Chapter Six

Assessing and Preparing for Project Uncertainties

"Anything that can go wrong will go wrong."
Murphy's Law

"Was I deceived, or did a sable cloud / Turn forth her silver lining on the night?"
John Milton

Chapter Learning Objectives

When you have mastered the material in this chapter, you should be able to:

- Describe the dimensions of project uncertainty as they apply to a specific project.
- Apply a systematic process for assessing potential uncertainties and preparing for them.
- In a team setting, apply risk assessment tools such as risk mapping, failure modes and effects analysis (FMEA), gut feel, Delphi, and fishbone diagrams.
- Design contingency plans to prepare for uncertainties.
- Revise a project plan to incorporate appropriate strategies for mitigating the potential outcomes associated with unfavorable uncertainties and enhancing the potential outcomes associated with favorable uncertainties.
- Develop a plan for monitoring uncertainties during a project's life cycle.

This chapter is about surprises or potential surprises, and how the effective project manager can anticipate, prepare for, monitor, and respond to them. In the context of surprises, we often think of risks with the potential to produce undesirable outcomes. However, uncertainties can lead to favorable outcomes, too, as noted in the Project Management Institute's *A Guide to the Project Management Body of Knowledge:* "A Project risk is an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective, such as time, cost, scope, or quality."[1] In a slight departure from PMI, we use the word 'risk' when referring to unfavorable uncertainties and we describe uncertainties with potential positive effects as 'favorable uncertainties.'

[1] Project Management Institute, *A Guide to the Project Management Body of Knowledge* (Newton Square, PA: PMI, 2004), p. 238.

EXAMPLES OF PROJECT UNCERTAINTIES

We begin with examples of **unfavorable project risks** and **favorable project uncertainties** that affected the outcomes of two projects. In each case, front-end brainstorming might have led the project team to envision the possibility of these uncertainties and appropriately adjust plans.

Example of an Unfavorable Project Risk: A Fence on the Neighbor's Property

In 2007, the U.S. government embarked on a controversial project to build a fence along its border with Mexico in several isolated areas where monitoring for illegal entrants was difficult. A few months into the project, Mexican officials determined that a 1.5-mile (2.4-kilometer) stretch of the fence had been built six feet (about two meters) south of the border on Mexican soil.[2] Crewmembers apparently had relied on the position of a rancher's fence line, rather than survey data, to determine the position of the border.[3] Existing Mexican opposition to the project was further inflamed as a consequence of the wrong positioning, and the U.S. government had to move the fence at an additional project cost of about $3 million. It seems possible that if project team members had brainstormed about the worst things that could happen, at least one person might have said, "We could put the fence in the wrong place!" This could have led the team to consider ways to avoid such a politically embarrassing outcome through more diligence in its survey methods.

Example of a Favorable Project Uncertainty: Lilly Discovers Unexpected Drug Application

Eli Lilly and Co. has had many drugs fail in clinical trials, an accepted possibility in any scientific endeavor. One such drug, Evista, initially developed for birth control, was put into the category of bad ideas when it failed clinical trials. But this turned out to be an example of a missed opportunity—the drug later was found to be effective in addressing a completely different problem: osteoporosis.[4] Evidence of the alternative application emerged during the trials, but team members had been so focused on birth control that they initially ignored it. This is a case where the organization could have been more aware of favorable uncertainties that had the potential to change the outcome of the project. Lilly has now implemented a formal process for uncovering other potentially missed opportunities in drug research.

THE ROLE OF PROJECT UNCERTAINTY ASSESSMENT

Uncertainty analysis occurs at every stage of the project management process, beginning with project selection and continuing to customer handoff and closure. In this chapter, we will highlight tools that are especially useful during the planning stage,

[2] A.A. Caldwell, "Border Barrier Accidentally Crosses Border," *Seattle Times,* June 30, 2007, p. 1.

[3] Although one might attribute this to stupidity, it is helpful to consider that ranchers' fences and the border had lined up elsewhere, perhaps lulling team members into a false confidence about the accuracy of the fence lines. Risk analysis can help us to avoid doing stupid things.

[4] T.M. Burton, "Flop Factor: By Learning from Failures, Lilly Keeps Drug Pipeline Full," *The Wall Street Journal,* April 21, 2004, p. A1.

after the *initial* work breakdown structure (WBS) has been developed. Uncertainty assessment at this stage is likely to lead a team to alter or expand the initial WBS to prepare for newly discovered possibilities.

Any project, regardless of its size, needs uncertainty analysis. If you are planning a children's birthday party, you might run through what could go right or wrong in your head ("The children might really enjoy Bingo and want to play several more times than we have planned." "Billy is prone to temper tantrums when he loses at Bingo!") If you were responsible for implementing a new companywide IT system, you would conduct a much more formal analysis involving the team and key stakeholders.

Even with the best uncertainty analysis, some events will still come as surprises—the **unknown unknowns**.[5] However, if the team has planned carefully and anticipated as many eventualities **(known unknowns)** as it possibly can, members will be more likely to have the time and resources to deal effectively with those they were unable to anticipate. Anyone involved in project uncertainty assessment has good intentions, but several human biases can interfere with the ability of individuals and teams to see future possibilities as clearly as they should. Being aware of these biases, which we highlight in Appendix 6A at the end of this chapter, is a good starting point.

DIMENSIONS OF UNCERTAINTY

Project team members should consider several risk or uncertainty dimensions to ensure they have cast a wide enough net during the assessment phase. Dimensions for consideration include: **source, outcome, and likelihood.** We highlight each of these below:

Uncertainty Sources

There are many perspectives on the sources of project uncertainty,[6] but most fit into five categories, which Exhibit 6.1 shows in relation to favorable and unfavorable uncertainties. Box 6.1 highlights examples of uncertainties in these five categories as they could be applied to a project to develop a new airplane. Some aspects of the scenarios described in Box 6.1 are based on factual information and others are based on conjecture to illustrate future thinking.

Uncertainty Outcomes

An undesirable uncertainty in itself is not a problem to the project manager, and not every favorable uncertainty necessarily makes a project an unprecedented success. It is what happens as a *consequence* of the risk or opportunity that creates headaches

[5] R.M. Wideman, *Project and Program Risk Management: A Guide to Managing Risks and Opportunities* (Newtown Square, PA: Project Management Institute, 1992).

[6] For example, I. Mitroff, *Managing Crises Before They Happen* (New York: American Management Association, 2001) includes economic, informational, physical, human resource, reputational, psychopathic (e.g., terrorism or product tampering), and natural disasters. T.D. Klastorin, *Project Management: Tools and Tradeoffs* (New York: Wiley and Sons, 2004) identifies technical, government, unexpected losses, market, legal, and natural hazards. Wideman, *Project and Program Risk Management,* includes scope, quality, information, contract, cost, time, quality, human resource, and integration. This last set, from our perspective, has more to do with the ***outcomes*** of risks, rather than sources.

EXHIBIT 6.1
Sources of Uncertainty

Uncertainty Source	Unfavorable Uncertainty	Favorable Uncertainty
Financial	Financial conditions inside or outside the organization that could potentially threaten the success of the project.	Financial conditions inside or outside the organization that could enhance the viability of the project.
Technical	A possible technical challenge that could alter the course of the project in a negative way.	A possible technical breakthrough that could alter the course of the project in a positive way.
Business Environment	A possible market, political, or regulatory condition that could make the project outcomes less attractive than anticipated.	A possible market, political, or regulatory condition that could make project outcomes more attractive than anticipated.
Social	A project challenge associated with potential stakeholder interference in the project. Stakeholders can be inside or outside the organization.	Unexpected support for the project from a stakeholder group that might help the project advance. Stakeholders can be inside or outside the organization.
External/Natural Environment	Acts of nature such as disease epidemics, floods, earthquakes, tornadoes, weather patterns, or oceanic circumstances that can have a negative effect on the project.	Acts of nature such as the spontaneous end of a disease epidemic, changes in weather patterns, or favorable tidal phenomena that can make the project unexpectedly easier to execute.

or opens doors.[7] Typical consequences of negative uncertainties include (but are not limited to) schedule delays, cost overruns, reductions in quality, project abandonment, physical or psychological harm to people, damage to facilities or the environment, and loss of reputation.

Likelihood of Occurrence

The project team must consider the likelihood of an uncertainty in determining where it should focus attention. In most project environments, it is not possible to assess likelihoods with precision. In the absence of historical data, project teams typically take a subjective approach, based on opinion and judgment. But, there are consensus-based or voting methods they can use to enhance their ability to forecast, as we discuss in this chapter.

"Prediction is very difficult, especially about the future."

Niels Bohr

[7] P.G. Smith and G. Merritt, *Proactive Risk Management* (Portland, OR: Productivity Press, 2002).

Dimensions of Uncertainty for the Boeing 787 Project

Box 6.1

© AP Photo/Elaine Thompson

In the mid-to-late 2000s, Boeing Commercial Airplanes was in the midst of a new development project for a mid-size (230–350) passenger jet to meet the needs of a variety of city-pair travel needs, including point-to-point, hub-to-hub, hub-to-point, etc. The airplane, initially called the 7E7 but later named the 787,* was promoted as fuel-efficient because it was to be made from lightweight composites supported by titanium structures.† The company had used this approach in military aircraft but had not tested it to any great extent in the commercial market. Not wanting to repeat the experience of high development costs associated with the 777 in the 1990s,‡ Boeing transferred large portions of the development expense to subcontractors in several countries. At the same time, development speed was a major priority. For example, China represented a big market for the airplane, and Boeing officials promoted it for transport of spectators and tourists during the 2008 Olympic Games. Potentially big sales to China depended on Boeing's ability to meet the 2008 target. (Unfortunately, Boeing was unable to reach this goal.) Examples of possible risk sources in each category shown in Exhibit 6.1 are highlighted below.

FINANCIAL UNCERTAINTIES

Unfavorable Uncertainty Example

A key supplier developing a critical component could go into financial default and be unable to deliver designs or build prototypes.§

Favorable Uncertainty Example

An airplane leasing company (often major customers for commercial jetliners) could become so optimistic about the 787 it would offer itself as a financial partner in the development process.

TECHNICAL UNCERTAINTIES

Unfavorable Uncertainty Example

Some informed observers warned that the 787's composite fuselage might not hold up in a crash because its structural properties made it more brittle than aluminum, the material used historically for airplane skins.**

* The "E" for "efficiency" in the 7E7 was later changed to an "8" at the encouragement of customers from China where the number "8" is considered lucky. Given the importance of China as a major customer, and the fact that this airplane was next in sequence after the 777, it made great sense to Boeing officials. Fact or urban legend, it makes a good story.

† S. Kotha and R. Nolan, *Boeing 787: The Dreamliner,* Harvard Business School case # 9-305-101 (Boston: Harvard Business School Publishing, 2005).

‡ Although Boeing has not made any public statements, some financial analysts estimate the cost of the 777 development program at about $15 billion.

§ As it turned out, when the first airplane was rolled out in July of 2007, it was actually missing several parts from suppliers and was not yet ready to fly (Gates, 2007a). See D. Gates, "First 787 Still Missing Parts," *Seattle Times,* August 21, 2007; www.seattletimes.com.

** D. Gates, "FAA Dismissed Criticism over 787 Safety Tests," *Seattle Times,* October 2, 2007; www.seattletimes.com.

Favorable Uncertainty Example

Boeing might be able to use technological advances from the 787 program to leverage developments in its defense and space programs to a greater extent than initially planned.

BUSINESS ENVIRONMENT UNCERTAINTIES

Unfavorable Uncertainty Example

Boeing was betting on the increasing demand for point-to-point and other short-haul air travel in medium-size airplanes. Had Boeing's bet proven to be wrong, the company and its suppliers would not have been able to recoup their huge investments (leading secondarily to a financial risk).[††]

Favorable Uncertainty Example

It was possible that increasing fuel costs (certainly a high possibility that did materialize) would increase demand for fuel-efficient commercial aircraft, raising demand for the 787 beyond that initially imagined.

SOCIAL UNCERTAINTIES

Unfavorable Uncertainty Example

Airplane components were to be built in large sections, in many cases outside the United States, and assembled in the company's Everett, Washington, facility. Union organizations objected to the new strategy because of the job losses it would produce.[‡‡] This could further evolve into bad public relations for the company.

Favorable Uncertainty Example

It is possible that organized consumer-advocacy groups could become increasingly vocal about the inconveniences of hub-to-hub travel. If passengers see the 787 as part of a potential remedy to the problem, they might initiate public campaigns that would positively influence airline purchase decisions.

UNCERTAINTIES ASSOCIATED WITH THE EXTERNAL/NATURAL ENVIRONMENT

Unfavorable Uncertainty

The Seattle area, home to the Boeing Commercial Airplanes group and the final assembly site for the 787, sits near a major geological fault.[§§] The fault is considered ripe for a devastating earthquake that could seriously damage Boeing's operations and facilities in the area, making it difficult or impossible to meet production schedules.

Favorable Uncertainty

In the process of preparing facilities for a big quake, Boeing might discover protective structural remedies it could patent and sell to other companies. Or, in creating a recovery plan for an earthquake, Boeing might develop strategies and processes that would be useful for responding to other types of disasters.

Source: As the references footnoted here suggest, some of the information in this example is drawn from newspaper articles about the 787 program. Other information is drawn from the authors' conversations with Boeing insiders and observers.

[††] As it turned out, Boeing received a record-high number of orders for the airplane (Lunsford, 2007). See J. L. Lunsford, "Boeing Vows On-Time Dreamliner," *The Wall Street Journal,* September 17, 2007, p. A8.

[‡‡] D. Gates, "Plan to Put 7E7 in Everett Tied to Boeing Transformation: Worker Support for New Production Strategy Is Key Factor As Board Weighs Site Proposal," *Seattle Times,* December 7, 2003, p. A1.

[§§] S. Doughton, "Pinpointing Devastation If Seattle Fault Ruptures," *Seattle Times,* February 20, 2005; http://seattletimes.nwsource.com/html/localnews/2002185299_earthquake20m.html; and T. Paulson, "New Shaky Ground in Seattle," *Seattle Post-Intelligencer,* October 12, 2007, p. A1.

LINKING LIKELIHOOD WITH DESIRABILITY OF OUTCOMES

Ultimately, we are looking for the relationships between likelihood and outcome/impact for each uncertainty. Utility theory describes how these two dimensions can be combined mathematically.[8] For example, imagine there is a 5 percent chance it will rain during a roofing project, causing a delay, requiring extra tenting equipment, and therefore costing an additional \$2,000. Conversely, there is a 95 percent chance it will not rain, and there will be no additional cost. The expected value is $(.05 \times -\$2{,}000) + (.95 \times \$0) = -\$100$. We can use this general concept in terms of schedule, budget, performance to weight the relevance of various uncertainties in cases where it is possible to estimate probabilities and where outcomes can be quantified (e.g.,). For more on utility theory, see Appendix B on decision analysis at the end of this book.

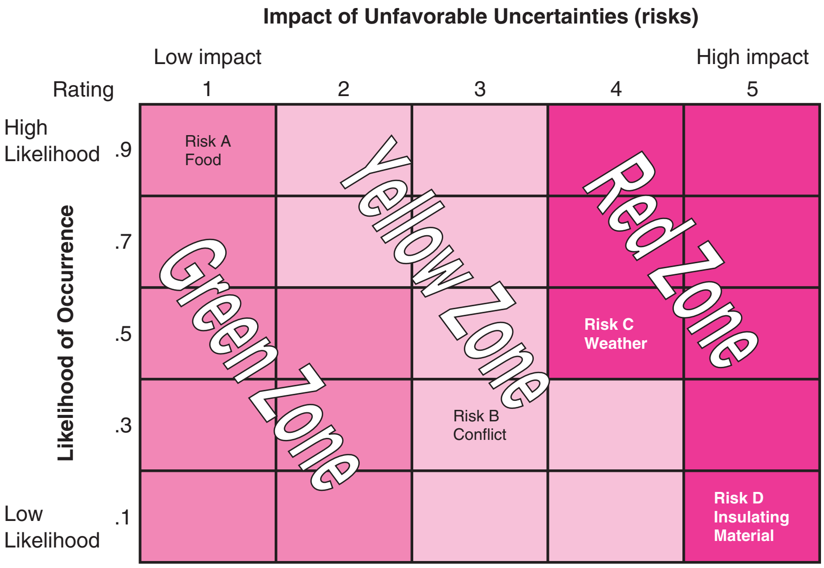
Exhibit 6.2 shows a traditional visual model combining likelihood with outcome desirability for unfavorable uncertainties (risks). The estimates of the two dimensions can be drawn from objective data or subjective assessments. This approach categorizes risks into three zones: red, yellow, and green. Risks in the red zone should receive the most attention, and a project team would seek ways to avoid these altogether. Those in the yellow zone might receive a wait-and-see status, and those in the green zone would be viewed in terms such as "Be aware, but don't worry too much about these." For the red zone, even those with low likelihoods are important because of the serious impact they can have on the project. Considering a space shuttle mission, we offer four examples (A through D) and locate them on the matrix in Exhibit 6.2.

- **Risk A, Food:** The astronauts might not like the food available on the shuttle. Given the nature of food delivery in zero-gravity conditions, this has a high likelihood.[9] However, it would be within the astronauts' expectations and probably would not have a negative effect on the project. Thus, it appears in the upper left-hand corner of the matrix.

[8] See J. Raftery, *Risk Analysis in Project Management* (London: E&FN Spon, 1994).

[9] One of our former students who worked for NASA in insists that in-flight food on shuttles is delicious, but we don't believe him.

EXHIBIT 6.2
Traditional Risk Matrix Showing Relationships Between Likelihood and Impact: Space Shuttle Example



- **Risk B, Conflict:** The astronauts might experience interpersonal conflict during the mission. Given the close quarters and the potential for disconnects between individual and team goals, this carries a moderate likelihood. It could have some effect on the mission, but command structures would be likely to keep it from getting out of hand. Thus, it might be best placed in the yellow zone—something to watch.
- **Risk C, Weather:** Weather conditions might make it too dangerous to land the shuttle at the scheduled time and date. Although this is moderately likely, NASA has contingency plans in place (delay mission or reroute landing), so the impact would be serious but not devastating. This one might deserve to be on the inner edge of the red zone.
- **Risk D, Insulating Material:** If there is a breach in the shuttle's insulating material, the result could be mission-shattering, as was the case with the Columbia Space Shuttle in 2003.[10] Although the probability of such an occurrence is low, it belongs in the red zone because of the disastrous outcome it would create.

A team could take the process a step further by adding numerical scores to the risks identified in Exhibit 6.2. The numbers adjacent to the vertical and horizontal axes can serve this purpose and may be used as somewhat subjective cutoff points for various types of actions. For example, a team or an organization might have a decision rule that any insurmountable risk with a 0.9 likelihood and a 5 on the impact scale (upper right-hand corner) would justify abandoning the project.

Expanded View of the Risk Matrix: Adding Favorable Uncertainties

The traditional risk matrix presented in Exhibit 6.2 does not include the possibility of potentially *favorable uncertainties*—things not currently within our expectations that have the potential to make the project even better or open doors for valuable opportunities currently outside the scope of the project. An historical example would be Norway's international fishing boundaries negotiation in 1961.[11] At the time, Norwegian officials secured exclusive rights to the fisheries within 12 miles (about 19 kilometers) of the country's shores but did not anticipate that this maritime boundary offered an unseen opportunity for oil exploration. The story has had a happy ending, but perhaps if Norwegian negotiators had anticipated the possibility of untapped oceanic oil reserves they might have been more aggressive than they were. In keeping with the idea of anticipating potentially favorable uncertainties, Hillson has developed an expanded presentation, a version of which is shown in Exhibit 6.3.[12] The Project Management Institute also has embraced this perspective.

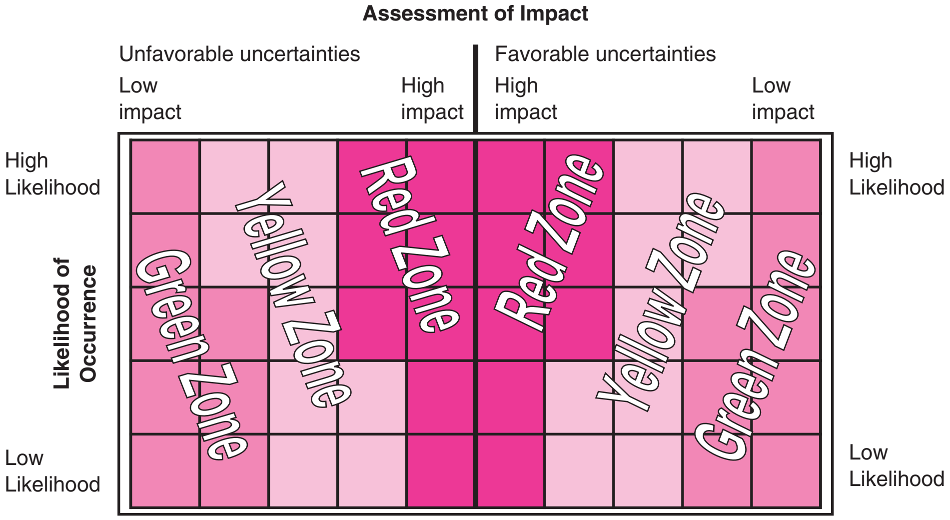
[10] On February 1, 2003, the Columbia Space Shuttle disintegrated in midair 15 minutes before its scheduled landing, apparently because a hole in one of the panels in the heat-protecting composite exposed the shuttle to the high temperatures (exceeding 3,000 degrees Fahrenheit or 1,649 Celsius) associated with reentry; see www.space.co/missionlaunches/caib_preview.

[11] H. Allen, *Norway and Europe in the 1970s* (Oslo: Universitetsforlaget, 1979).

[12] D. Hillson, "Extending the Risk Process to Manage Opportunities," *International Journal of Project Management* 20, no. 3 (2002), pp. 235–40.

EXHIBIT 6.3
Uncertainty Matrix Showing both Favorable and Unfavorable Uncertainties

Source: D. Hillson, "Extending the Risk Process to Manage Opportunities," *International Journal of Project Management* 20 (2002), pp. 235–40.



As in the case of the traditional risk matrix displayed in Exhibit 6.2, red zone uncertainties in Exhibit 6.3 should receive the most attention. The general rule is to look for high-likelihood, big-impact uncertainties on either side of the mirror-image matrix. High-likelihood, high-impact favorable events should be the target of most efforts because they offer relatively easy ways to enhance a project. However, drawing from work on implications wheels by Barker[13] and on Kepner and Tregoe's work on decision making,[14] we suggest a project team can sometimes find ways to increase the likelihood of *low probability* positive uncertainties. Consequently, the rules for selecting uncertainties for further consideration and action are more clearly cut for potential unfavorable risks than they are for potential favorable uncertainties. A caution is appropriate here: Going too far with favorable uncertainties can lead to scope creep, or the inappropriate expansion of a project beyond its mission.

THE UNCERTAINTY ASSESSMENT PLANNING AND ACTION PROCESS

Although uncertainty assessment should occur in every project phase, the team should engage in its most detailed analysis after it possesses a clear idea of project mission, goals, and scope, and it has developed the WBS. Without knowledge of project content, it will be difficult for the team to imagine potential uncertainties. As shown in Exhibit 6.4, a team involved in uncertainty assessment typically gathers data and brainstorms possibilities, considers root causes, assesses likelihoods, envisions outcomes, considers risk preferences, selects relevant uncertainties, develops strategies, assigns responsibilities, and finds ways to monitor each relevant uncertainty. The extent of formality in this process, and the time spent, will depend on the size and complexity of the project.

[13] J. Barker, "Implications Wheels® Training Video," 1994; www.joelbarker.com/downloads.php.

[14] C.H. Kepner and B.B. Tregoe, *The New Rational Manager* (Princeton, NJ: Princeton University Press, 1981).

EXHIBIT 6.4 **Project Uncertainty Assessment Process**

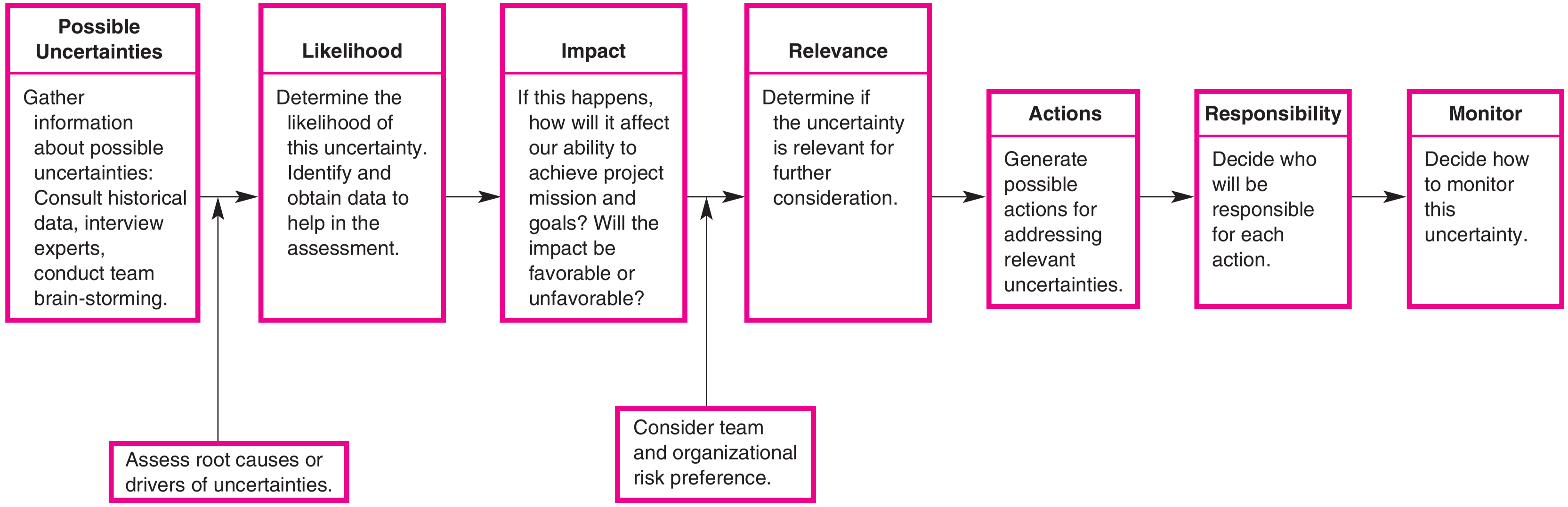


EXHIBIT 6.5
Uncertainty Responses

Source: Adapted from D. Hillson, "Extending the Risk Process to Manage Opportunities," *International Journal of Project Management* 20 (2002), pp. 235–40.

General Objective	Countermeasures for Risks or Unfavorable Uncertainties	Enhancements for Positive or Favorable Uncertainties
Alter the likelihood	Mitigate	Take action to increase the possibility this will happen
Find partners	Transfer risk	Share opportunity
Influence impact	Avoid	Exploit
Nonresponse with knowledge	Accept and develop contingency plans if appropriate	Ignore or accept, but develop contingency plans if appropriate

A project team can devise several types of actions in preparing for negative and positive uncertainties. We highlight these in Exhibit 6.5.

Uncertainty Preparation and Response Strategies: Return to the Boeing Example

Returning to the Boeing 787 example highlighted earlier in this chapter, we examine an unfavorable financial risk and a potentially favorable technical uncertainty. Box 6.2 demonstrates how Boeing might respond using the strategies listed in Exhibit 6.5. Some strategies for addressing uncertainties will represent new work packages, and these should be added to the WBS. As part of this process, the team must assign responsibility—who will ensure this uncertainty is monitored and the response strategy is enacted? If the newly identified actions blend well with the existing WBS, responsibility will reside with the individual or team associated with the deliverable for which the uncertainty is linked. If a gigantic new deliverable is added, the project organization structure will undoubtedly need to be expanded and new responsibilities assigned. In the 787 example, if Boeing decided to avoid the risk of a supplier's financial failure by in-sourcing fabrication and assembly of a key component, this would add a very major deliverable to the project plan, significantly expanding project scope. A project manager who can demonstrate that a request for change in scope and budget is based on a rigorous risk assessment process will be more likely (but not guaranteed!) to receive additional funding than one who simply asks for more money with only vague justification.

An uncertainty, by definition, is something that *might* happen,[15] but is currently not a goal or expected project outcome. Consequently, teams need monitoring systems that provide early warning signals, allowing them to respond appropriately.[16] In Exhibit 6.6

[15] As Martin and Tate so aptly observe, a risk with 100 percent probability is actually an assumption; see P.K. Martin and K. Tate, *A Step by Step Approach to Risk Assessment* (Cincinnati: MartinTate, LLC, 2001).

[16] M.D. Watkins and M.H. Bazerman, "Predictable Surprises: The Disasters You Should Have Seen Coming," *Harvard Business Review* 81, no. 3 (2003), pp. 72–80; and Mitroff, *Managing Crisis Before They Happen*.

EXHIBIT 6.6
Monitoring Project Uncertainties

Uncertainty Example	Monitoring Approaches
Unfavorable risk: Financial failure of a key supplier.	Require full financial disclosure from supplier, with a contract stipulation allowing quarterly audits. Run routine credit checks on the organization.
Favorable Uncertainty: Composite nose cone technology proves appropriate for transfer to programs in other Boeing divisions.	Assign a team from defense and space division to meet at regularly scheduled times with key personnel from the 787 and receive technology briefings on progress and new findings.

Enhancements and Countermeasures for Uncertainties in the Boeing 787 Case*

Box 6.2

Potential Financial Risk: Financial failure of a key supplier.
Outcome: Boeing would find itself without a supplier and have to delay the project while it seeks another partner.

Mitigate: To mitigate the potential risk, Boeing could ensure it has the most up-to-date digital designs stored in its databases and find a backup supplier who can be ready for quick ramp-up if needed.

Transfer: To transfer the risk, Boeing might place responsibility for this supplier under the control of an intermediary supplier with financial strength and the capacity to serve as a business advisor to the smaller supplier.

Avoid: To avoid the risk, Boeing could decide to in-source this particular part, building its own fabrication and assembly facility and ending the contract with the supplier.

Accept and prepare: Boeing might decide to accept the supplier-related risk, either because countermeasures are too expensive or because it views the likelihood to be low. In this case, the company still would monitor the situation closely and have a contingency plan for responding if the risk does materialize. For example, the company might identify one of its military facilities with composite capability as a backup.

The strategy choice (mitigate, transfer, avoid, accept) will depend on the overall risk tolerance associated with the project, the estimated likelihood of the risk and its outcomes, the impact the risk's outcomes will have on the project, perceived root causes, and the cost of each of the options. The company could decide to choose a combination of options.

Potential Favorable Technical Uncertainty: Potential to use nose-cone composite technologies for other Boeing applications.
Outcome: Boeing could use the technology transfer to is advantage in winning new military contracts.

Take action to increase the possibility this will happen: Initiate internal benchmarking activities that encourage people from other Boeing divisions to learn about composite developments on the 787.

Share opportunity: Bring in an outside consultant or supplier with expertise in composite applications to facilitate knowledge exchange. This might involve some sharing of patent benefits that result from the collaboration.

Exploit: Develop a human resource plan for moving key technical personnel from the 787 (after it is designed) to one of the programs anticipating adoption of the technology. Keep detailed records of key lessons from all tests and experiments.

Ignore: Let the opportunity arise if it does, but don't necessarily do anything to promote it. Keep good lab notes on development findings, and have some informal plans in mind in case other applications materialize.

With respect to actions related to positive uncertainties, the strategy choice will depend on the relative desirability of the opportunity, root causes, estimated likelihood of its occurrence, and cost associated with leverage initiatives. Again, Boeing could choose a combination of these strategies.

* Recall that this case is based partly on information documented in the media and partly on hypothetical future events.

we consider two of the uncertainties associated with the Boeing 787 example and discuss how each might be monitored.

TOOLS FOR ASSESSING PROJECT UNCERTAINTIES

All project teams must understand the dimensions of uncertainty and possess a sense of the process required for assessing and preparing for unknown events. Many approaches are available for tackling project uncertainties, and several fit well with the team-based theme of this book. These include risk mapping, failure modes and effects analysis (FMEA), gut feel, Delphi, fishbone diagramming, and various types of simulation.

Risk Mapping

For a small project, members of the project team can brainstorm a set of possible risks, writing them on sticky notes.[17] Using a matrix similar to the one shown in Exhibit 6.2, members can discuss assumptions about each risk's likelihood and impact, then reach consensus about where each risk should be placed on the matrix. At this meeting or at a later meeting, team members can decide how they will prepare for the most important risks (red and yellow zones) and what, if anything, they need to do about less important (green zone) risks. Although this is typically done in relation to unfavorable uncertainties in a traditional risk matrix such as the one in Exhibit 6.2, it can be expanded to include favorable uncertainties, as well.

Failure Modes and Effects Analysis (FMEA)

FMEA is a widely used tool with origins in the fields of safety and quality[18] and is a prescribed component of **Six Sigma.** It involves a systematic, team-based process for examining what could go wrong with products (e.g., a component that fails because it is not sufficiently durable to withstand the rigors of its intended use), or what can go wrong in the production process (e.g., failure of an adhesive curing process intended to fasten two components together). Although FMEA was created for use in product design and the analysis of routine manufacturing operations, it can be adapted to project management, as we demonstrate below. Note that FMEA is geared toward uncertainties with undesirable outcomes.

The FMEA process begins when a team brainstorms about possible failure modes—things that might go wrong during the project itself or technical failures with respect to what is actually delivered at the end of the project. Then, team members assign ratings for severity, occurrence (likelihood or frequency), and difficulty of detection for each possible failure mode. The product of the three ratings determines a risk priority score for each failure mode. Exhibit 6.7 highlights instructions

[17] Some readers may think we have a fascination with sticky notes. We believe they may represent one of the most useful tools available to a project team because of the opportunity they provide for individuals to quickly translate individual brainstorming into a flexible process of collaboration with a recordable result.

[18] R.E. McDermott, R.J. Mikulak, and M.R. Beauregard, *The Basics of FMEA* (New York: Productivity Press, 1996).

EXHIBIT 6.7 Team-Based FMEA Process for Project Uncertainty Assessment

1. **Foundation.** The team begins with FMEA only after it has developed a WBS and members have a shared understanding of project goals and expected outcomes.
2. **Individual Brainstorming.** Team members work alone, initially, to brainstorm possible failure modes for the project, keeping in mind things that could occur during project execution (what could happen during the project that would cause us to fail, e.g., a supplier is late to deliver a key project component), as well as possible flaws or risks associated with the project's final product (e.g., a design flaw in the product that does not become evident until the product is out in the market).
3. **List Failure Modes.** A facilitator uses a round-robin approach to gather failure modes ideas from participants. The facilitator should list these on the left side of a whiteboard or large piece of paper mounted on the wall.
4. **Understand Meanings and Causes.** The group discusses the meaning, causes, and effects of each failure mode listed. The facilitator should write key information about each one in the column just to the right of the failure modes list. This activity helps the group develop a shared understanding of each risk.
5. **Rating.** The team rates each failure mode for severity, likelihood, and difficulty of detection* on scales of 1–10, where 1 is low and 10 is high. The facilitator can ask each person to complete his or her own ratings, then compute averages, or the group can use a consensus approach. To facilitate the rating process, it can be useful for the team to first agree on the meanings of the 1–10 scores. (Some organizations have formal definitions already in place. We offer an example in Exhibit 6.9.)
6. **Calculate Risk Priority Numbers (RPNs).** Team members multiply their three ratings for each failure mode to derive a score for each one. The facilitator calculates group averages.
7. **Prioritize and Discuss.** Some failure modes will emerge as higher priorities for action, based on their RPN scores. Before jumping to conclusions about what is important and what is not, the team should carefully review the ratings and underlying assumptions to ensure there are no serious flaws in logic. Given the multiplicative nature of the calculation, a small overestimate in one of the numbers can result in an exaggerated RPN. Thus, the team might wish to make adjustments before agreeing on final priorities. One way to summarize the discussion about priorities is to arrange the most significant failure modes on sticky notes on a whiteboard or wall-mounted paper from highest to lowest priority.
8. **Decide on Actions.** Once the team has agreed on which risks are most important based on RPN scores, the facilitator can guide members in a discussion of the actions they will take to limit negative outcomes, who will be responsible, how the failure mode will be monitored, and what contingency plans should be established.

*For some projects, difficulty of detection might not be an important risk metric. In those cases, the team can decide to rate risks on severity and likelihood, but leave out the detection rating.

for the FMEA process, as adapted for project environments and Exhibit 6.8 shows an example from a real project.

An example of an FMEA matrix based on a team effort is displayed in Exhibit 6.8. This example is drawn from a volunteer project executed by a team of MBA students who installed an irrigation system in the gardens surrounding a residential hospital for medically fragile children.

The criteria presented in Exhibit 6.9 are examples only. The team can create its own criteria to meet the needs of a particular project, or the organization can develop standards. We believe it is not necessary (or prudent) to develop descriptions for all 10 of the numerical scores. The 1–10 ratings should be treated as an interval scale, built on the assumption that gaps between all adjacent pairs of numbers are equidistant. Overspecification of the meanings of numbers within the scale could be in conflict with this assumption and can create unnecessary complexity and confusion. Thus, it is sufficient just to specify high, medium, and low anchors.

EXHIBIT 6.8 **Sample FMEA Results for a Project to Create an Irrigation System and Landscape the Grounds Surrounding a Residential Hospital for Medically Fragile Children**

Type of Failure	Failure Mode	Potential Effect on Project	Possible Causes	Severity Rating	Likelihood Rating	Detection Difficulty Rating	RPN
Failure Related to Project *Outcome*	Irrigation system fails to produce water	Grass and plants die	Leaks in irrigation pipes	8	5	10	$8 \times 5 \times 10 = 400$
Failure Related to Project *Execution*	Crew accidentally cuts into under-ground electrical wires	Power outage affects crew's progress, medical care is dangerously disrupted, and neighbors become irate	Not having correct information about underground utility locations	8	2	4	$8 \times 2 \times 4 = 64$

EXHIBIT 6.9
Sample Rating Criteria for FMEA

Source: Adapted from R.E. McDermott, R.J. Mikulak, and M.R. Beauregard, *The Basics of FMEA* (New York: Productivity Press, 1996) to fit project environments.

Rating	Severity	Likelihood	Detection Difficulty
10	A rating of 10 indicates that this failure mode would have a disastrous effect on the project.	A rating of 10 indicates that it is almost inevitable (100%) that this failure mode will happen.	A rating of 10 indicates this failure mode is not detectable with our current measurement approach.
5	A rating of 5 indicates that this failure mode would have a moderately negative effect on the project.	A rating of 5 indicates that there is about a 50% chance that this failure will occur.	A rating of 5 indicates that there is about a 50% chance we would be able to detect this failure mode if it did occur.
1	A rating of 1 indicates that this failure mode would have no effect on the project or its intended outcomes.	A rating of 1 indicates that it is not at all likely this failure mode will occur.	A rating of 1 indicates that this failure mode would be obvious.

The Gut-Feel Method

The **gut-feel method** is built on concepts from FMEA, but offers a more visual approach to uncertainty assessment.[19] The value of gut feel comes from the way it uses group input to generate ideas and estimate likelihood and impact. Research has demonstrated that groups make more accurate judgments about uncertain events than individuals do.[20] Although the method was originally conceptualized to include only unfavorable risks, we have expanded it to include potentially favorable uncertainties, as well. The process, as we have adapted it from LaBrosse, is described in Exhibit 6.10. A board layout and an example of how the results might appear are shown in Exhibit 6.11.

[19] M.A. LaBrosse, *Accelerated Project Management* (New York: HNB Publishing, 2001).

[20] J.A. Sniezek and R.A. Henry, "Accuracy and Confidences in Group Judgment," *Organizational Behavior and Human Decision Processes* 4, no. 3 (1989), pp. 1–28.

EXHIBIT 6.10
Gut-Feel Method for Uncertainty Assessment

1. **Identify deliverables.** Using the team-generated WBS mind map or outline as a starting point, record the name of each major deliverable along the left-hand side of a large piece of wall-mounted paper or a whiteboard.
2. **Brainstorm uncertainties.*** The facilitator instructs participants to spend 10 minutes working alone to brainstorm potential uncertainties associated with each deliverable. Participants should write favorable uncertainties on one color of sticky note and unfavorable uncertainties on a different color. (One uncertainty per note.) The time working alone is critical to the process. To stimulate team members to cast a wide net around possibilities, the facilitator can remind participants to consider the five risk sources: financial, business environment, social, technical, and external/natural environment.
3. **Combine uncertainties.** Team members place favorable uncertainty and unfavorable risk notes next to the corresponding deliverables, working collaboratively to discover and eliminate duplicates.† Participants may add new uncertainty statements as the exercise triggers ideas. At the end of the sorting process, the team steps back to see if it all makes sense and to ask if anything is missing.
4. **Discuss uncertainty meanings and outcomes.‡** The team jointly reviews each uncertainty to ensure intended meanings are clear to all. Perhaps most importantly, the team should discuss possible outcomes for each uncertainty. For example, if a subcontractor is late in delivering hardware, this would be a risk, but how would it affect the project? Would there be a schedule delay for the entire project? This will help the team focus on the most important uncertainties.
5. **Assess likelihoods with dot voting.** Ask each team member to affix an adhesive-backed red dot along the periphery of any uncertainty note he or she considers high likelihood and to affix yellow dots on notes associated with uncertainties that seem to have moderate likelihoods. For those perceived to be of low likelihood, affix no dot. Ask people to work silently and refrain from talking with or attempting to influence others.
6. **Assess impacts with dot voting.** Use a dot-voting process similar to that used in assessing likelihoods. This time, each person places a blue dot next to any uncertainty that, if it does occur, will have a major impact on the project. A green dot is for moderate impact and no dot indicates low or no impact. (Remember, these effects may be either favorable or unfavorable depending on the nature of the uncertainty.) And, again, there should be no discussion or attempts to influence others during the dot-voting process.
7. **Assess for significance/relevance.** At the end of the voting, the team considers which uncertainties are most relevant. Relevant items are generally those with patterns of colored dots indicating high likelihood and significant impact, but a team can have other reasons for deciding that an uncertainty is worthy of attention. Once the team has agreed on which uncertainties are most relevant, these should be moved to the designated column, just to the right. The example in Exhibit 6.11 shows, in particular, one unfavorable risk and one favorable uncertainty that definitely should be moved to the right. Exhibit 6.12 provides a detailed example of two uncertainties that would be characterized as relevant based on dot-voting results. Exhibit 6.13 shows a team engaged in the gut-feel process.
8. **Discuss root causes and drivers.** The team considers forces underlying uncertainties they have selected as relevant. For unfavorable risks, brainstorm potential root causes—factors that could potentially cause this risk and its associated outcomes. For favorable uncertainties, brainstorm key drivers—factors that would be likely to cause this to happen. Sometimes underlying causes are readily apparent and this discussion can be brief. In other cases, a more extensive discussion may be appropriate, and the team may wish to use a fishbone diagram, an example of which is shown in Exhibit 6.16.
9. **Consider actions.** Drawing from the discussion of root causes and key drivers, the team brainstorms possible actions for (1) enhancing favorable opportunities, (2) mitigating high-likelihood, undesirable risks, and (3) creating contingency plans to prepare for uncertainties that cannot be controlled. (Recall the framework shown in Exhibit 6.5.) The facilitator will play an important role in guiding this process. If the list of relevant uncertainties is somewhat large, it can be useful to break the group into smaller subteams and have each one generate ideas for addressing the uncertainties associated with a particular deliverable.

10. **Assign responsibility.** Determine who will be responsible for each action, and add these actions to the WBS and responsibility matrix where appropriate.
11. **Develop a plan to monitor uncertainties.** The facilitator asks the question, "How will we know if any of our relevant uncertainties materialize? Is there a way to watch for them?" The team brainstorms ideas for monitoring each uncertainty.
12. **Summarize the results of the analysis in a risk-response matrix.** The risk-response matrix extracts key findings from the gut-feel process and summarizes them in an electronic document available to all team members for review, approval, and continued use during the project. Possible content for a risk-response matrix is shown in Exhibit 6.14.

*This is a departure from M.A. LaBrosse, *Accelerated Project Management* (New York: HNB Publishing, 2001), which emphasizes unfavorable risks but does not include positive uncertainties.
†This process follows the approach used in affinity diagramming; see M. Brassard and D. Ritter, *The Memory Jogger II* (Salem, NH: Goal/QPC, 1994).
‡This is another place where our adaptation differs from that originally prescribed by La Brosse. She does not explicitly include a step for uncertainty outcome discussion, although it may be implied in her process.

EXHIBIT 6.11 Gut-Feel Structure and Appearance After Dot Voting

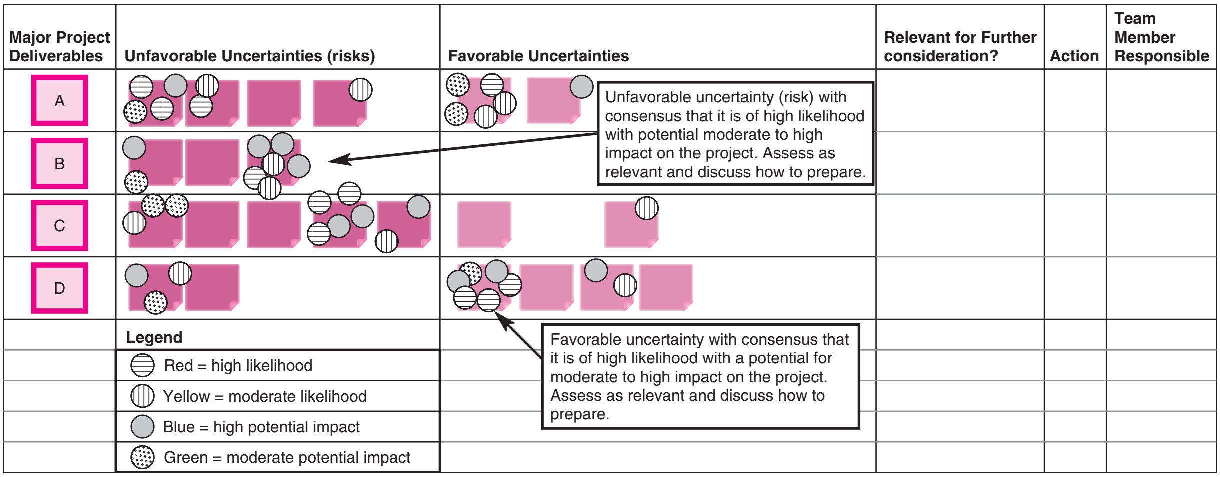


EXHIBIT 6.12
Examples of Relevant Uncertainties Identified Through the Gut Feel Method

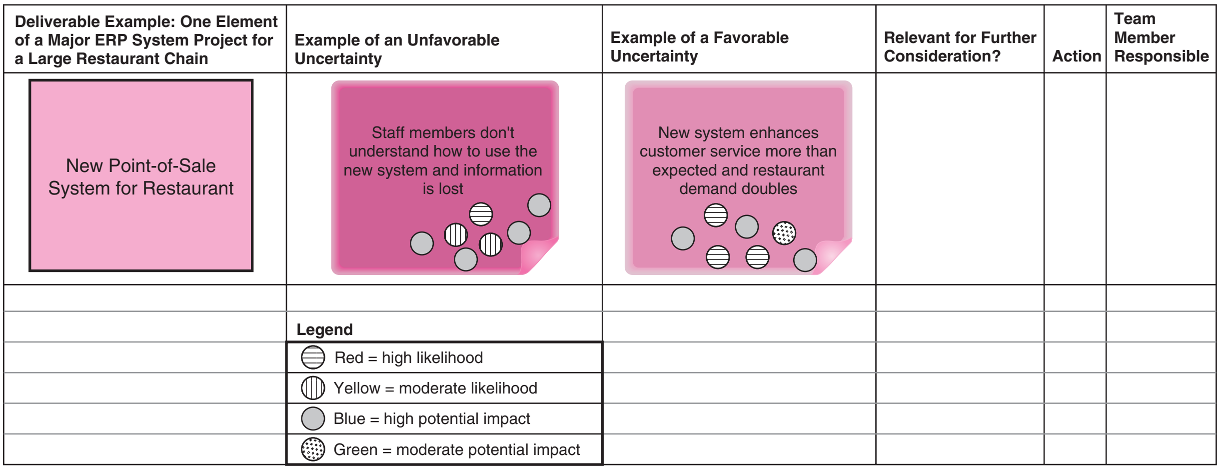


EXHIBIT 6.13
Gut-Feel Process: Team in Action

EXHIBIT 6.14
Risk-Response Matrix

Relevant Uncertainty	Preparation	Contingency	Trigger	Team Member Responsible
Short summary or full description of the favorable or unfavorable uncertainty	How will we prepare for it? What will we need to add to the WBS? What will all team members need to keep in mind?	What is our backup plan if the unfavorable uncertainty arises despite our preparation? What is our backup plan if the favorable uncertainty does not appear, despite our best efforts?	What evidence will tell us that this uncertainty has occurred, is occurring, or is imminent?	Who will take responsibility for preparing for this uncertainty? Who will develop and execute the contingency plan, should it become necessary?

The Delphi Method

The risk mapping, FMEA and gut-feel approaches discussed above work well when the project manager can gather the core team and critical stakeholders in the same room and take advantage of the synergies and commitment that are derived from face-to-face interaction. However, it is not always possible to hold an on-site brainstorming and analysis session, particularly when project team members or technical experts are geographically distributed. The Delphi method is an interactive approach for involving dispersed experts in forecasting that can be adapted for project uncertainty analysis.[21]

[21] G. Rowe and G. Wright, "The Delphi Technique as a Forecasting Tool: Issues and Analysis," *International Journal of Forecasting* 15, no. 4 (1999), pp. 353–75.

To do so, the project manager or process facilitator selects a group of 5 to 20 participants to form a virtual task force. All participants must have a clear understanding of the project's purpose, goals, and the content of the WBS. They then follow an interactive approach to risk brainstorming from their dispersed locations, as described in Exhibit 6.15.

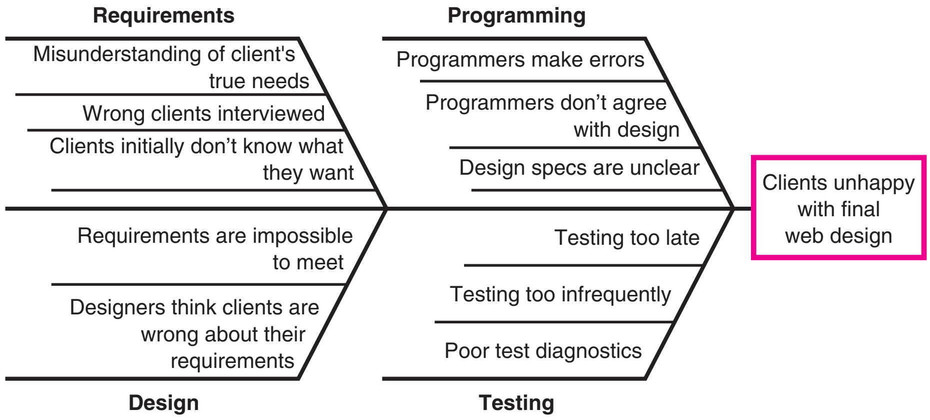
A Web-based tool for a Delphi process is available at http://armstrong.wharton.upenn.edu/delphi2/. Additionally, some Web-based collaboration tools for virtual teams we mentioned in Chapter 2 can be adapted for use with the Delphi method. For example, Meetingworks.com offers Web-based tools for anonymous brainstorming and for rating items to determine relative importance.

Delphi offers the advantage of bringing together a larger group than might be practical in an on-site session, and it opens the possibility of tapping into insights from external experts. Because it permits anonymous inputs, Delphi also can reduce the likelihood that a high-status person can override others and bias results. However, it probably will not engage participants to the extent that a synchronous, on-site meeting does. A team can partially compensate for this by using collaborative Web-based tools such as Meetingworks.com, to conduct something like a Delphi process with dispersed individuals who are all participating at the same time from remote locations. Additionally, by scheduling participants to meet virtually at a specified time, the facilitator can increase the likelihood they will allocate time for the process. Moreover, they will be more likely to find appeal in the immediacy of the communication with other participants.

EXHIBIT 6.15
The Delphi Method for Uncertainty Assessment with Virtual Teams

1. **Brainstorming, Round 1.** In the first round, the facilitator asks team members to list the unfavorable uncertainties (risks) and favorable uncertainties (sometimes referred to as opportunities) that could potentially arise in relation to each project deliverable. The facilitator must emphasize that the focus is on events the group currently does not expect or assume as project outcomes.
2. **Compilation of Round 1.** The facilitator compiles Round 1 results, consolidates similar items, and sends them back to participants without identifying who said what. In the next round, participants review the consolidated list and suggest items to add, delete, or clarify. The process can have two or three iterations, but, ultimately, an agreed-upon list emerges.
3. **Ratings.** To obtain likelihood and impact information, the facilitator can engage participants in a rating process similar to the one used in FMEA. (To keep things simple, it may be appropriate to include likelihood and impact ratings but omit the rating for difficulty of detection.) This will result in multiplicative scored ratings that enable participants to see which uncertainties are worthy of further consideration. Further online or telephone discussion will help to clarify assumptions.
4. **Selection of Uncertainties and Discussion of Strategies.** The next step, also handled interactively, is to engage team members in a numerical voting process to select the most important uncertainties. They may consider the numerical ratings from step 3 but also incorporate insights gained from online or telephone discussions.
5. **Ideas for Preparation.** Once the most important uncertainties have risen to the surface, virtual team members submit ideas for preparing or responding to them.
6. **Compilation of Results.** The facilitator compiles the results of the process and submits them to the team for final review. Once the team reaches agreement, the project manager makes the appropriate revisions to the project plan.

EXHIBIT 6.16
Fishbone Diagram for Risk Causes



Fishbone Diagrams

A **fishbone diagram,** also known as a **cause-effect diagram** or an **Ishikawa diagram**[22] is a brainstorming tool that encourages a team to consider all the possible causes of a problem. We introduced it in Chapter 3 as part of the assessment process for understanding project drivers. A fishbone diagram probably will not stand alone as an uncertainty assessment tool, but it can be used as an adjunct to risk mapping, FMEA, gut feel, Delphi, or other team-based tools. Imagine that in a Web-design project, team members think there is some risk the client may be unhappy with the final product. If this happens, they would have to rework the design, extending the completion date and wiping out profits. If this were moderately or highly likely to happen, the team could dig more deeply into its possible causes. A team presented with the question, “What factors might contribute to unhappiness on the part of our client?” could generate a fishbone diagram such as the one shown in Exhibit 6.16. The fishbone diagramming exercise will alert the team to potential pitfalls and, in this example, should lead members to consider ways to increase diligence in requirements assessment, quality control, and testing.

Simulation

Technical simulation methods have broad applications, from queuing to virtual reality to analysis of manufacturing bottlenecks.[23] For project environments, simulation models are frequently associated with project risk analysis.[24] These tools can be useful when a full set of technical and financial risks is understood, when outcomes can be quantified (e.g., cost, time, or technical failure), and when probability distributions are known with relative certainty. Despite the interest in computer-based Monte Carlo simulation for project risk assessment, we believe these tools are too often used without input from team-based tools such as the ones we have described in this chapter. Consequently, a quantitatively based analysis, regardless of its rigor, may not include

[22] K. Ishikawa, *What is Total Quality Control? The Japanese Way* (Englewood Cliffs, NJ: Prentice Hall, 1985).

[23] J.J. Swain, “New Frontiers in Simulation,” *ORMS Today* 34, no. 5 (2007), pp. 32–43.

[24] For examples, see Klastorin, *Project Management: Tools and Tradeoffs;* S.J. Mantel, J.R. Meredith, S.M. Shafer, and M.N. Sutton, *Project Management in Practice* (New York: Wiley and Sons, 2001); and A. Shtub, J.F. Bard, and S. Globerson, *Project Management: Processes, Methodologies, and Economics,* 2nd ed. (Englewood Cliffs, NJ: Prentice Hall, 2004).

EXHIBIT 6.17
Expanded Perspective on Simulation for Project Management

Timing of Use	Examples of Team-Based, Creative Simulation Tools	Examples of Analytically Based Simulation Tools
Before the project or early in the project	• Physical mock-ups • Rehearsals or dry runs • Tabletop exercises	• Three-dimensional design • Wind tunnel tests on preliminary designs • System dynamics modeling • Monte Carlo simulation
During the project, after some conceptual and design work has been completed	• Market tests • Clinical trials	• Test software on sample data • Run a wind tunnel test on a more fully developed design

all possible and relevant uncertainties.[25] Also, these tools cannot necessarily help a team envision the circumstances under which the project will ultimately operate. In response to these and other limitations, we offer a broader perspective on simulation, beginning with the following definition of **simulation** from *The American Heritage College Dictionary:* "Representation of the operation or features of one process or system through the use on another."

Based on this broad definition, Exhibit 6.17 highlights a few possibilities of simulation applications for project risk assessment. We discuss each of these and offer examples in the paragraph below.

Physical Mock-ups

A **physical mock-up** is a three-dimensional representation of a product (the outcome of a project). A team can use it to assess the characteristics of a product in ways not possible with a computerized two- or three-dimensional drawing. Boeing used physical mockups of 777 lavatories to test options for designs that would offer access to people with disabilities. Hundreds of potential passengers, all with physical disabilities of various types, went through the mock-up and offered valuable insight. The result was a disability-friendly design that occupied a minimum amount of space.[26]

Dress Rehearsals

A **dress rehearsal** is a practice run for an event or activity. We generally associate these with theater, but they have applications beyond the stage.[27] For example, two teams preparing to beat the world's record for building a house each built a practice house two weeks before the final event so they could learn where the potential risks were. The result was a world record of two hours and 45 minutes to build a three-bedroom, two-bathroom house.[28]

[25] Smith and Merritt, *Proactive Risk Management.*

[26] K.A. Brown, K.V. Ramanathan, and T.G. Schmitt, "Boeing Commercial Airplane Group: Design Process Evolution," in *Technology Management: Text and International Cases,* ed. N. Harrison and D. Samson (New York: McGraw-Hill/Irwin, 2002).

[27] R. Austin and L. Devin, *Artful Making* (Englewood Cliffs, NJ: Prentice Hall, 2003).

[28] For more information, contact the Building Industry Association of San Diego. The organization has a great video that captures the event. An Internet search will produce the one-minute version of the project.

Tabletop Exercises

Tabletop exercises engage team members in imagining a scenario and placing themselves into the circumstances. A brainstorming process such as gut feel might produce some critical uncertainties for which the team feels ill-prepared. The team can then gather around a table (or other surface), possibly using miniature props to get people into the right frame of reference to discuss possible risks/opportunities and consider responses.

For example, a transportation team for a major international competitive sports event considered the following risk, based on past history of similar events:

> Boxers will be transported to the clinic where drug tests are administered. Tight timing requires us to get them out of the clinic and back to the bus so they can return to the athlete's village for a team photo. And, we will need the buses for other purposes as soon as they arrive at the village. Based on past experience, we believe one or more of the boxers will not be able to urinate because he has dehydrated himself in order to stay under the weight limit for his class. If this happens, the entire team could potentially be delayed for two or three hours.

As part of the tabletop exercise built around this scenario, the team placed miniature buses, a clinic, roads, and so on, on a tabletop while they brainstormed the situation. This enabled the group to consider numerous options and to recognize which were within the group's purview and which were not. Ultimately, the team decided to add a small number of passenger vehicles to the fleet as a way of enhancing flexibility. Could they have done this without putting the props on the table? Perhaps, but team members contend that the visual nature of the props allowed them to understand the situation better.

Market Tests and Clinical Trials

Market tests and clinical trials are team-oriented simulations intended to represent eventual realities for products. Both involve extensive customer involvement, and the team's effective use of the results will determine the value of these efforts. For example, software companies such as Apple often run tests of new or revised applications by releasing beta versions to enthusiastic expert users. These users subject the software to all sorts of tests the companies might not have ever imagined, thereby simulating many of the scenarios under which the software might be used. The results are invaluable in shaping the version that is ultimately released to the market.

Technical Simulation

New product efforts in technical environments often involve three-dimensional simulations of designs. For example, CATIA, a three-dimensional software package developed by Dassault in France, has come into widespread use around the world, with applications in automotive, aerospace, and computer design, just to name three examples. It allows a design team to see where interferences potentially exist among structural elements, reducing the chance that assemblers will discover the problem when it is too late to fix in an economical manner.[29]

System Dynamics Modeling

System dynamics, a term coined by Jay Forrester,[30] describes a general set of simulation tools that allow users to examine the relationships among a constellation of interrelated social and technical variables. Such models can incorporate real data, or they can use subjective data generated by the user.[31] Although overuse of such models might

[29] Brown et al., "Boeing Commercial Airline Group."

[30] J. Forrester, *Urban Dynamics* (Cambridge, MA: MIT Press, 1969).

[31] P.M. Senge, *The Fifth Discipline* (New York: Doubleday Currency, 1990).

distract a team from getting down to project business, the models may be worthwhile to consider in the context of highly complex projects with multiple implications.[32]

Monte Carlo Simulation

Software tools such as @Risk or Crystal Ball use Monte Carlo simulation to assess risk profiles associated with time, cost, and other factors. (Swain offers a comprehensive listing of these software programs.[33]) One common application assesses probabilistic time estimates to gain insights into the range and distribution of project completion times. These programs can yield percentile probabilities of completing a project within various time frames. We discuss probabilistic time estimates in Chapter 7. For more information on Monte Carlo simulation in project environments, see Klastorin.[34]

ADDING TIME AND RESOURCES BASED ON PROJECT UNCERTAINTIES

Uncertainty analysis increases a team's awareness of unknowns that can affect project outcomes. To address these uncertainties, the team must make adjustments in the project schedule, budget, resource distribution, specifications, and other project dimensions. For example, team members might discover that the project will require more funding because of previously unforeseen items not included in the original project plan. (For example, think about the need for additional lifeboats on the Titanic). In other cases, the project manager may request contingency funds designated for use in the event an uncertainty does emerge. Another type of contingency can be linked to the schedule. Perhaps uncertain weather conditions or technical unknowns could extend the time required for the project. Major scope changes or necessary schedule extensions discovered as a result of risk assessment will require approval from the project sponsor. The bottom line on uncertainty assessment is that it is not just an exercise in imagination or scenario planning, but an essential input to the project plan.

NEXT STEPS: MONITORING PROJECT UNCERTAINTIES

Uncertainty assessment is an ongoing activity in any project. The project team needs a way to keep tabs on uncertainties as they are uncovered throughout project planning and execution. An uncertainty or risk log can be the ideal tool for this purpose. Exhibit 6.18

[32] N. Repenning and J. Sterman, "Capability Traps and Self-Confirming Attribution Errors," *Administrative Science Quarterly* 47, no. 2 (2002), pp. 265–95.

[33] Swain, "New Frontiers in Simulation."

[34] Klastorin, *Project Management: Tools and Tradeoffs.*

EXHIBIT 6.18
Sample Risk/ Uncertainty Log for a Student Orientation Session

Current Date: 12 January						
Risk ID #	**Date Logged**	**Priority**	**Person Responsible**	**Description**	**Response**	**Current Status or Resolution**
15	12 January	High	Bobbette	Registrant no shows—prospective students who register for the weekend, but do not attend	Admissions staff will follow up with each registrant 2 weeks and again 5 days in advance of orientation	Action planned for 1 April and 15 April

presents a portion of a risk log for a student orientation program at a university. The team should review and update the log at each meeting.

Chapter Summary and Onward

Projects are unique and nonroutine. Consequently, they present potential unknowns for which the team must prepare. We have emphasized the importance of recognizing both unfavorable risks *and* favorable uncertainties. Many tools are available for assessing potential project surprises, and all consider likelihood and impact of outcomes in some way. Ultimately, the project team must decide on actions to prepare for or respond to uncertainties, adjust the project plan accordingly, assign responsibility for managing them, and set up methods to monitor them.

Qualitative tools offer the advantage of engaging team members in interactive, visually based processes that can generate a wide range of possible uncertainties. Tools that involve team members in assessment of uncertainty include risk mapping, FMEA, gut feel, Delphi, fishbone diagramming, tabletop exercises, dry runs, and dress rehearsals. Quantitative models for uncertainty assessment have their place, especially when there is sufficient historical information for making numerical parameters reasonably valid.

Once it has considered risks and modified the WBS accordingly, the team is ready to formulate a schedule. Uncertainty factors represent important inputs to the scheduling process. For example, if team members discover that a material delay is highly likely, they might decide to schedule the order further in advance than they initially deemed necessary. Additionally, they could insert into the schedule a task called "confirm order" at some point during the order lead time. We move on to the project schedule with a full appreciation of the important steps that precede it.

Team Activities

1. Gather a team of three to five of your classmates. Imagine you are planning a celebration to commemorate the high school graduation of one of your children, a sibling, a niece or nephew, or the child of another relative or close friend. You have identified major project deliverables, including: venue, guests, food and beverages, entertainment, and gifts. Do the following:
   a. Write the names of these deliverables on the left side of a large (about 1 meter by 2 meters) sheet of l paper mounted horizontally on the wall.
   b. Follow the instructions in this chapter for executing the gut-feel method. Begin with individuals working alone to brainstorm unfavorable risks and favorable uncertainties, and take the process through dot voting, identification of relevant uncertainties, and development of actions associated with at least four of the most relevant risks/uncertainties. At least one of the four should be a favorable uncertainty. Your result should be in a format similar to that shown in Exhibits 6.11–6.13.
   c. Summarize your results in a risk-response matrix either as a Word or Excel document. See Exhibit 6-14 for a framework.
   d. Submit your summary along with two photos of your team conducting the analysis on the wall-mounted paper.
2. Watch the movie *Ocean's Eleven* with your team. Make notes during the movie of all of the risks the *Ocean's Eleven* team identified in its planning process. How did the team prepare for each one? In other words, which actions did the team take to minimize negative uncertainties? Make a list of at least 10 risks and associated actions. Which of the methods described in this chapter were used, either explicitly

or implicitly, in the project? Were there any risks the team failed to anticipate? If so, what were they? Submit the product of your analysis as a Word or Excel document.

3. Conduct an Internet search to find a video clip of "Exploding Whale." Watch this short clip with your team members. Write a three-page paper highlighting the following:
   a. A problem statement for the project (as described in Chapter 3, your statement should describe the nature of the problem, its location, timing, and magnitude.)
   b. A project objective and key performance indicators. Include KPIs not considered when the project actually occurred. How would *you* measure the performance of this project?
   c. Options for solving the problem. Be creative.
   d. Key deliverables of the WBS for this project as it was actually executed (at least four—be creative!).
   e. At least two potential unfavorable risks associated with each deliverable.
   f. For each of the unfavorable risks, conduct a failure modes and effects analysis (FMEA) that incorporates team member scoring. Calculate an RPN for each risk and identify the ones that are most significant.
   g. Describe how, in retrospect, you would have addressed the top three risks you identified in part f.
4. Form a team of classmates for a virtual teaming exercise on project uncertainty. Consider the graduation celebration project described in Team Activity 1, above. Do the following:
   a. Set up a time when you can all meet virtually at the same time. (It is also possible to do this asynchronously, so check with your instructor. We recommend the synchronous approach, however.) Each team member will need an internet connection.
   b. With team members in separate locations, use the Delphi method to brainstorm possible project risks. For the sake of this exercise, consider *unfavorable* risks only. You may use one of the decision support Web tools recommended in Chapter 2 for virtual teams. Consider www.meetingworks.com, or the Web site specifically designed for Delphi processes: http://armstrong.wharton.upenn.edu/delphi2/.
   c. Use the features of the tool you have chosen to consolidate brainstorming results and move to the next stages, as prescribed in Exhibit 6.15.
   d. Summarize the results of your uncertainty assessment using a risk-response matrix. Include at least six risks in the table.
   e. Exchange e-mail messages relating your impressions of the virtual process—its advantages and disadvantages. Collaborate to write a two-page summary of your reflections about your experience with the process.

Discussion Questions and Exercises

1. Why is it useful to consider both unfavorable risks and favorable uncertainties as part of the project planning process? Describe an example from your own work or personal life in which an unfavorable risk interfered with your ability to execute a project as you had initially envisioned it. Describe another example, also from your own work or personal life, in which an unexpected positive implication changed the course of a project such that it turned out better than you had envisioned it.

2. Why is it useful to have a complete WBS before engaging in formal risk/uncertainty assessment? Use an example of your own creation to support your explanation.
3. Find the following article, H. Karp, "Why Protesters Are Playing Ping-pong in Your Parking Space." *The Wall Street Journal,* September 21, 2007, p. W7. This article describes how activists are attempting to "raise awareness about the lack of open space in urban areas, and to draw attention to the gas wasted and pollution created by drivers circling the block for low-cost urban parking spaces." In short, they have set up lawn chairs, ping-pong tables, even a beauty parlor, in metered spaces in cities in the United States and Europe. Refer to Exhibit 6.1, which describes uncertainty sources. For each of these sources, describe a real or hypothetical unfavorable uncertainty and a real or hypothetical favorable uncertainty associated with the protestors' activities. Demonstrate connections with the content of the article, but use your imagination, as well.
4. Visit www.historylink.org and find links to Web pages describing the sinking of the Lake Washington Floating Bridge on November 25, 1990. Read several of these descriptions. A brief description from Historylink is as follows:

   > On November 25, 1990, after a week of high winds and rain, the 50-year-old Lacey V. Murrow Bridge (Lake Washington Floating Bridge) breaks apart and plunges into the mud beneath Lake Washington. Since it took some time for the bridge to sag and finally crack apart, news cameras were poised and ready to show post-Thanksgiving TV viewers a once-in-a-lifetime telecast of the demise of the historic I-90 span. It is later discovered that hatchways into the concrete pontoon air pockets were left open, allowing water to enter, while the bridge was undergoing a $35.6 million renovation.

   a. In hindsight (which we know is biased) where would you place the risk of water entering the pontoons in the uncertainty matrix presented in Exhibit 6.2? Discuss your rationale for the position you choose.
   b. Of the five sources of uncertainty described in this chapter (see Exhibit 6.1) which one (or ones) best described the risk of water entering the pontoons on the bridge? Explain your answer.
   c. Do you see any potential positive outcomes that could have emerged from this project crisis? Name and discuss at least one.
   d. What tools could the team have used to uncover the possibility of water entering the pontoons? Name at least three and explain how they would be applied.
   e. What biases (see Appendix 6A) may have prevented the team from seeing this risk as a possibility?
5. Read the article, E. Nelson and E. Ramstad, "Trick or Treat: Hershey's Biggest Dud Has Turned Out to Be Its New Technology," *The Wall Street Journal,* October 29, 1999, p. A1. This article describes a disastrous ERP (enterprise resource planning) system implementation at Hershey. Based on your reading of the article, as well as your own creative ideas, describe a negative outcome risk for each of the risk sources presented in Exhibit 6.1. For each of these risks, describe actions you could take to prevent it or prepare for it, and describe how you would monitor the situation so that you were assured of being aware of the risk if it did occur.
6. A famous British expedition aimed at crossing Antarctica, led by Ernest Shackleton from 1914 to 1916, was derailed by unexpected ice floes.[35] Although this

[35] See www.shackleton-endurance.com, or C. Alexander, *The Endurance: Shackleton's Legendary Antarctic Expedition* (New York: Knopf, 1998).

act of nature presented an initial risk, Shackleton and his crew were able to later take advantage of ice floe movements to escape from a prolonged and cold entrapment that, remarkably, did not take any of their lives. Imagine yourself as Shackleton, and that you are developing an uncertainty assessment before you set sail. Prepare a gut-feel matrix similar to Exhibits 6.11 and 6.12. If you need more information about the Shackleton expedition, consult the sources cited in the footnote below or conduct an internet search. Identify three major project deliverables, and for each one identify one potential negative risk and one potential favorable uncertainty. Assess the likelihoods, outcomes, impacts on the project, and key drivers. Discuss your analysis and demonstrate critical thinking.

7. A project team at Scanda Pharmaceutical is using FMEA to assess risks for a celebration to be held when a major project milestone, completion of clinical trials for a promising new drug, is completed. The celebration will be held on the luxurious gardens of Scanda headquarters in Bergen, Norway. Project team members, top company officials, and representatives from major customer groups will attend the event, which will include a gourmet meal, elaborate decorations, speeches, and live entertainment. The team responsible for planning the event decided to use FMEA, and members generated a long list of risks, five of which are shown in the matrix below. Each team member had the opportunity to give his or her ratings for these risks, which are shown in the matrix that follows the risk list.

Top Five Risks

Risk	Effect on the Project as It Is Currently Planned	Possible Causes
1. Invited VIP guests don't attend the event	Major embarrassment to company. Loss of marketing opportunity.	Invitations sent to incorrect addresses. Invitations don't convey a sense of the importance of the event.
2. Guests get food poisoning	Bad image for the company. Could hurt sales.	Food spoils in hot weather. Careless caterer.
3. Clinical trials prove to be unsuccessful but it is too late to cancel the event	Bad publicity in the market. Delay in getting to market. Stock analysts produce negative reports.	Researchers giving falsely optimistic reports during the trials. Error in data analysis not caught soon enough. Event scheduled prematurely.
4. Another major event hosted by a competitor is scheduled for the same day.	Dilution of publicity. Some VIPs attend competitor's event.	Insufficient investigation of potential conflicts. Intentional move on part of competitor.
5. Major rainstorm	Not possible to hold the event outdoors without everyone getting wet.	Atmospheric conditions outside the control of the team. Weather patterns characteristic of the time of year.

FMEA Ratings for Milestone Celebration

Risk #	Rater #	Severity	Likelihood	Detection Difficulty	Individual RPN	RPN Mean
1	Evelyn	9	3	4		
	Arve	8	5	6		
	Kyrre	6	6	2		
	Sindre	3	6	3		
2	Evelyn	10	2	7		
	Arve	9	4	5		
	Kyrre	6	4	3		
	Sindre	8	5	2		
3	Evelyn	10	4	6		
	Arve	9	4	9		
	Kyrre	7	2	4		
	Sindre	8	5	3		
4	Evelyn	8	5	1		
	Arve	7	6	1		
	Kyrre	9	3	4		
	Sindre	5	8	1		
5	Evelyn	10	5	2		
	Arve	9	6	1		
	Kyrre	5	3	3		
	Sindre	8	8	2		

a. Calculate the RPN for each of the five risks.

b. Based on RPN scores, identify the risks most relevant for further consideration. Would you completely trust the numbers, or would you seek further discussion or investigation? Why?

c. For each of the three most relevant risks, describe the actions you would take when considering the possibility that they might occur. For each of the actions you recommend, identify which of the four negative uncertainty action categories (see Exhibit 6.5) best describes what you are recommending.

d. Prepare a risk-response matrix.

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APPENDIX 6A

Human Biases in Risk/Uncertainty Assessment

Human beings have a tendency to underestimate the likelihood of some types of risks[36] and overestimate the likelihood of others.[37] They can be unjustifiably over confident or under confident. These biases can affect uncertainty assessments in project environments.[38]

AVAILABILITY HEURISTICS

This refers to recall based on vividness and recency. If a potential occurrence has happened to us (or someone we know) recently, or has been in the news, we will be likely to overestimate its likelihood (think house fire, plane crash, hurricane, child abduction).

RETRIEVABILITY

This is a judgment error based on memory structures. If a risk, opportunity, or issue is easy for us to retrieve because of our mental models, we will be more likely to recall it and associate it with the project. Imagine that you are an expert programmer with strong technical skills and you are thinking about things that could go wrong in a software project. You might be more likely to consider technical problems because this is your area of expertise. Consequently, you might tend to overlook the possibility of social risks such as stakeholder resistance, which could carry a higher likelihood than the technical issues you are envisioning.

MISCONCEPTIONS OF CHANCE

People are not good mental statisticians and tend to make statistical inferences based on cognitive biases about how random event patterns should appear. For example, imagine you have experienced a sequence of independent, random coin tosses: H-H-H-H-H-T-T-T-T-T-T-T-T-T. You might be inclined to estimate a high likelihood that the next toss would be heads (H). This is because you have a subconscious belief that the two possibilities should even out over the course of the toss series, even though each toss is an independent, random event. In fact, heads (H) or tails (T) are equally likely as the outcome of the next toss. In a project environment, this can lead people to believe a string of bad luck will even out—as a consequence, they underestimate the likelihood that unfavorable conditions will continue. (“We’re due for some good

[36] M.D. Watkins and M.H. Bazerman, “Predictable Surprises: The Disasters You Should Have Seen Coming,” *Harvard Business Review,* March 2003, pp. 72–80.

[37] J. Spencer and C. Crossen, “Fear Factors: Why Do Americans Feel That Danger Lurks Everywhere?” *The Wall Street Journal,* April 24, 2007, p. A1.

[38] G.E. McCray, R.L. Purvis, C.G. McCray, “Project Management Under Uncertainty: The Impact of Heuristics and Biases,” *Project Management Journal* 33, no. 1 (March 2002), pp. 49–57.

luck."). This bias, known as the **gambler's fallacy,** can play a role when a team is assessing project risks in relation to a series of past projects, or if members are making go-no-go decisions in the context of a series of failures within the project.

CONJUNCTIVE EVENTS

This describes the tendency for individuals to **overestimate** the probability of conjunctive events occurring. Conjunction occurs when several things *all* must happen, or when several attributes *all* must be present. There is no compensation or tradeoff. In a project environment, an example of a conjunctive event would be a milestone dependent on the merger of several predecessor activities. For the milestone to be complete so that the next phase may begin, all of these predecessors must be complete. The project manager has a sense of the probability of each of these predecessor events being completed on time, but might not intuitively apply joint probability statistical models to predict the likelihood of *all* of them being completed by a specified date. The following example illustrates: Imagine activities A, B, and C, in combination, are predecessors to activity D. Each of the three is estimated with a 90 percent probability to have a duration of 20 days. Based on conjunctive event biases, one might naively predict a 90 percent probability that C can start at the end of day 20, but this would be incorrect. The actual joint probability would be the product of these probabilities, or $90 \times .90 \times .90 = .729$

OVERCONFIDENCE IN ESTIMATES

Once they have made estimates, people tend to be far more confident than they should be about their accuracy. This has serious implications for the estimations project participants make about the impact and likelihood of potential uncertainties. Fortunately, group judgments tend to be more accurate than individual judgments, but, unfortunately, groups are just as subject to the overconfidence bias as individuals are, particularly in instances where groupthink[39] rules. The result can be that a team wears blinders when it comes to seeing risks that might cause schedule slippages or cost overruns.

RISKY SHIFT

With respect to risk preferences, the project manager should be familiar with the potential for what is known as **risky shift.** Research and practice have consistently demonstrated that individuals are likely to take on more risks after a group discussion about the action under consideration than they would have without the discussion.[40] This can be a two-edged sword. On the one hand, it can lead reluctant team members to go along with a good idea they had initially feared. On the other hand, it could lead a team to make a foolish choice because of groupthink effects. A well-structured, balanced discussion will be important to the team in making the best decisions and avoiding risky shifts.

Source(s): Adapted from M.H. Bazerman, *Judgment in Managerial Decision Making,* 5th ed. (New York: Wiley and Sons, 2002); R. Hogarth, *Judgement and Choice* (Chichester, England: Wiley and Sons, 1980); J. Raftery, *Risk Analysis in Project Management* (London: E&FN Spon, 1994); A. Tversky and D. Kahneman, "Judgment under Uncertainty: Heuristics and Biases," *Science* 185, no. 4157 (1974), pp. 1124–31; and J.S. Hammond, R.L. Keeney, and H. Raiffa, *Smart Choices: A Practical Guide to Making Better Life Decisions* (New York: Broadway Books, 1999).

[39] I.L. Janis, "Groupthink," *Psychology Today* 5, no. 6 (1971), pp. 43–46, 74–76.

[40] Although some research has also documented the potential for **cautious shifts** in some circumstances, the risky shift is more common. R.J. Ebert and T.R. Mitchell, *Organizational Decision Processes: Concepts and Analysis* (New York: Crane, Russak & Co., 1975).