	1190.25
9	7	10.50	73.50	5402.25
10	10	9.50	95.00	9025.00
11	16	8.50	136.00	18496.00
12	19	7.50	142.50	20306.25
13	26	6.50	169.00	28561.00
14	46	5.50	253.00	64009.00
15	65	4.50	292.50	85556.25
16	82	3.50	287.00	82369.00
17	88	2.50	220.00	48400.00
18	91	1.50	136.50	18632.25
19	90	0.50	45.00	2025.00
20	87	-0.50	-43.50	1892.25
21	85	-1.50	-127.50	16256.25
22	71	-2.50	-177.50	31506.25
23	56	-3.50	-196.00	38416.00
24	42	-4.50	-189.00	35721.00
25	37	-5.50	-203.50	41412.25
26	23	-6.50	-149.50	22350.25
27	19	-7.50	-142.50	20306.25
28	17	-8.50	-144.50	20880.25
29	11	-9.50	-104.50	10920.25
30	5	-10.50	-52.50	2756.25
31	4	-11.50	-46.00	2116.00
Sum	1000			[illegible]

Sum	1000			628505.50

$\sigma = 25.07$

Exercise 6-1. Greater Accident Variation

The formulas and process for completing this exercise are identical to the ones in Exercise 5-2 above.

Risky Business Insurance Company Historical Numbers of Covered Accidents Per 100,000 Policyholders, 2000-2010 Mean: 100			
Year	**Number of Accidents**	**Distance from the Mean**	**d²**
2000	150	-50	2500
2001	50	50	2500
Year	**Number of Accidents**	**Distance from the Mean**	**d²**
2003	125	-25	625
2004	100	0	0
2005	110	-10	100
2006	90	10	100
2007	50	50	2500
2008	150	-50	2500
2009	90	10	100
2010	110	-10	100
Sum	1100		11650

$$\sigma = \sqrt{(11650/1100)} = 3.25$$

Exercise 6-2. Premium Income and Claims Outlays

Year	Number of Accidents = number of accidents from Exercise 6-1 times 10	Premiums Charged = $10 per customer times 1,000,000 customers	Claims Paid = number of accidents from Column 2 times $10,000 per accident	Net Income (Loss) = premiums charged minus claims paid
2000	1500	$10,000,000	$15,000,000	$(5,000,000)
2001	500	$10,000,000	$5,000,000	$5,000,000
2002	750	$10,000,000	$7,500,000	$2,500,000
2003	1250	$10,000,000	$12,500,000	$(2,500,000)
2004	1000	$10,000,000	$10,000,000	$0
2005	1100	$10,000,000	$11,000,000	$(1,000,000)
2006	900	$10,000,000	$9,000,000	$1,000,000
2007	500	$10,000,000	$5,000,000	$5,000,000
2008	1500	$10,000,000	$15,000,000	$(5,000,000)
2009	900	$10,000,000	$9,000,000	$1,000,000
2010	1100	$10,000,000	$11,000,000	$(1,000,000)
TOTALS	11000	$110,000,000	$110,000,000	$0

Exercise 6-3. Pricing Risk

a. Llewellyns of Los Angeles is responsible for Risky Business Insurance losses whenever those losses in a given year are greater than $750,000 over the premium income. That means Llewellyns writes three checks during the eleven years of coverage. Without considering any other factors, this works out to a premium of 84¢ charged to each Risky Business policy.

Llewellyns of Los Angeles Reinsurance Estimate of Risky Business Insurance				
Year	Net Income (Loss)	Reinsurer's Exposure	Base Value of Risk Per Year	Cost Per Policyholder
2000	$(4,670,000)	$(3,920,000)	$(841,818.18)	$(0.84)
2001	$5,330,000	$-	$(841,818.18)	$(0.84)
2002	$2,830,000	$-	$(841,818.18)	$(0.84)
2003	$(2,170,000)	$(1,420,000)	$(841,818.18)	$(0.84)
2004	$330,000	$-	$(841,818.18)	$(0.84)
2005	$(670,000)	$-	$(841,818.18)	$(0.84)
2006	$1,330,000	$-	$(841,818.18)	$(0.84)
2007	$5,330,000	$-	$(841,818.18)	$(0.84)
2008	$(4,670,000)	$(3,920,000)	$(841,818.18)	$(0.84)
2009	$1,330,000	$-	$(841,818.18)	$(0.84)
2010	$(670,000)	$-	$(841,818.18)	$(0.84)
	Exposure over 11 years	$(9,260,000)	$(9,260,000)	

b. There are many other factors to consider in coming up with the final premium. Your list may vary, but these are some items we would consider.

1. The costs of doing business. Like all businesses, Llewellyns of Los Angeles has overhead, sales costs, cost of money, and desired profit.
2. Risk that the actual payouts over 11 years might be greater than premium charged. If Risky Business has one more bad year than the track record suggests, the reinsurer is on the hook for as much $5 million in additional payouts.
3. Risk that the maximum potential payout is $5 million, not $4.67 million.
4. The cost of the capital necessary to underwrite the insurance.
5. Surprises and black swan events.

c. Covering excess risk up to $10 million rather than capping the policy at $5 million is an exercise in judgment. We have no cases on record in which total losses have even hit the $5 million mark, our current maximum. One possibility is to do additional research. Are other insurance companies around the world in the same line of business? If so, have any of them experienced years in which covered events were dramatically more frequent than normal? If we can glean a pattern from our investigation, we can use that to price the additional risk. If you discovered, say, that the circumstance in which you'd have to pay an additional $5 million occur about 2% of the time, that suggests adding $100,000/1,000,000 to the premium cost, or another 10¢ per policy.

What if you can't find any evidence whatsoever that such an event has ever happened? That doesn't mean it's impossible, but it's fair to say it's unlikely. At this point, risk managers end up having to make an assumption. In this case, we might say we were unwilling to underwrite the risk for less than 5¢ per policy, which equates to an assumed risk of 1%. Given the minor difference, we'll use the 10¢ figure.

d. Pricing the cost of the reinsurance, as you can see, involves some judgment. Here's our answer:

	$5 million cap	**$10 million cap**
Base Cost of Risk	$0.84	$0.84
Additional Exposure (assuming 2% chance of catastrophic event)	$-	$0.10
Overhead (25%)	$0.21	$0.24
Profit Target (15%)	$0.13	$0.14
Total	$1.18	$1.32

Llewellyns of Los Angeles might well add safety for itself by rounding up these numbers, and charge a premium of $1.25 for a $5 million cap and $1.40 for a $10 million cap. For the purposes of our example, however, we'll use $1.32 as the cost of reinsurance for Risky Business (we thought an extra 5¢ for protection against the larger loss was a bargain).

Your analysis may yield a different number, but as long as you considered the same basic issues and used a similar process, consider it equally valid. As we've noted, pricing risk involves judgment as well as analysis.

Exercise 7-1. Deterministic or Probabilistic?

Number	Deterministic	Probabilistic
Make 100,000 new widgets per year with the new equipment *Rated capacity is under specified conditions. Actual number will vary. If 100,000 is a guarantee, it's the minimum number.*		✔
Sell the additional 100,000 widgets to customers *Sales forecasts and estimates of customer demand are never exact.*		✔
Buy a widget maker for a price of $100,000 to $250,000 *Advertised prices are usually good for a certain period of time. If we plan to act within that margin, the advertised price for the unit we select should be as predicted.*	✔	
Make a gross profit of $5 to $7 per widget *Cost of raw materials, labor, overhead, maintenance, and other factors can change cost; market conditions can change price.*		✔
Incur overhead costs of $3 per widget sold *Unless these costs are unusually solid, there's probably uncertainty here as well.*		✔

Exercise 7-2. Calculating Expected Monetary Value (EMV)

Create a spreadsheet with the following formula:

Manufacturing Cost for 10,000 units	Fixed Costs	Number of Errors in 10,000	Cost of Repairs at $200/each	Subtotal	Probability	Total
$15 x 10,000	$50,000	From the table x 10	Number of errors x $200	Sum of manufacturing cost, fixed costs, and cost of repairs	From the table	Subtotal x probability

The EMV is the sum of the numbers in the final column. That's the combined probability times the impact of each of the states of nature.

Now, let's plug in the actual numbers.

Manufacturing	Fixed Costs	Errors	Repair Cost	Subtotal	Probability	Total
$150,000	$50,000	0	$-	$200,000	30%	$60,000
$150,000	$50,000	10	$2,000	$202,000	40%	$80,800
$150,000	$50,000	20	$4,000	$204,000	20%	$40,800
$150,000	$50,000	30	$6,000	$206,000	10%	$20,600
$150,000	$50,000	50	$10,000	$210,000	5%	$10,500
$150,000	$50,000	100	$20,000	$220,000	1%	$2,200

EMV = $214,900

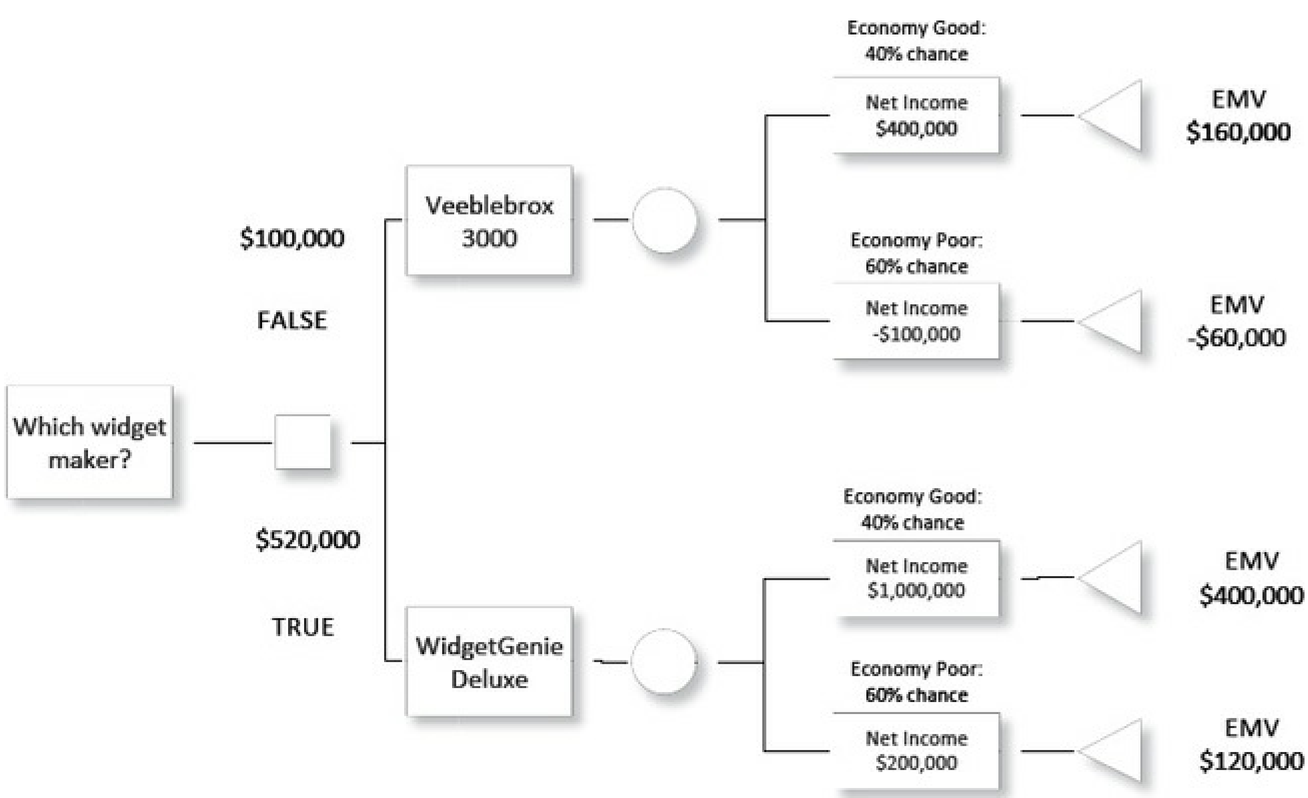
Think About It … (Decision Tree)

The difference between the EMV for Investment A and Investment B is $5,750 minus $2,800, or $2,950. Subtract that amount from the asking price for Investment B and you get $9,050.

Exercise 7-3. Decision Tree

Here's a spreadsheet containing all the net income data, and the filled-in decision tree follows.

	Veeblebrox 3000		WidgetGenie Deluxe	
	Good Economy	Poor Economy	Good Economy	Poor Economy
Widgets Sold	500,000	300,000	500,000	300,000
Price Per Widget	$20	$19	$20	$19
Gross Revenue	$10,000,000	$5,700,000	$10,000,000	$5,700,000
Cost Per Widget	$15	$15	$13	$13
Manufacturing Cost	$7,500,000	$4,500,000	$6,500,000	$3,900,000
Error Rate	2%	2%	3%	3%
Number of Errors	10,000	6,000	15,000	9,000
Cost Per Error	$200	$200	$150	$150
Total Cost of Errors	$2,000,000	$1,200,000	$2,250,000	$1,350,000
Cost of Equipment	$100,000	$100,000	$250,000	$250,000
Net Income	$400,000	($100,000)	$1,000,000	$200,000
Probability of Outcome	40%	60%	40%	60%
EMV	$160,000	($60,000)	$400,000	$120,000
EMV of Decision	$100,000		$520,000	



The more expensive WidgetGenie is a better investment, even considering its higher error rate.

Exercise 7-4. Sensitivity Analysis

Scenario: Veeblebrox defects only 1%.

	Veeblebrox 3000		WidgetGenie Deluxe	
	Good Economy	Poor Economy	Good Economy	Poor Economy
Widgets Sold	600,000	400,000	500,000	300,000
Price Per Widget	$20	$19	$20	$19
Gross Revenue	$12,000,000	$7,600,000	$10,000,000	$5,700,000
Cost Per Widget	$15	$15	$13	$13
Manufacturing Cost	$9,000,000	$6,000,000	$6,500,000	$3,900,000
Error Rate	2%	2%	3%	3%
Number of Errors	12,000	8,000	15,000	9,000
Cost Per Error	$200	$200	$150	$150
Total Cost of Errors	$2,400,000	$1,600,000	$2,250,000	$1,350,000
Cost of Equipment	$100,000	$100,000	$250,000	$250,000
Net Income	$500,000	($100,000)	$1,000,000	$200,000
Probability of Outcome	40%	60%	40%	60%
EMV	$200,000	($60,000)	$400,000	$120,000
EMV of Decision	$140,000		$520,000	

Advantage: Veeblebrox by $240,000. Even though Veeblebrox has a lower defect rate, the higher cost of repairs is a huge drag on net income.

Scenario: Veeblebrox produces an additional 100,000 widgets.

	Veeblebrox 3000		WidgetGenie Deluxe	
	Good Economy	Poor Economy	Good Economy	Poor Economy
Widgets Sold	600,000	400,000	500,000	300,000
Price Per Widget	$20	$19	$20	$19
Gross Revenue	$12,000,000	$7,600,000	$10,000,000	$5,700,000
Cost Per Widget	$15	$15	$13	$13
Manufacturing Cost	$9,000,000	$6,000,000	$6,500,000	$3,900,000
Error Rate	2%	2%	3%	3%
Number of Errors	12,000	8,000	15,000	9,000

	Veeblebrox 3000		WidgetGenie Deluxe	
	Good Economy	Poor Economy	Good Economy	Poor Economy
Cost Per Error	$200	$200	$150	$150
Total Cost of Errors	$2,400,000	$1,600,000	$2,250,000	$1,350,000
Cost of Equipment	$100,000	$100,000	$250,000	$250,000
Net Income	$500,000	($100,000)	$1,000,000	$200,000
Probability of Outcome	40%	60%	40%	60%
EMV	$200,000	($60,000)	$400,000	$120,000
EMV of Decision	$140,000		$520,000	

Advantage: WidgetGenie by $380,000. At a price of $19 per widget, the company can't make money no matter how many widgets they make.

Scenario: Veeblebrox errors only cost $100 to fix

	Veeblebrox 3000		WidgetGenie Deluxe	
	Good Economy	Poor Economy	Good Economy	Poor Economy
Widgets Sold	500,000	300,000	500,000	300,000
Price Per Widget	$20	$19	$20	$19
Gross Revenue	$10,000,000	$5,700,000	$10,000,000	$5,700,000
Cost Per Widget	$15	$15	$13	$13
Manufacturing Cost	$7,500,000	$4,500,000	$6,500,000	$3,900,000
Error Rate	2%	2%	3%	3%
Number of Errors	10,000	6,000	15,000	9,000
Cost Per Error	$100	$100	$150	$150
Total Cost of Errors	$1,000,000	$600,000	$2,250,000	$1,350,000
Cost of Equipment	$100,000	$100,000	$250,000	$250,000
Net Income	$1,400,000	$500,000	$1,000,000	$200,000
Probability of Outcome	40%	60%	40%	60%
EMV	$560,000	$300,000	$400,000	$120,000
EMV of Decision	$860,000		$520,000	

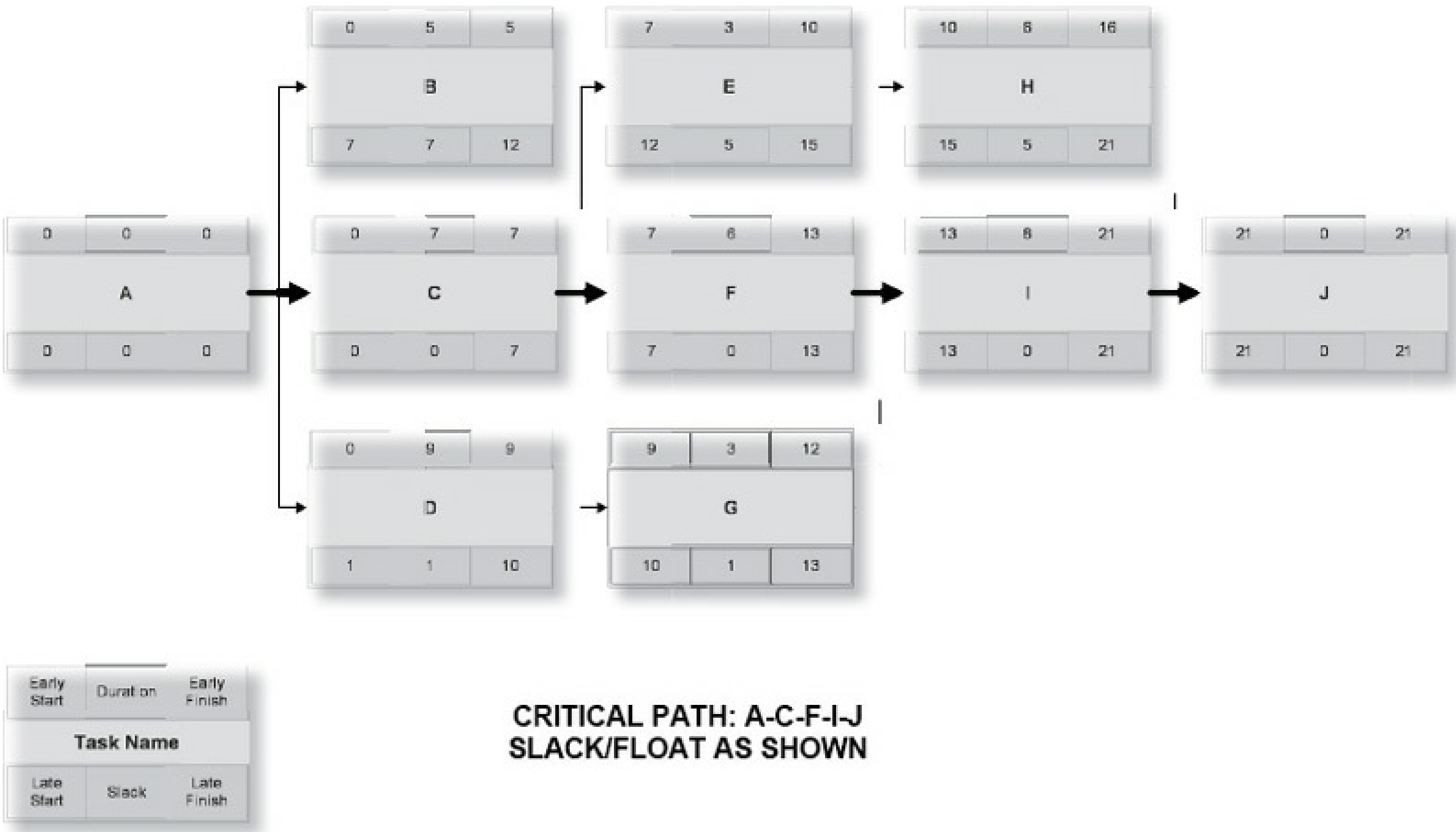
Advantage: Veeblebrox by $340,000. The lower cost per error takes $1 million out of costs.

Scenario: WidgetGenie doubles its price.

	Veeblebrox 3000		WidgetGenie Deluxe	
	Good Economy	Poor Economy	Good Economy	Poor Economy
Widgets Sold	500,000	300,000	500,000	300,000
Price Per Widget	$20	$19	$20	$19
Gross Revenue	$10,000,000	$5,700,000	$10,000,000	$5,700,000
Cost Per Widget	$15	$15	$13	$13
Manufacturing Cost	$7,500,000	$4,500,000	$6,500,000	$3,900,000
Error Rate	2%	2%	3%	3%
Number of Errors	10,000	6,000	15,000	9,000
Cost Per Error	$200	$200	$150	$150
Total Cost of Errors	$2,000,000	$1,200,000	$2,250,000	$1,350,000
Cost of Equipment	$100,000	$100,000	$500,000	$500,000
Net Income	$400,000	($100,000)	$750,000	($50,000)
Probability of Outcome	40%	60%	40%	60%
EMV	$160,000	($60,000)	$300,000	($30,000)
EMV of Decision	$100,000		$270,000	

Advantage: WidgetGenie by $170,000. A $500,000 price tag is a bit high, because that means the WidgetGenie loses money in a bad economy. It could easily charge $400,000, however, and still be a better value.

EXERCISE 8-1. CRITICAL PATH



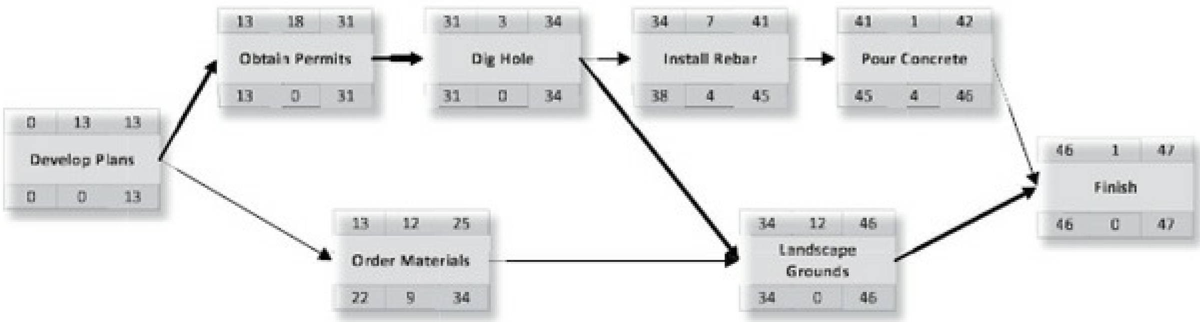
EXERCISE 8-2. SCHEDULING WITH PERT ESTIMATES

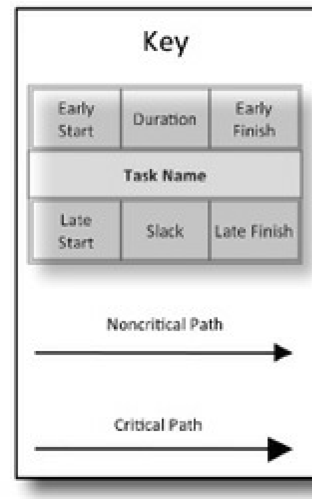
Step 1 Answer:

	Optimistic	Most Likely	Pessimistic	PERT Estimate	Standard Deviation
Develop Plans	6	12	24	13	3.00
Obtain Permits	10	15	40	18	5.00
Order Materials	10	12	15	12	0.83
Dig Hole	2	3	5	3	0.50
Install Rebar	5	7	9	7	0.67
Pour Concrete	1	1	2	1	0.17
Landscape Grounds	10	12	14	24	0.67
Finish	1	1	1	1	0.00

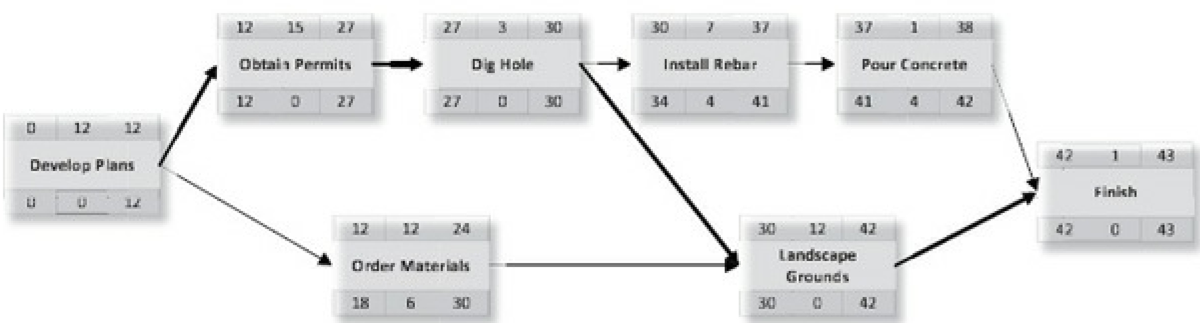
Step 2 Answer:

Swimming Pool Schedule
with PERT Estimates





Swimming Pool Schedule
with "Most Likely" Estimates



Exercise 8-3. Calculating Standard Deviation for a Path or Network

	Optimistic	Most Likely	Pessimistic	PERT Estimate	Standard Deviation	σ2
Develop Plans	6	12	24	13	3.00	9.00
Obtain Permits	10	15	40	18	5.00	25.00
Order Materials	10	12	15	12	0.83	
Dig Hole	2	3	5	3	0.50	0.25
Install Rebar	5	7	9	7	0.67	
Pour Concrete	1	1	2	1	0.17	
Landscape Grounds	10	12	14	24	0.67	0.45
Finish	1	1	1	1	0.00	0.00
					Sum of Squares	34.70
					Critical Path σ	5.89

Critical path tasks are shown in bold. Only the standard deviations of those tasks are used in the root sum square. The basic project duration using PERT estimates, as you recall, is 47 days. To that we add the following (rounding our answers to the nearest whole day):

80% confidence = 47 days + (1.28 * 5.89 days) = 55 days
90% confidence = 47 days + (1.64 * 5.89 days) = 57 days
95% confidence = 47 days + (1.96 * 5.89 days) = 59 days

Exercise 9-1. Risk Response Planning

Your answers, of course, will vary based on the risks you chose. We will take an existing risk response strategy from Exercise 4-3: "If customer emergencies require us to make a special shipment during the inventory process, we may need to work overtime to meet the original deadline."

The proposed risk response was: "We will do the following things in response to this risk:

1. The sales department will provide as much advance notice as possible of any customer emergencies requiring shipping.
2. If emergency shipping is necessary, overtime is authorized for the inventory team to ensure they meet the three days. The project lead will assign overtime if it is needed and report the information to payroll and to the department head for budget control.
3. If the project lead for any reason feels that the three-day window is in jeopardy, the project lead will immediately notify the department head and VP/Ops to acquire the necessary additional resources."

Exercise 9-2. Residual and Secondary Risk

What level of residual risk will remain after the risk response has been implemented? Perhaps more than one emergency order will come in; perhaps people will be sick or unavailable when we need them for the overtime, or perhaps the emergency order will come too late in the process to allow action. These seem unlikely enough not to require separate action, and if they happen, the solution is more of the same: more people, more overtime.

How about secondary risk? Well, the obvious secondary risk is that if these orders come in, the cost of doing the project (overtime, in particular) will increase. We've explicitly accepted that the additional cost is superior to the consequences of failing to meet a customer emergency.

Exercise 9-3. Types of Risk Response

The particular risk strategy we've selected is a *contingent response.* We think it's unlikely that this risk is going to happen, and so we don't want to spend money on it unless it's necessary to do so. There are other potential responses. Let's see how we'd approach the same risk using the other available strategies.

Avoidance. To avoid the risk of a conflict between the inventory and customer emergencies, we could decide to skip the inventory or ignore the customer. Either avoids the risk at hand, but both have substantial negative secondary consequences.

Transfer. We could hire an outside contractor to perform the inventory and hold the contractor responsible for the risk. This might cost a lot more money, and it could have other undesirable consequences as well. We could also make the sales department pay for our overtime out of its budget, meaning they would be more likely to check if this was indeed a true emergency.

Mitigation. Instead of waiting until we see if an emergency order arrives, we could go ahead and schedule extra resources to make sure we were enough ahead of schedule so that any delay would not matter. This certainly reduces the risk (but does not completely eliminate it for the reasons previously discussed), but costs a lot more money.

Acceptance. Because the situation is improbable, we could simply take our chances and try to cope in case the feared order arrives.

Exploitation. We could make sure our customers knew we were open for business even during inventory, and try to reap additional goodwill. We might also make the possibility of that emergency order more likely.

Enhancing. If we can find ways to speed up the time it takes to do the inventory, we save money long-term and at the same time lower the potential impact of emergency orders.

Sharing. The extra work in this case falls to the project team, but the benefit goes to the organization as a whole in the form of improved customer relationships. If that translates into extra sales, the sales force is likely to reap some additional reward in the form of increased commissions.

Exercise 10-1. Earned Value Method (EVM) Performance Index Ratios

Today, the schedule says you should be completely done with Task A ($7,500) and Task B ($5,000), and half done with Task C (total cost of $10,000). You have completed 75% of Task A, spending $6,000 to date; all of Task B at a cost of $6,000; and you are completely done with Task C, having spent $12,000. How are you doing?

Task	Planned Value (PV)	Actual Cost (AC)	Earned Value (EV)
A	$7,500	$6,000	$5,625 (75% of $7,500)
B	$5,000	$6,000	$5,000
C	$5,000 (50% of $10,000)	$12,000	$10,000
Totals	PV = $17,500	AC = $24,000	EV = $20,625

SPI = $20,625 / $17,500 = 1.18 (118%)

CPI = $20,625 / $24,000 = 0.86 (86%)

We're probably ahead of schedule because we're paying for it. This is not necessarily unreasonable, if the value of a speeded-up project is greater than the cost of the additional resources you may need.

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Additional Resources

In addition to the many fine books (some listed in the bibliography) and seminars available from a variety of sources, the web is a rich source of information on project risk management.

The list below is not intended to be comprehensive, and new resources appear on the web all the time.

American Management Association

http://www.amanet.org

Self-study programs: http://www.amaselfstudy.org/

Sidewise Insights (Michael Dobson, PMP)

http://sidewiseinsights.com

http://sidewiseinsights.blogspot.com

http://www.twitter.com/SideWiseThinker

Risk Management Information

Department of Defense Acquisitions Community:

https://acc.dau.mil/CommunityBrowser.aspx?id=108201

NASA:

http://www.hq.nasa.gov/office/hqlibrary/ppm/ppm22.htm

Hulett & Associates:

http://www.projectrisk.com/Welcome/White_Papers/white_papers.html

Risk Management Policy and Planning Templates

Ethics and compliance risks:

http://www.lrn.com/PPCCorporateCompliance/form.php?
crcat=ppc&crsource=google&crkw=Risk%20management&keyword=Risk%20_management&en

UdHA

Information security risks:

http://www.sans.org/security-resources/policies/

Public safety/environmental health and safety/disaster preparedness:

http://policies.csusb.edu/riskmgmt.htm

Sport and recreation:

http://www.scribd.com/doc/31691777/Guide-to-using-SPARC's-Risk-Management-Tookit

Hazardous materials:

http://www.fpaa.com.au/licencing/docs/Risk_Management_Planning_Tool.pdf

Project Management information

http://en.wikipedia.org/wiki/Project_management

http://www.projectmanagement.com/

http://www.achievemax.com/books/project-management/index.htm

Project Management Institute (PMI)

http://www.pmi.org

Project Management Professional (PMP) Certification

http://www.pmi.org/Certification.aspx

Network Diagramming Methods

Arrow diagramming:

http://en.wikipedia.org/wiki/Arrow_Diagramming_Method

Precedence diagramming:

http://en.wikipedia.org/wiki/Precedence_Diagram_Method

Monte Carlo Simulation Software for Microsoft Project

@RISK for Project from Palisade Corporation (www.palisade.com)

RiskyProject from Intaver Institute (www.intaver.com)

Pertmaster software from Pertmaster Limited (www.pertmaster.com)

Risk+ from S/C Solutions Inc. (www.cs-solutions.com).

Glossary

Actuary A person who analyzes business risk (primarily financial) using mathematical and statistical tools, most often found in the insurance industry.

Acceptance A risk management strategy involving no action whatsoever unless the risk actually occurs.

Assumptions For planning purposes, assumptions are things considered to be true, real, or certain, without actual proof or demonstration. For example, it might be assumed that organizational priorities will not shift in the next six months, or that the work is technically feasible even though it has not been done before. Assumptions are often necessary, but carry risk.

Authority The right to make decisions, spend funds, allocate resources, or approve choices. Your authority can be defined in three categories: things you can do for which you do not need permission, things you can do with permission, and things that must be done by someone else.

Average See *mean.*

Avoidance A risk management strategy that involves changing the project so the risk event cannot occur or the project is protected from its consequences.

Backward pass See *forward and backward pass.*

Baseline (v) The process of establishing the planned value of the project at different points of the project life cycle. The **baseline (n)** is therefore the approved project plan plus or minus approved changes. Use the baseline to compare actual to planned results so you can determine if the project is on track. Revise the baseline if there are major changes that make the original baseline useless as a measuring point.

Black swan event A risk event that is high impact, and either hard to predict or extremely rare.

Business risk A risk situation that combines the possibility of positive and negative outcome in the same decision or event.

Capping Establishing a maximum level for a risk. If you have an insurance deductible on your policy, your risk is capped at the amount of that deductible because that is the maximum amount you will have to pay for a covered event.

Cause-and-effect diagram A tool to help identify root causes of problems, risks, or other situations. Sometimes referred to as a *fishbone diagram* because it resembles the skeleton of a fish, and as an *Ishikawa diagram* for its creator, Kaoru Ishikawa.

Central Limit Theorem (CLT) A fundamental idea in probability theory, the CLT says, in short, that if there are a large number of independent random variables (rolling hundreds of dice of different shapes and sizes, some with six sides and others with eight or four or twelve, for example), the outcome will naturally fall into an approximately normal distribution. There is a full technical proof which is beyond the scope of this course; you can find it at http://mathworld.wolfram.com/CentralLimitTheorem.html.

Closeout The formal process of bringing a project to an end.

Confidence level A probability that a project will achieve a certain goal of time or budget based on its level of risk. The *Program Evaluation and Review Technique (PERT)* and the *Monte Carlo simulation* both provide methodologies for establishing confidence levels.

Contingency A risk management strategy involving a plan to be triggered if the risk occurs or appears likely.

Contingency allowance Extra time or money to compensate for known risks.

Contingency reserve Money or time set aside for unknown risks.

Convergence risk See *schedule risk.*

Cost-benefit analysis The process of comparing the total expected benefits of a course of action with the total expected costs of that action. In addition to analyzing a specific course of action, cost-benefit analysis can also compare costs and benefits of different alternative actions.

Cost estimating A process for determining the likely or potential cost associated with a project or work package.

Critical path The sequence of project activities that determines the duration of the project; the longest path through a project *network diagram.*

Decision tree analysis A graphical tool for comparing the *Expected Monetary Values* (EMV) of different alternatives.

Dependency relationship In a *network diagram,* a connection between two work packages that describes the conditions under which the dependent task can start or finish.

Deterministic costs Costs that are definite and known before they are incurred, such as the price in a firm fixed price contract. Compare with *probabilistic costs.*

Distribution The range of possible outcomes and the number of times each outcome has or is expected to occur. Distributions come in many types, of which the *normal distribution* (often described as the bell curve) is best known. In project management, the *triangular distribution* appears frequently, especially in *three-point estimates.*

Downside risk See *threat.*

Earned Value Project Management An advanced tool for comparing schedule and cost performance to plan. Considered an exceptionally valuable tool for identifying troubled projects early.

Enhancement A risk management strategy for improving the probability or impact of an opportunity.

Exclusion A provision in an insurance policy that removes a particular cause from the list of covered events. If a homeowner's policy does not cover flood damage, for example, it is excluded from the risks assumed by the insurer, and the homeowner therefore retains those risks—or buys separate flood insurance.

Expected Monetary Value (EMV) The sum of the probability times the impact for each possible outcome, used as a basis for comparison and decision-making among alternatives with risk. For example, if an investment is 70% likely to produce a $25,000 gain, and 30% likely to produce a $10,000 loss, the EMV is (0.7 × $25,000) + (0.3 × -$10,000), or $17,500 + (-$3,000), which reduces to $14,500.

Exploitation A risk management strategy that involves using an opportunity to improve the timeliness, cost, or quality of a project.

Facultative insurance See *reinsurance.*

Filtering A process for analyzing risks, performed as an initial sorting process during *qualitative risk analysis.* See also *risk triage.*

Fishbone diagram See cause-and-effect diagram.

Float Extra time to accomplish certain tasks before the accumulated lateness threatens the expected project completion date. *Free float* is extra time before the next task begins, whether the subsequent task is on the critical path or not. Also known as *slack.*

Forward and backward pass A technique for calculating the *critical path* on a *network diagram.*

Gantt chart A bar graph drawn over a calendar grid, showing when specific tasks will be accomplished in the schedule.

Initiation The process of starting a project.

Insurable risk See *pure risk.*

Ishikawa diagram See cause-and-effect diagram.

Joint probability The probability that both Event A and Event B will happen; the product of the individual probabilities.

Law of Large Numbers (LLN) A principle of probability theory that argues that the larger the sample population or number of trials, the more likely that the actual probability will converge with the theoretical one.

Lessons learned The process of evaluating a project's performance for future improvement.

Mean The *average* of a group of numbers.

Measures of Central Tendency The *mean, median,* and *mode* of numbers in a distribution.

Median The central number in a range of numbers; half the cases are above and half below the median.

Mitigation A risk management strategy for lowering a combination of the likelihood or impact of a risk.

Mode The number in a distribution that occurs most often.

Monte Carlo simulation A probability simulation technique. In project management, a Monte Carlo simulation is a specialized computer program that usually works as an add-on to popular project management software packages. Instead of entering a single number as an estimate of a task's duration, the project manager enters a range of numbers (optimistic, pessimistic, and most likely) for each task. The program simulates the course of the project hundreds or thousands of times, selecting a weighted random number from the range for the duration of each task, and records the finish date. By analyzing the number of times the project finishes on any given date, you can calculate a *confidence level,* or probability you will meet that date.

Negative brainstorming A brainstorming technique that focuses on reasons something might fail rather than on ways to make it succeed; useful in the process of risk identification.

Network diagram A flow chart picture of the work of the project that shows interdependencies and connections. There are two types of network diagrams. The *Precedence Diagramming Method (PDM)* has largely replaced an older technique, the *Arrow Diagramming Method (ADM)*.

Normal distribution A "bell curve" distribution in which most values tend toward the mean and few values are found at the extremes. The most common kind of distribution, although it's never wise to assume a distribution will automatically follow the normal shape without evidence.

Odds The number of favorable outcomes divided by the number of unfavorable ones.

Opportunity A term for *upside risk,* the chance of experiencing a positive outcome from a risk event.

Path duration risk See *schedule risk.*

PERT analysis See *Program Evaluation and Review Technique (PERT).*

Precedence Diagramming Method (PDM) See *network diagram.*

Program Evaluation and Review Technique (PERT) Invented by the U.S. Navy and Booz Allen Hamilton to manage the Polaris nuclear submarine project in the late 1950s, the PERT method is considered one of the major breakthroughs in project management practice. In the area of risk management, PERT pioneered the use of the three-point estimating technique.

Probabilistic costs Costs that are subject to change depending on circumstances. Labor costs, for example, increase if the schedule slips, so the final price for labor on the project may be greater or less depending on how quickly the project goes. The labor estimate is a probabilistic cost in your budget because the final actual price is unknown and variable. Compare with *deterministic costs.*

Probability The number of desired outcomes divided by the number of possible outcomes.

Project A temporary endeavor undertaken to create a unique product, service, or result. Projects have a definite beginning and end.

Project management The application of knowledge, skills, tools, and techniques to project activities to meet the project requirements.

Pure risk A risk situation that only has a negative outcome (also known as *insurable risk*).

Qualitative risk analysis The process of sorting and prioritizing risks. Risks can be sorted according to characteristics such as probability, impact, category, ownership, actionability, and acceptability. Risks deemed significant can be prioritized for further *risk analysis* and for *risk response planning.*

Quantitative risk analysis The process of using measurable and objective data to value risks, such as *Earned Monetary Value (EMV)* and other statistical and financial techniques.

Reinsurance A type of insurance purchased by insurance companies to offset excess risk by transferring it to a larger entity. Two types of reinsurance are *treaty insurance,* in which a large risk is apportioned among different payers, and *facultative insurance,* in which a single large entity assumes the risk.

Reserve See *contingency reserve.*

Residual risk Risk left over after you have taken action on the primary risk.

Risk An uncertain event or condition that if it occurs will have a significant impact, whether negative (*threat,* or *downside risk*) or positive (*opportunity,* or *upside risk*).

Risk analysis The process of studying the risks of a particular project, operation, or organization in order to define their probability, impact, and other characteristics. The results of risk analysis help us decide which risks should be addressed, which risks should be accepted, and which strategies are likely to be most cost-effective in managing them. Two types of risk analysis are *qualitative risk analysis* and *quantitative risk analysis.*

Risk cost analysis The process of analyzing the range of potential costs and benefits of particular risks, and using the analysis to calculate a value for that risk.

Risk identification The process of identifying and describing the risks associated with the project.

Risk management The process of identifying, analyzing, responding to, and managing threats and opportunities.

Risk management plan A document that is part of the project plan and that identifies and describes the risks, rates their relative seriousness by considering their probability and impact, lists any planned responses or actions intended to reduce downside risks or improve upside risks, and explains how the project team will monitor risks and responses for effectiveness.

Risk management policy A document that applies to an entire organization or category of projects. It describes how the organization wants risk management to be performed, which projects and activities are covered by the policy, the definitions and steps involved in the process, the types of reports and documents that need to be prepared and disseminated, who must be consulted or who must approve risk responses, and similar matters.

Risk mitigation cost The amount you would need to spend to reduce the risk to an acceptable level.

Risk monitoring and control Activities involved in executing the risk management plan and making adjustments based on actual experience.

Risk premium The difference between the cost of responding to a risk and the underlying value of the risk itself.

Risk register A list of all the project's identified risks, often in a spreadsheet format, with information and analysis about the risk—along with a summary of planned responses.

Risk response planning The process of deciding what action (if any) to take in response to a specific risk or category of risk, both *threats* and *opportunities.* Basic strategies for threats are *avoidance, transfer,* and *mitigation.* Basic strategies for opportunities are *exploitation, sharing,* and *enhancement.* The remaining strategies, *acceptance* and *contingency planning,* apply to both threats and opportunities. In addition, some risk responses are multi-staged; that is, they use more than one risk response, sometimes together or sometimes the additional strategy is used as a contingency response. Finally, some risk responses are "wait and see" measures, in which a final decision or action is postponed until a triggering event causes reevaluation.

Risk triage The process of prioritizing risks for further analysis and response. Often associated with *filtering,* and a process used in *risk analysis.*

Risk trigger An event or point in time that determines whether to execute a particular risk response or contingency plan. If the risk response to running out of gas is to fill up the tank, you might establish a mental risk trigger that you should find a gas station as soon as the fuel gage drops below an eighth of a tank.

Schedule risk The risk that the actual schedule of a project will differ from the planned schedule. There are three kinds of schedule risk: *task duration risk* (the risk that a specific task or work package will take more or less time than expected), *path duration risk* (the risk that a sequence of tasks or work packages will take more or less time than expected), and *convergence risk* (the risk that when a task has multiple predecessors that at least one of the predecessors will be late in finishing).

Secondary risk A risk that comes into existence as a result of your attempt to solve the primary (original) risk. If you rent a tent to mitigate the risk it will rain on your picnic, the risk that the tent will be damaged and you will have to pay for it is a secondary risk. A secondary risk may be minor enough to ignore, it may be serious enough to cause you to find a different solution, or the secondary risk itself can be lowered through additional risk response planning.

Sensitivity analysis An analysis to determine the effect on a mathematical model if you change one of the variables. If the model is robust, small changes in variables have correspondingly small impact on the output. If the model is highly sensitive, small changes in variables (the difference between 2% growth and 2.2% growth, for example) can have a disproportionate effect on the output.

Sharing A risk management strategy that involves transferring the value of an opportunity elsewhere.

Slack See *float.*

Standard deviation A mathematical measurement of the variance in a given normal distribution, calculated by the formula:

Statistical significance In statistics, a statistically significant result is one that is unlikely to have occurred by chance. In risk, statistical significance is often described as a function of the standard deviation.

SWOT Analysis A structured brainstorming tool that identifies the strengths (S), weaknesses (W), opportunities (O), and threats (T) of an actual or potential event or situation to aid in analysis and response planning.

Task duration risk See *schedule risk.*

Threat A term for *downside risk,* the chance of experiencing a negative outcome from a risk event.

Three-point estimate When the estimated time or cost of a given work packages is variable, a three-point estimate identifies the optimistic (best case with a probability of at least 1%), the pessimistic (worst case with a probability of at least 1%), and the most likely *(mode)* values. Three-point estimates are used in both *PERT analysis* and the *Monte Carlo simulation.*

Tradeoffs Choices among different priorities. A project may take longer or cost more if we set a higher performance target. Tradeoffs can be within a project or among multiple projects (when more for Project A means less for Project B).

Transfer A risk management strategy that involves moving the ownership of the risk to some other entity. Insurance is a common form of risk transfer.

Treaty insurance A type of *reinsurance.*

Triangular distribution A type of *distribution* that resembles a triangle. It is typically used as a subjective description of a population for which there is only a limited amount of information or sample size. A *three-point estimate,* used in many simulation techniques, is in effect a triangular distribution of the range of possible outcomes.

Triple constraints The three common boundaries of all projects: the time constraint, the cost (resources) constraint, and the performance standard.

Union The probability that Event A or Event B will happen; the sum of the individual probabilities.

Upside risk See *opportunity.*

WBS See *Work Breakdown Structure (WBS) dictionary.*

Work Breakdown Structure (WBS) dictionary A form or template for each WBS component that briefly defines the scope or statement of the work, defines deliverables, contains a list of associated activities, and provides a list of recognized milestones to gauge progress.

Post-Test

Project Risk and Cost Analysis

Course Code 98008

INSTRUCTIONS: *Record your answers on one of the scannable forms enclosed. Please follow the directions on the form carefully. Be sure to keep a copy of the completed answer form for your records. No photocopies will be graded. When completed, mail your answer form to:*

Educational Services
American Management Association
P.O. Box 133
Florida, NY 10921

If you are viewing the course digitally, the scannable forms enclosed in the hard copy of AMA Self-Study titles are not available digitally. If you would like to take the course for credit, you will need to either purchase a hard copy of the course from www.amaselfstudy.org or you can purchase an online version of the course from www.flexstudy.com.

1. Qualitative risk analysis is defined as:
   (a) numerically analyzing the effect of identified risks on overall project objectives.
   (b) measuring the accuracy and quality of risk data in objective terms.
   (c) identifying risks that may affect your project.
   (d) prioritizing risks for further analysis by assessing and combining their probability and impact.
2. If the cost of insurance for a particular risk is greater than the value of the underlying risk, the difference between the two numbers is known as:
   (a) risk premium.
   (b) contingency reserve.
   (c) degree to which the policy is overpriced.
   (d) price-to-book ratio.
3. One category of threat risk response is:
   (a) mitigation.
   (b) exploitation.
   (c) sharing.
   (d) enhancement.

4. If there is a 20% probability of an event that would cost the project $20,000, what is the value of the risk?
   (a) $20,000
   (b) $4,000
   (c) $24,000
   (d) $2,000

5. To run a Monte Carlo simulation program, you must first:
   (a) prepare three-point estimates for task durations.
   (b) perform decision tree analysis of make vs. buy options.
   (c) calculate the root sum square of the schedule standard deviation for tasks on the critical path.
   (d) perform a full PERT analysis of the schedule network.

6. In developing risk responses for opportunities, you may consider:
   (a) avoidance.
   (b) mitigation.
   (c) transfer.
   (d) sharing.

7. What does a project network diagram do?
   (a) Displays a project schedule graphically
   (b) Shows a project schedule as a bar graph over time
   (c) Connects project resources with project activities
   (d) Establishes the communication plan for the project

8. How does negative brainstorming differ from conventional brainstorming?
   (a) Negative brainstorming is the result of failure of a conventional brainstorming.
   (b) Negative brainstorming allows criticism and evaluation of ideas during the process.
   (c) Negative brainstorming looks at the potential problems with conventional brainstormed answers.
   (d) Negative brainstorming involves brainstorming a negative question to identify downside risks.

9. What is a characteristic of a black swan event?
   (a) Hard to predict and rare
   (b) Something that cannot possibly occur
   (c) Conforms to project assumptions
   (d) Has a relatively small impact

10. To compare costs and benefits, you must:
   (a) describe all costs and benefits in deterministic form.
   (b) perform expected monetary value analysis on costs and benefits impacting 10% or more of total project value (TPV).
   (c) perform a PERT analysis of the project network to determine schedule risk.
   (d) quantify all aspects of the project in the same unit of measurement and at the same point in time.

11. In the PMBOK® model, which of the following processes involves studying risks to understand their nature, probability, and impact?
    (a) Risk response planning
    (b) Risk identification
    (c) Risk monitoring and control
    (d) Risk analysis

12. What does a decision tree analysis do?
    (a) Filters risks during qualitative risk analysis
    (b) Shows causes and effects of risks in a "fishbone" diagram
    (c) Calculates total risk exposure on a project
    (d) Compares expected monetary values (EMV) of different alternatives, choices, or conditions

13. What is the probability that you will *not* roll a 4 or a 6 on a six-sided die?
    (a) 2/6
    (b) 2/12
    (c) 4/24
    (d) 4/6

14. The confidence level for a project measures:
    (a) how much we know about project risks.
    (b) how good the project manager's track record has been.
    (c) how stable the customer's requirements will be.
    (d) how likely the project will finish on or before a given date.

15. What technique should you use to perform risk triage of your identified risks?
    (a) Cause-and-effect diagramming
    (b) Filtering
    (c) PERT analysis
    (d) Risk response planning

16. Which measure of central tendency describes the average of a group of numbers?
    (a) Median
    (b) Mode
    (c) Mean
    (d) Medium

17. When you write a risk as an "if–then" statement, what are the two parts called?
    (a) Business risk and pure risk
    (b) Condition and consequence
    (c) Probability and impact
    (d) Problem and solution

18. Which of the following words is one of the named categories in a SWOT analysis?
    (a) Supervision

(b) Wildly-Aimed Guess
(c) Other Factors
(d) Threat

19. Convergence risk is the risk that:
    (a) a task will take longer than scheduled.
    (b) a sequence of dependent tasks will take longer than scheduled.
    (c) critical tasks will take longer than scheduled.
    (d) at least one predecessor of a task with multiple predecessors will take longer than scheduled.

20. What does a risk matrix do?
    (a) Combines word descriptions of probability and impact into a grid
    (b) Applies a numerical scale to risk probability and impact
    (c) Classifies risks when probability and impact are known and definite
    (d) Supports Boolean analysis of risk data

21. In qualitative risk analysis, what can you do with the risks you identify?
    (a) Avoid, transfer, or accept them
    (b) Exploit, enhance, or share them
    (c) Accept them or prepare a contingent response
    (d) Accept, transfer, or do something about the risk

22. A risk management plan should be prepared:
    (a) only after important project milestones have been missed.
    (b) as an integral part of any well-prepared project management plan.
    (c) as part of a postmortem project review.
    (d) after serious organizational consequences have been incurred.

23. One strategy for approaching risks that are very low in probability but potentially catastrophic in outcome is:
    (a) decision-tree analysis.
    (b) cost-benefit analysis.
    (c) Monte Carlo simulation.
    (d) multi-stage solution.

24. Business risk differs from pure risk in what way?
    (a) Business risk is about the potential for loss.
    (b) To manage a business risk, you can purchase insurance.
    (c) Business risk combines the possibility of positive and negative outcomes in the same decision or event.
    (d) Business risk is upside risk.

25. In risk management, a cause-and effect diagram allows you to:
    (a) find better solutions to specific risks.
    (b) find the critical path in a project network diagram.

(c) brainstorm root causes of risk in a structured fashion.
(d) filter risks during qualitative risk analysis.

Index

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