Figure 1-1. San Francisco Bay Bridge Construction (Photo by Oleg Alexandrov)

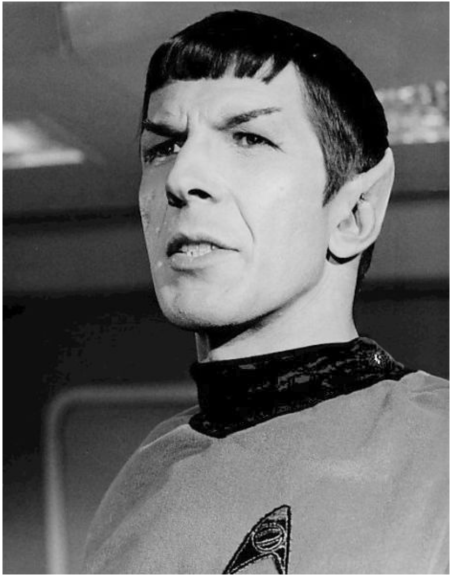


Figure 2-1. Spock from *Star Trek* had the ability to think rationally (Credit: NBC Television, 1967)

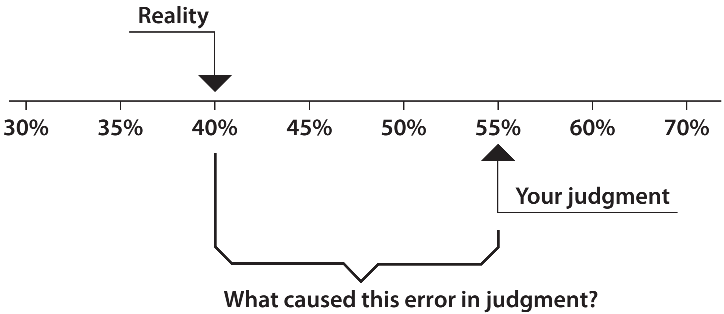


Figure 2-2. Bias in Estimation of Poll's Results

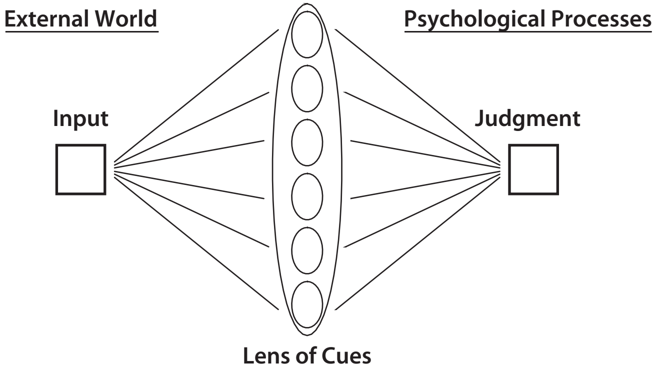


Figure 2-3. Lens Model of Judgment

Figure 2-4. What brand is this car, and where was it produced? (Photo by Areo7)

Figure 2-5. CN Tower (Photo by Wladyslaw)

Figure 2-6. View from CN Tower glass floor (Photo by Franklin.vp)

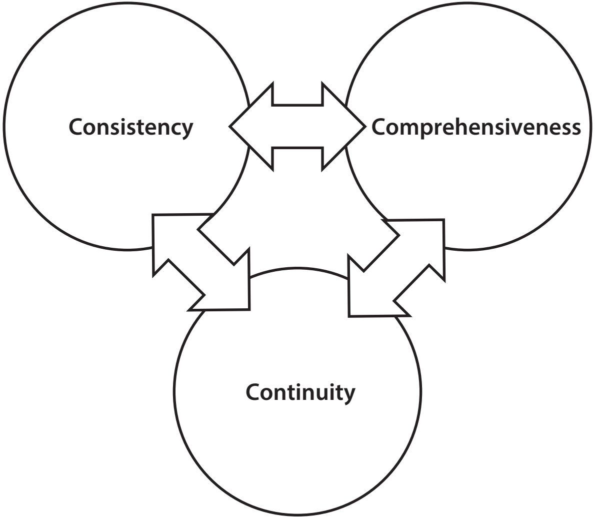


Figure 3-1. "3C" Principle of Project Decision Analysis

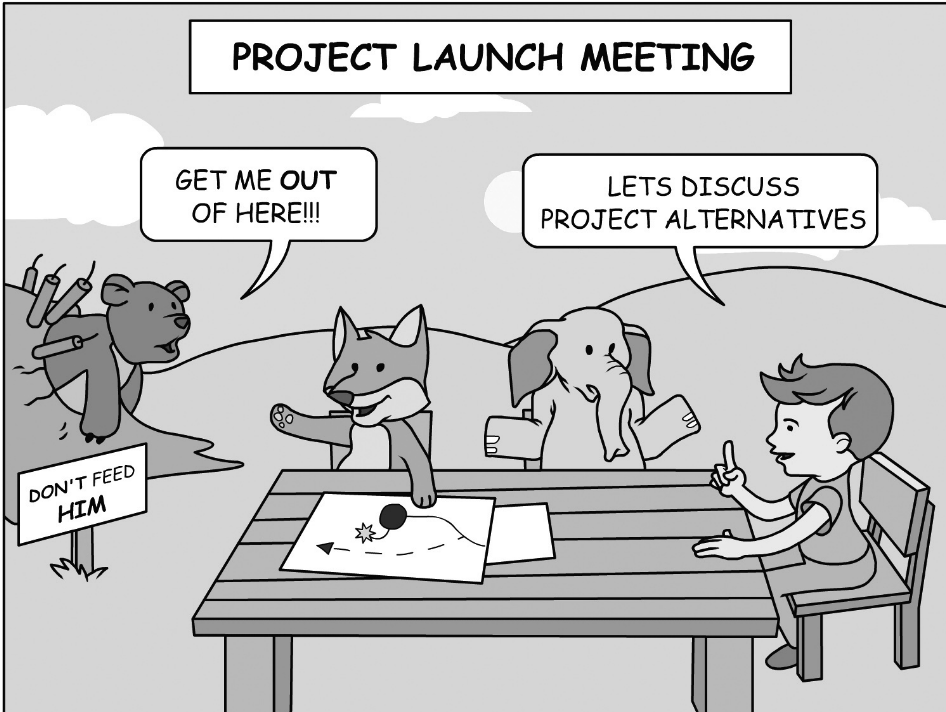


Figure 3-2. Using Decision Analysis to Resolve Complex Problems

	Steps of Decision Analysis Process	Project Risk Management Processes (*PMBOK Guide*)
Decision Framing	Identification of Problems or Opportunities Assessing Business Situation Determining Success Criteria Identifying Uncertainties Generation Alternatives	Risk Management Planning Risk Identification
Modeling the Situation	Creating Models for Project Alternatives Quantifying Uncertainties	Qualitative Risk Analysis Quantitative Analysis Risk-Response Planning
Quantitative Analysis	Determining What Is Most Important Quantifying Risks Associated With Project Determining the Value of New Information Deciding on a Course of Actions	
Implementation Monitoring Review	Implementing the Best Alternative Monitoring the Project Implementation Review of the Decision Experience	Risk Monitoring and Control

Figure 3-3. Decision Analysis Process

Table 3-1. Decision Analysis Process for Various Types of Projects

Type of Decision	Suitable Decision Analysis Process	Some Comments
Small tactical decisions during the course of projects	Try to process information logically by answering a few simple questions: • What is the problem? • What do we want to achieve? • What are the uncertainties? • What are the alternatives? • What will happen if each alternative is implemented?	You may use any components of the process described in this chapter that you find both easy to implement and useful. For example, you may start with decision-framing with some simple analysis.
Important decisions concerning small projects or tactical decisions in large projects	You may use some components of the process described in this chapter, if you find them easy to implement and useful. For example, you may start with decision-framing with some simple analysis.	This is the first step toward a formalized decision analysis process in the organization.
Strategic project decisions	Apply the decision analysis process described in this chapter for a comprehensive evaluation of alternatives.	If the complete project depends on this decision, a full decision analysis process will be useful.
Strategic enterprise-wide decisions	Use a consistent, continued, and comprehensive decision analysis process for all project decisions within a portfolio.	Enterprise-wide decisions should be made based on a comprehensive analysis of alternatives, with continued monitoring of results.

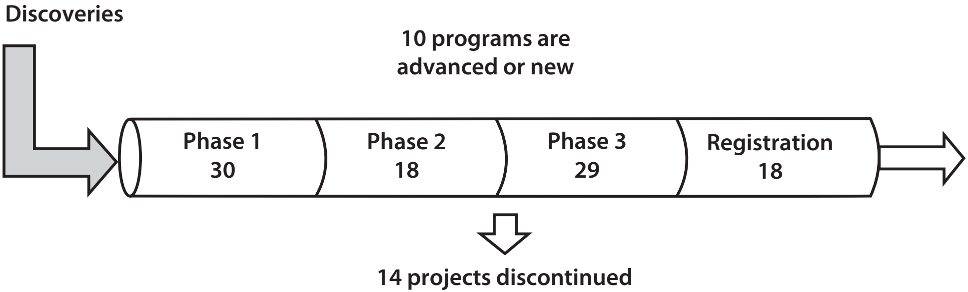


Figure 4-1. Pfizer Project Pipeline as of January 30, 2018

Table 4-1. Bernoulli's Coin-Tossing Game

Toss	Payoff	Probability	Expected Value	Total Expected Value of the Game: sum of the Expected Values after each turn
1	$2	50%	$1	$1
2	$4	25%	$1	$2
3	$8	12.5%	$1	$3
4	$16	6.25%	$1	$4
				Infinite amount of money

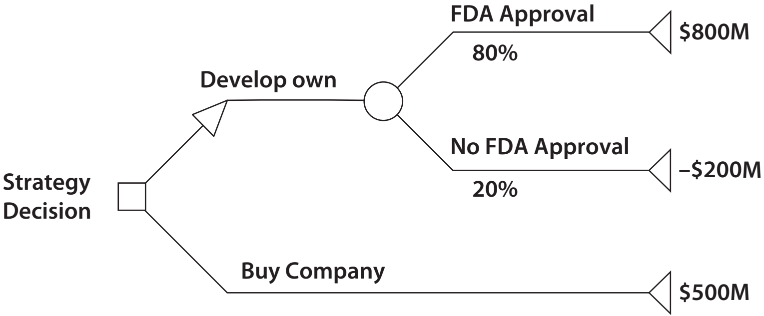


Figure 4-2. Decision Tree

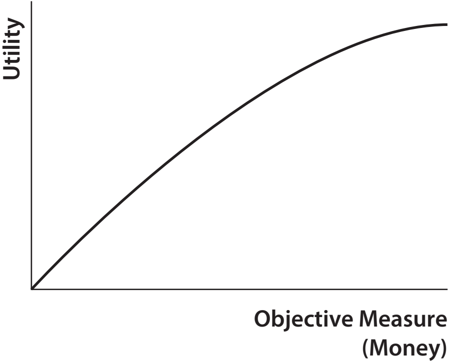


Figure 4-3. Utility Function

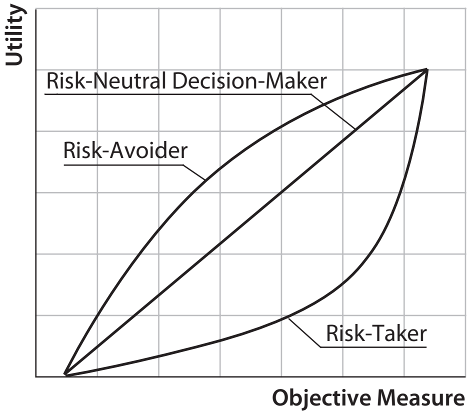


Figure 4-4. Using the Utility Function to Depict Risk Behavior

Table 4-2. Calculation of Expected Utility

Outcome Name	Outcome	Utility	Probability
Develop own drug (no FDA approval)	–$200	2.5	20%
Develop own drug (FDA approval)	$800	4.6	80%
Buy company	$500	4.5	

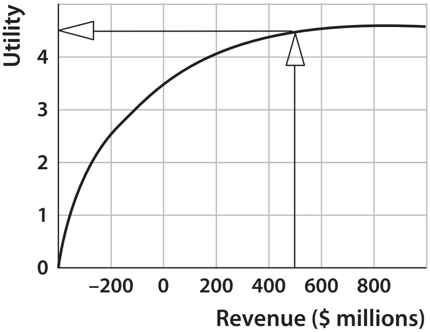


Figure 4-5. Using the Utility Function to Select an Alternative

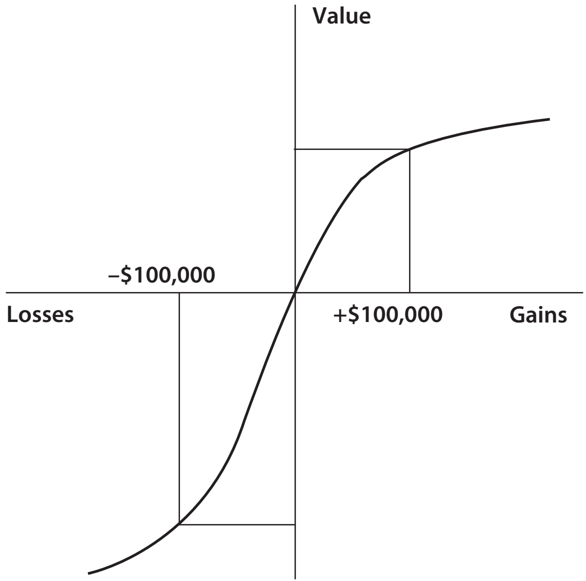


Figure 4-6. Value Function in the Prospect Theory

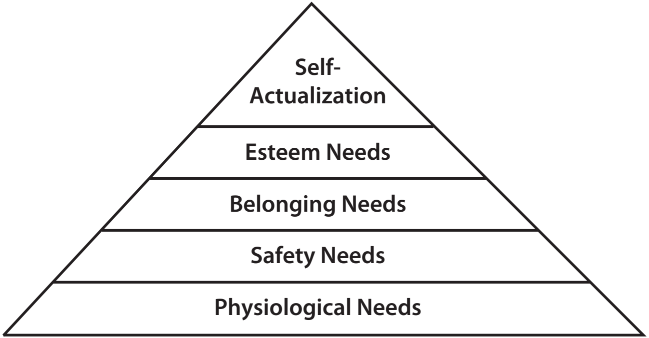


Figure 5-1. Maslow's Hierarchy of Needs

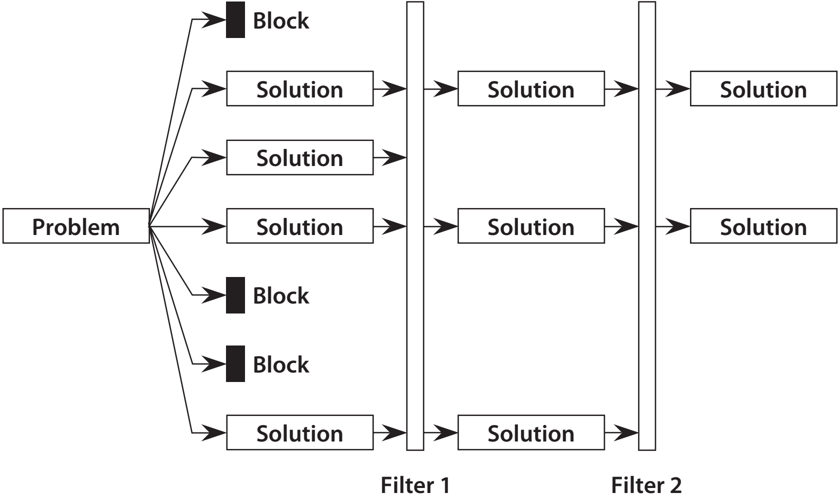


Figure 5-2. Example of Creative Process with Blocks and Filters

Figure 5-3. Finding Creative Solutions

Figure 5-4. "Would You Invest in This Company?"

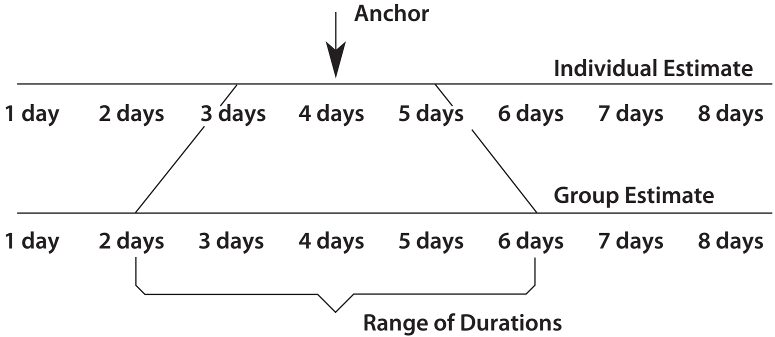


Figure 6-1. Developing a Range of Activity Durations

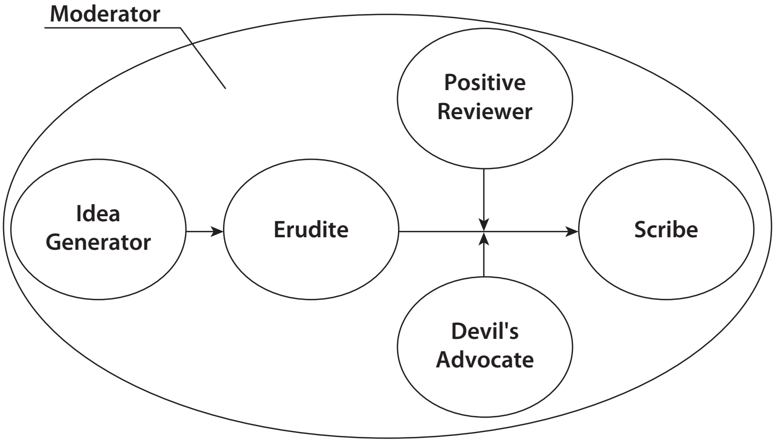


Figure 6-2. Brainstorming Technique

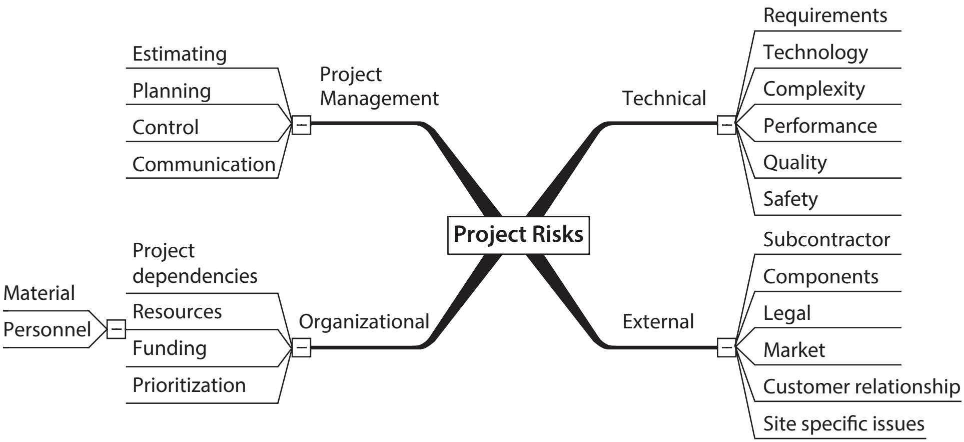


Figure 6-3. Mind Map of Project Risks

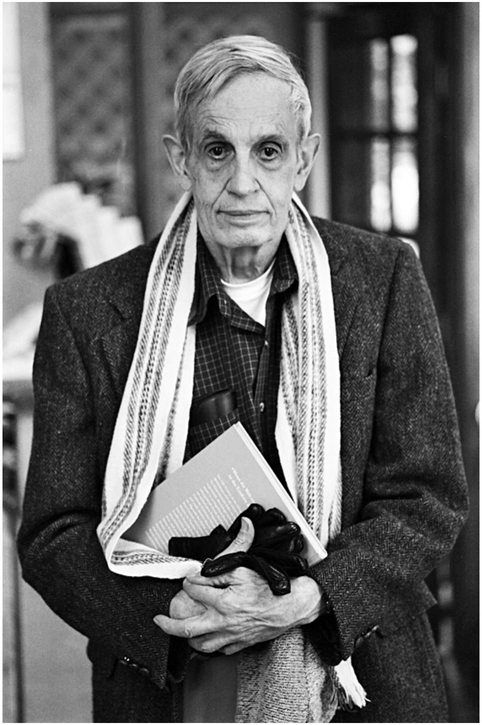


Figure 6-4. John Forbes Nash in 2006 (Photo by Peter Badge)

Table 7-1. Motivations and Incentives. *Source*: McConnell 1996

	Project Managers	**General Population**
1	Responsibility	Achievement
2	Achievement	Recognition
3	Work itself	Work itself
4	Recognition	Responsibility
5	Possibility for growth	Advancement
6	Interpersonal relationship	Salary
7	Advancement	Possibility for growth
8	Salary	Interpersonal relationship
9	Company policies and administration	Status
10	Job security	Technical supervision opportunities
11	Technical supervision opportunities	Company policies and administration
12	Status	Working conditions
13	Personal life	Personal life
14	Working conditions	Job security

Figure 8-1. James Bond Assessing a Business Situation. Sean Connery shooting the movie *Diamonds Are Forever* in Amsterdam (Photo by Rob Mieremet)

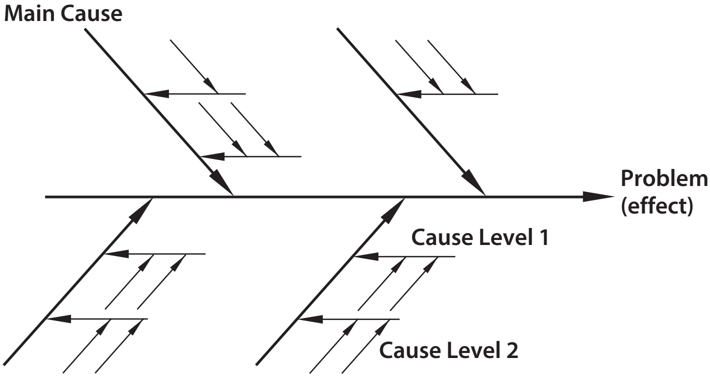


Figure 8-2. Cause-and-Effect Diagram

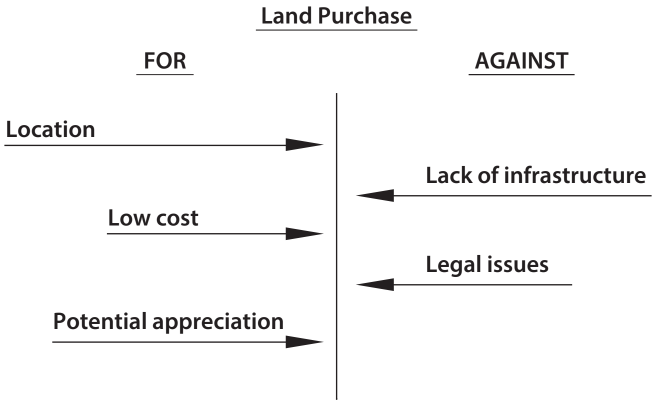


Figure 8-3. Force-Field Diagram

Table 9-1. Different Goals and Decision-Making Criteria for U.S. Army and Sgt. Bilko

	Sgt. Bilko	**U.S. Army**
Objectives	1. Financial performance of Bilko's army unit 2. Entertainment and gambling	1. Improve military preparedness 2. Design and production of a prototype hover tank
Decision-making Criteria	1. Revenue 2. Quality of entertainment and gambling 3. No transfers to a location in Greenland	1. Quality of military training 2. Completion of hover tank project on time and within budget

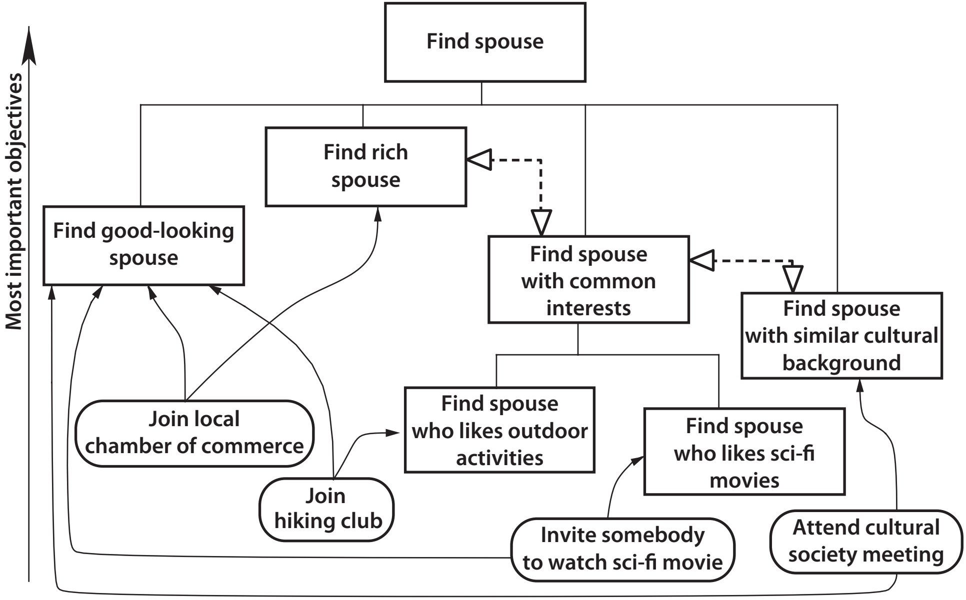


Figure 9-1. Project Objectives Hierarchy

Cost	Quality	Scope
Purchase materials offshore	Testing on each project phase	Clarify requirements upfront
Reduce cost of labor	Use QA tools	Demonstrate product to the client regularly
Hedge fuel costs	Hire more QA analysts	Use requirement management system

Figure 10-1. Strategy Table for Identifying Project Alternatives

Table 11-1. Inaccuracy of Transportation Project Cost Estimates (Adapted from Flyvbjerg et al. 2002)

Project Type	Number of Cases	Average Cost Escalation
Rail	58	44.7%
Fixed-link (bridges and tunnels)	33	33.8%
Roads	167	20.4%
All projects	258	27.6%

Table 11-2. Example of Previous Activities Related to the Current Task

Date	Activity	Clearly Remembers	Duration
Q1, 2017	Pie chart	No	10 days
Q2, 2017	Interactive bar chart	No	12 days
Q1, 2018	Multiple line chart	Somewhat	7 days
Q2, 2018	Small bar chart	Yes	3 days
Q4, 2018	Bar chart	Yes	5 days

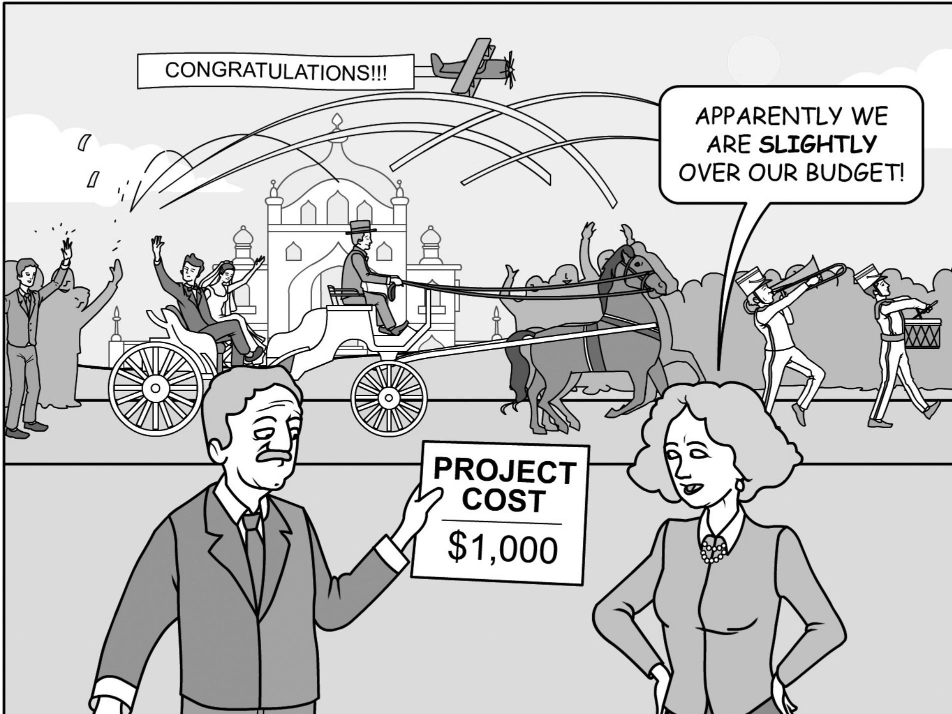


Figure 11-1. Risks and Uncertainties of Budgeting

Table 11-3. Analysis of Relevant Activities

	Activity	Duration	Relevance
1	Development of user interface (UI) for customer support software	20 days	Relevant
2	Website development	32 days	Not very relevant
3	Charts in business analysis software	10 days	Almost the same
4	UI improvements for selected client	5 days	Relevant

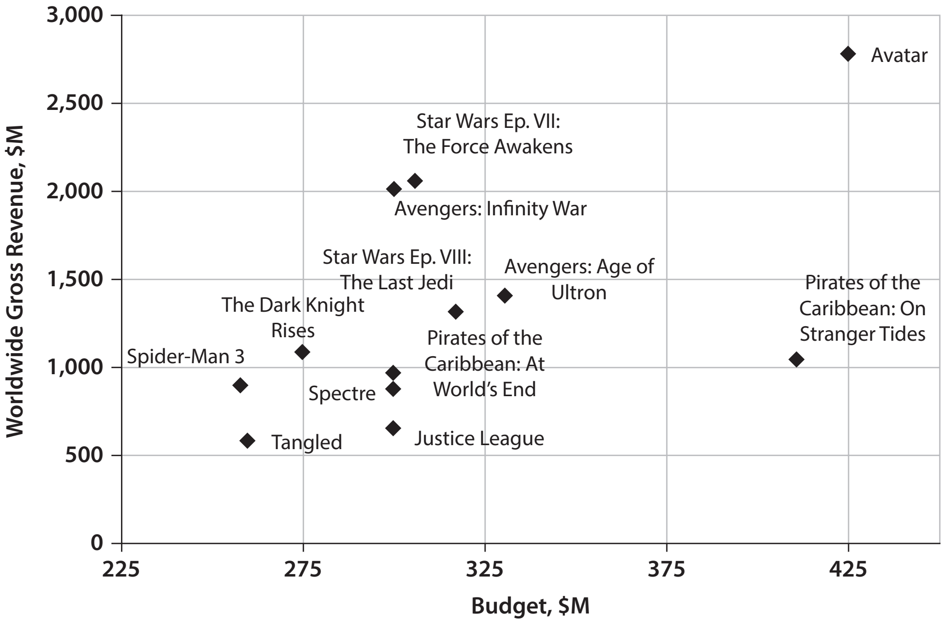


Figure 11-2. Gross Revenue of Most Expansive Movies vs. Budget

Figure 12-1. Robbing a Bank Involves Complex Modeling

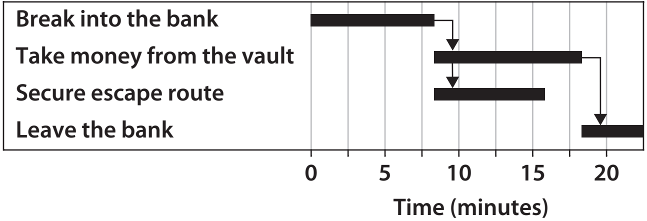


Figure 12-2. Gantt Chart for Bank Robbery Project

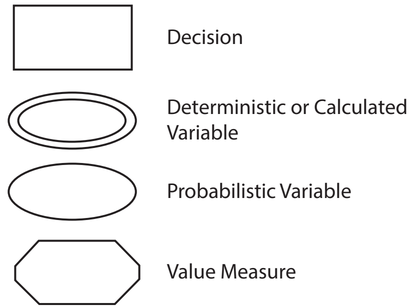


Figure 12-3. Different Types of Nodes

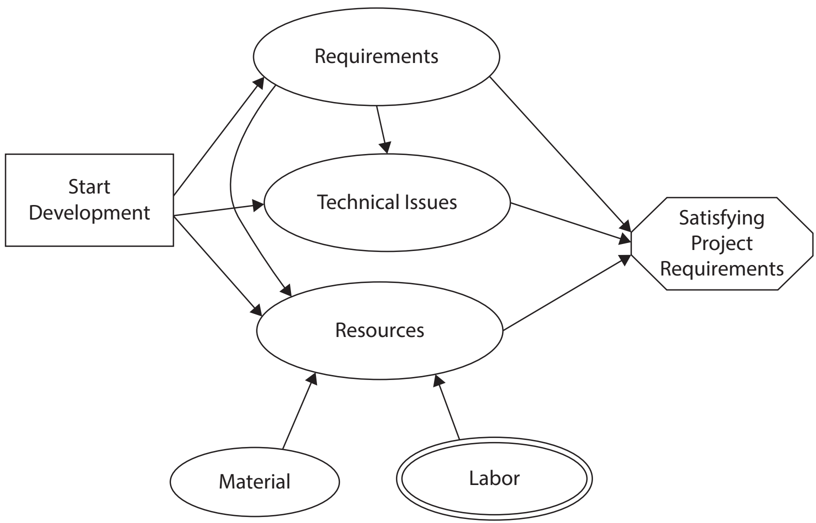


Figure 12-4. Influence Diagram

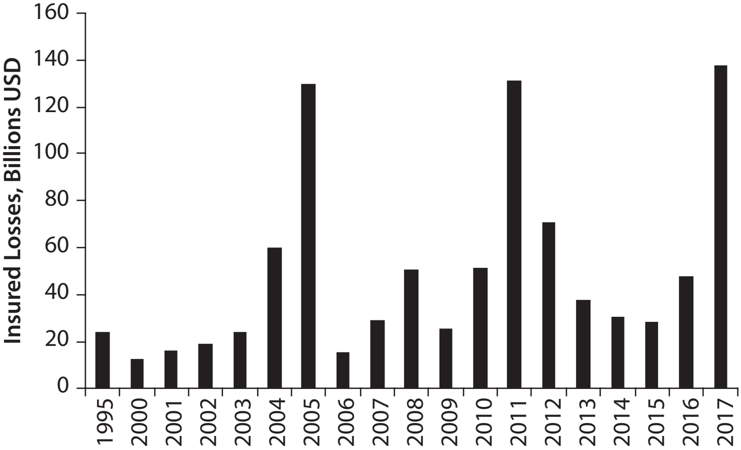


Figure 13-1. Insured losses caused by natural disasters worldwide from 1995 to 2017 (in billion U.S. dollars)

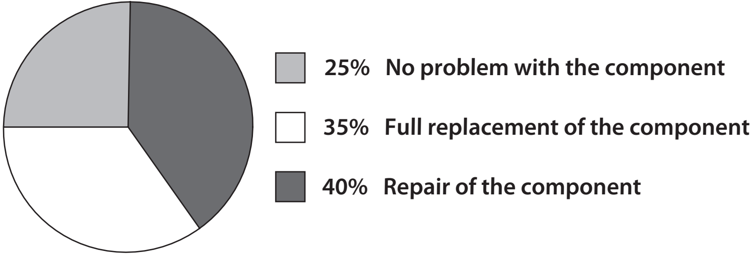


Figure 13-2. Probability Wheel

Figure 13-3. The Atlas V Rocket with New Horizon Liftoff from Cape Canaveral, September 24, 2005 (Credit: NASA/Kim Shiflett, 2006)

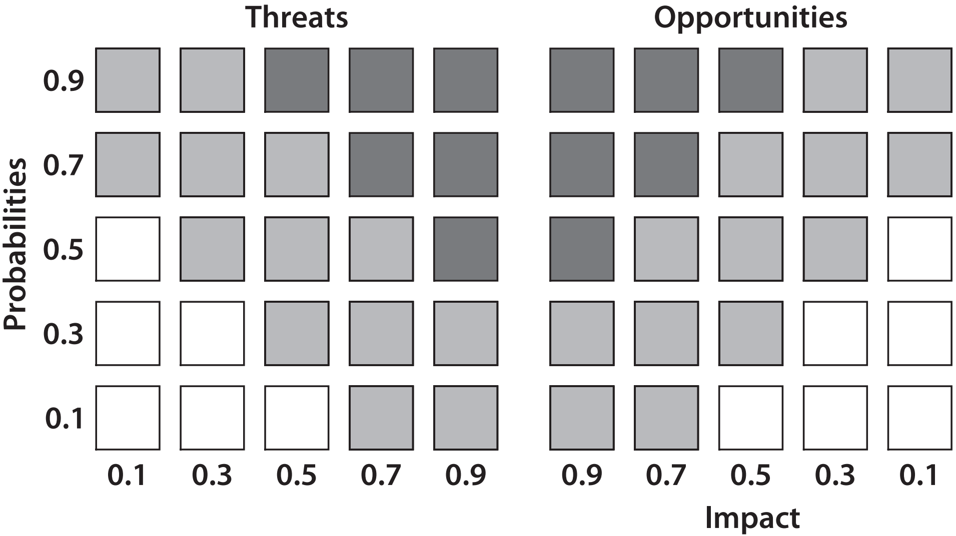


Figure 13-4. Probability and Impact Matrix

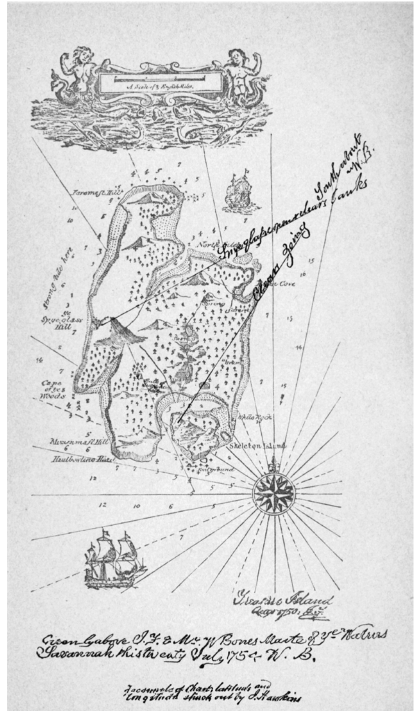


Figure 14-1. Stevenson's Map of Treasure Island (Credit: Robert Louis Stevenson)

Table 14-1. Example of Covariation Assessment

	Project Deadline Missed	**Project on Schedule**
Subcontractor involved in project	8 times	2 time
Subcontractor not involved in project	4 times	1 time

Source: Adapted from Plous 1993.

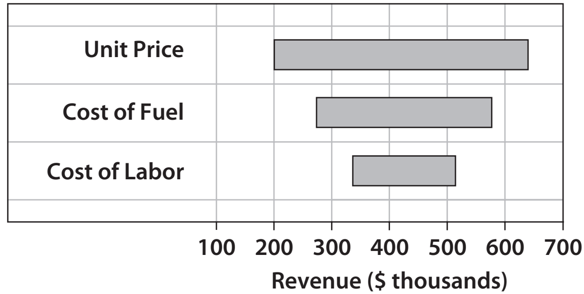


Figure 14-2. Tornado Diagram

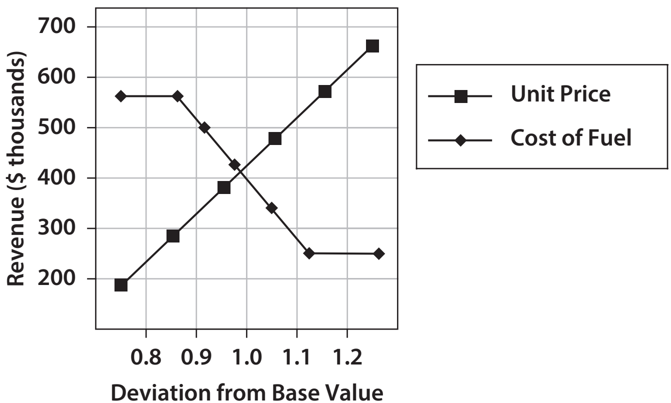


Figure 14-3. Spider Diagram

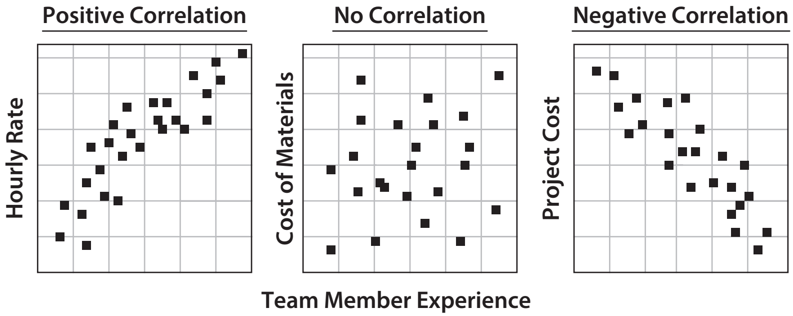


Figure 14-4. Scatter Diagrams Showing Different Types of Correlation

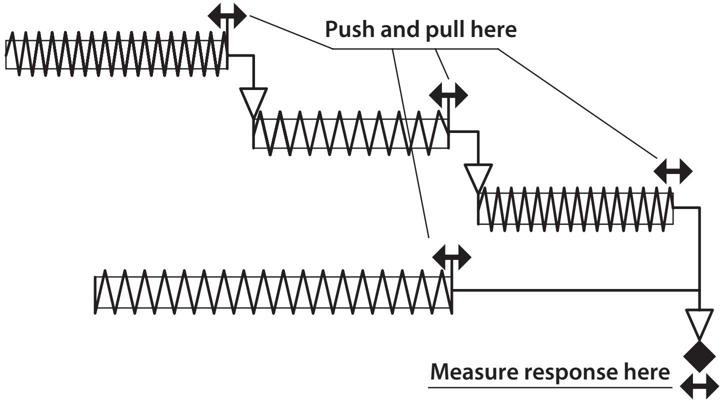


Figure 14-5. Spring Analogy for Crucial Tasks

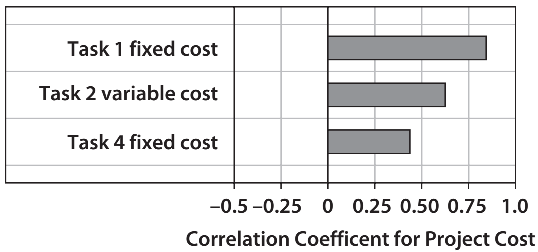


Figure 14-6. Sensitivity Chart

Figure 15-1. Applying Decision Analysis to Make a Better Choice

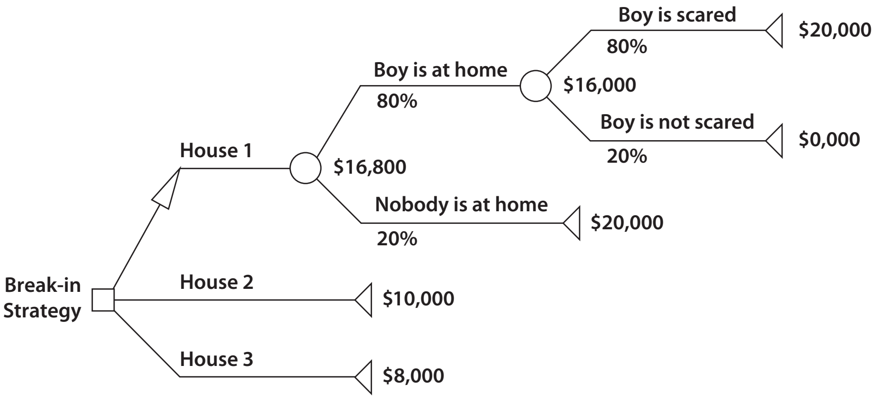


Figure 15-2. Analysis of Break-In Strategy Using a Decision Tree

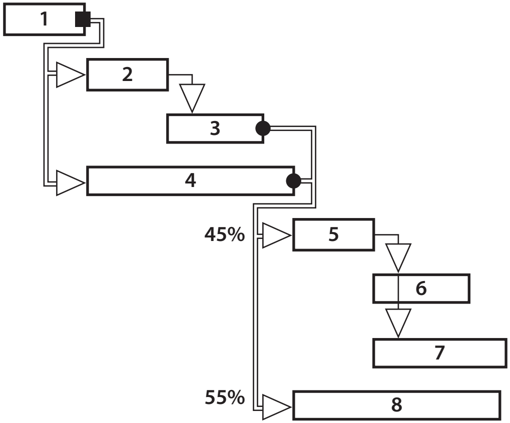


Figure 15-3. Project Schedule to Be Converted to a Decision Tree

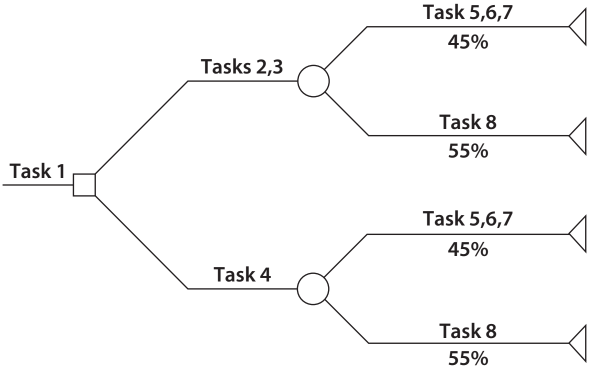


Figure 15-4. Results of a Schedule-to-Decision Tree Conversion

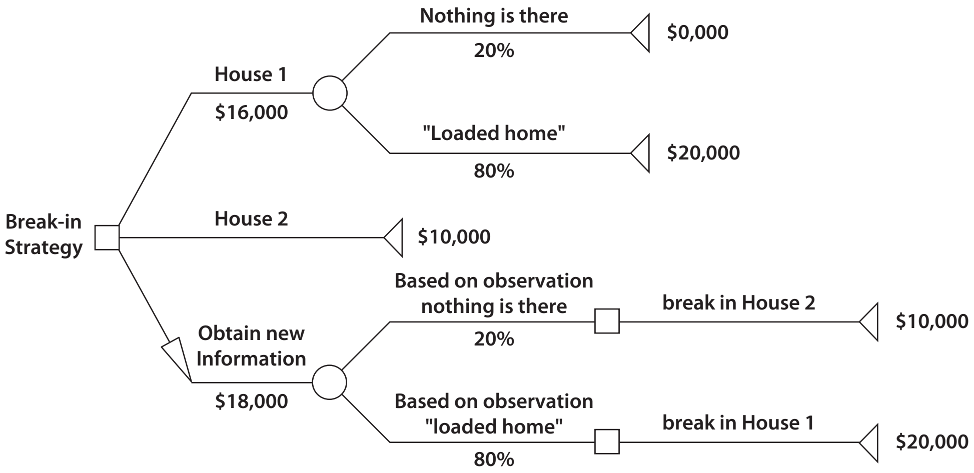


Figure 15-5. Analysis of Value of Perfect Information for Break-In Strategy

Figure 16-1. Starting Point for the Four Tunnels of East Side Access in Queens (Photo by Metropolitan Transportation Authority/Patrick Cashin)

Table 16-1. Activity Duration on Different Trials

Duration of the activity "install kitchen sink"	Occurrences	Probability: Number of occurrences divided by total number of installations (20)
Between 0 and 0.5 hour	2	$2 \div 20 = 0.1$ (10%)
Between 0.5 and 1 hour	10	50%
Between 1 hour and 1.5 hours	5	25%
Between 1.5 and 2 hours	3	15%

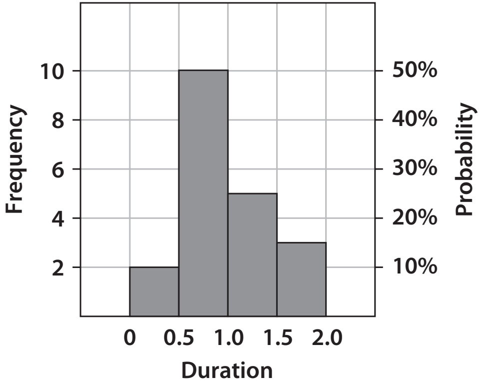


Figure 16-2. Frequency Histogram

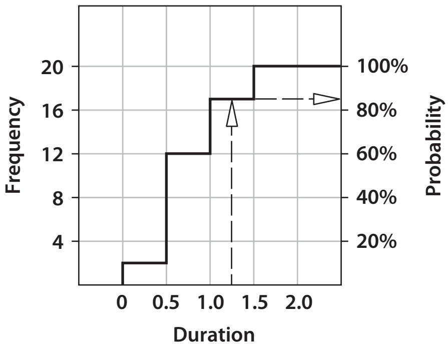


Figure 16-3. Cumulative Probability Plot

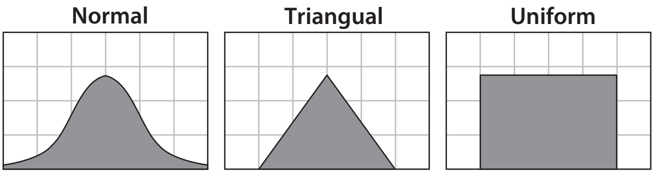


Figure 16-4. Different Continuous Statistical Distributions

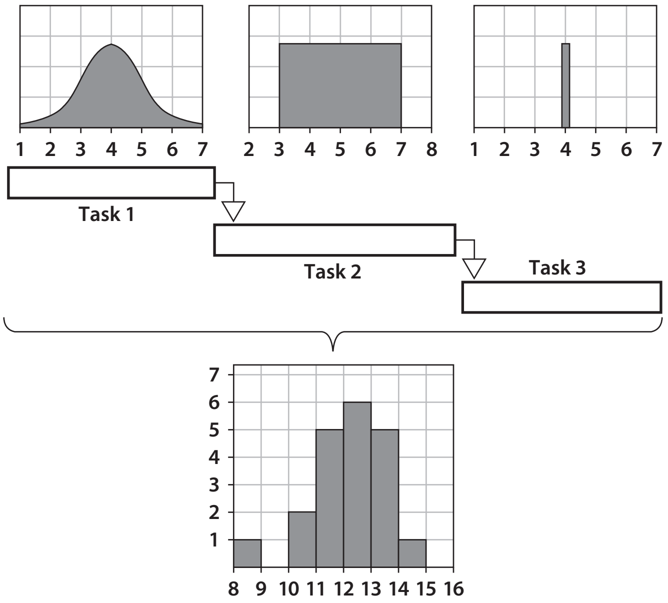


Figure 16-5. Monte Carlo Simulation Process

Table 16-2. Monte Carlo Simulation Results

Trial	Task 1	Task 2	Task 3	Project	**Trial**	Task 1	Task 2	Task 3	Project
1	1.2	3.5	4.0	8.7	**11**	4.8	3.1	4.0	11.9
2	4.0	2.8	4.0	10.8	**12**	4.2	4.9	4.0	13.1
3	2.5	4.0	4.0	10.5	**13**	3.9	5.5	4.0	13.4
4	3.0	6.0	4.0	13.0	**14**	2.3	5.1	4.0	11.4
5	3.5	4.4	4.0	11.9	**15**	5.8	3.1	4.0	12.9
6	4.2	3.9	4.0	12.1	**16**	3.4	3.9	4.0	11.3
7	3.8	6.2	4.0	14.0	**17**	4.6	3.7	4.0	12.3
8	4.4	4.4	4.0	12.8	**18**	3.7	4.8	4.0	12.5
9	2.1	5.9	4.0	12.0	**19**	3.9	3.5	4.0	11.4
10	4.1	5.8	4.0	13.9	**20**	4.3	5.5	4.0	13.8

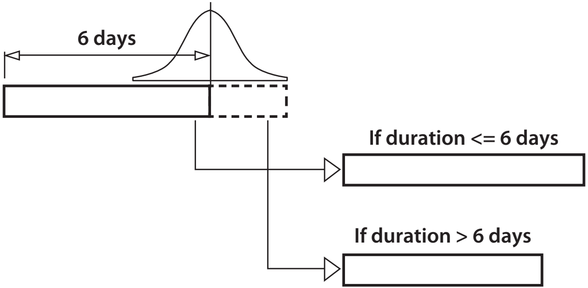


Figure 16-6. Conditional Branching

Figure 17-1. Tesla Model 3 (Photo by Smnt)

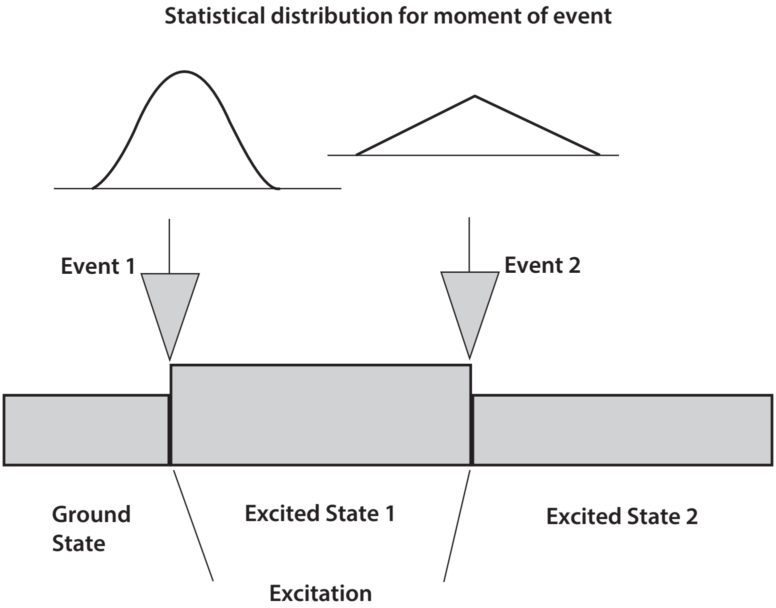


Figure 17-2. Moment of a Single Event

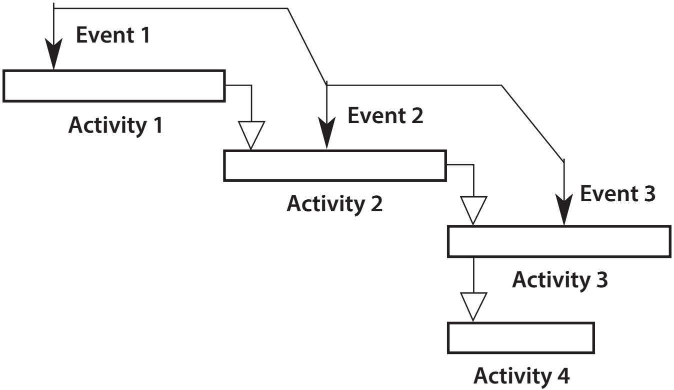


Figure 17-3. Connected Events Forming a Chain

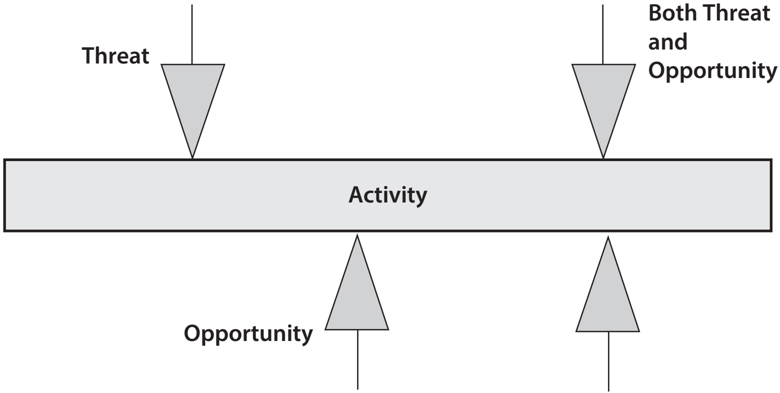


Figure 17-4. Threats and Opportunities

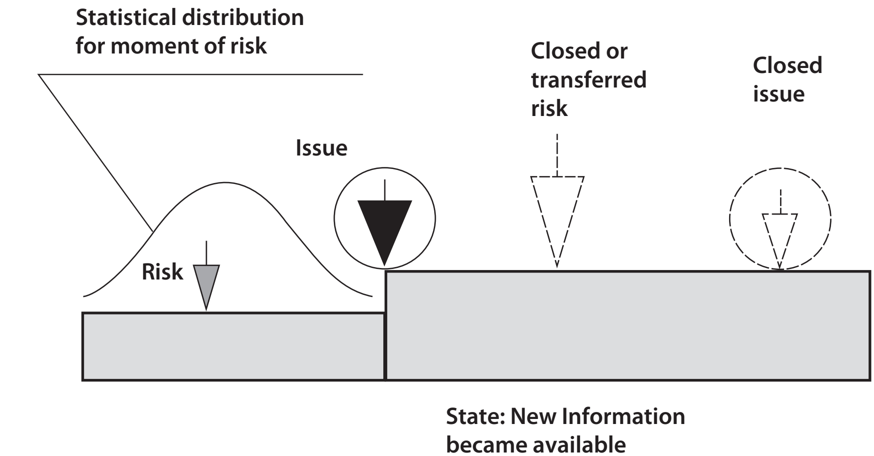


Figure 17-5. Risks, Issues, Transferred Risk

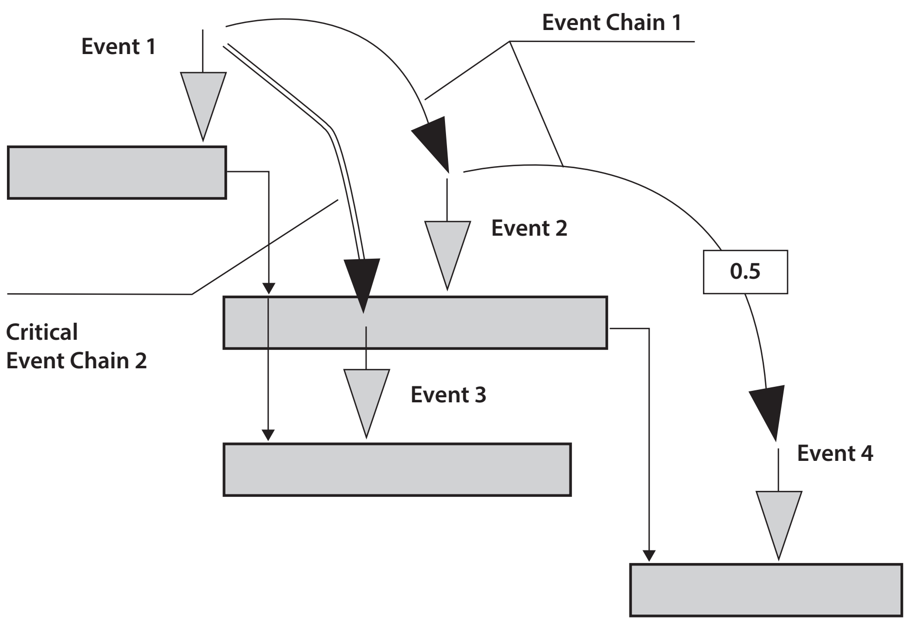


Figure 17-6. Event Chains

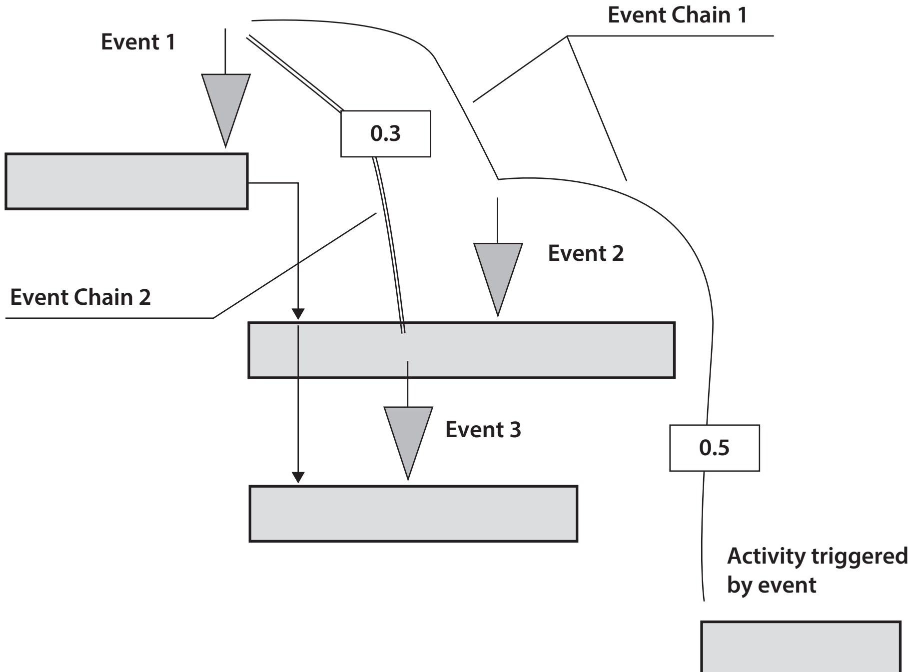


Figure 17-7. Activity Triggered by Event Chain

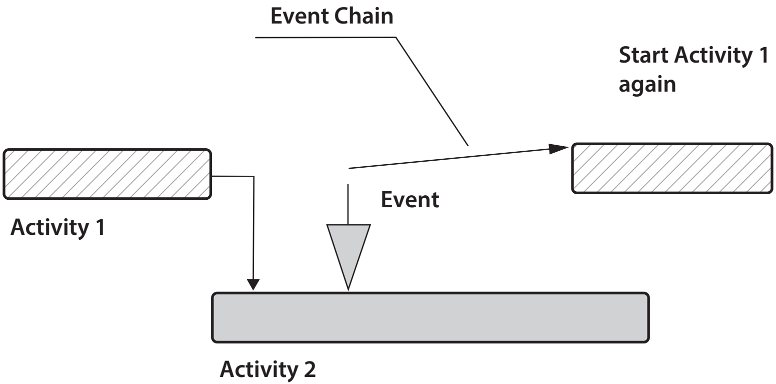


Figure 17-8. Repeated Activity

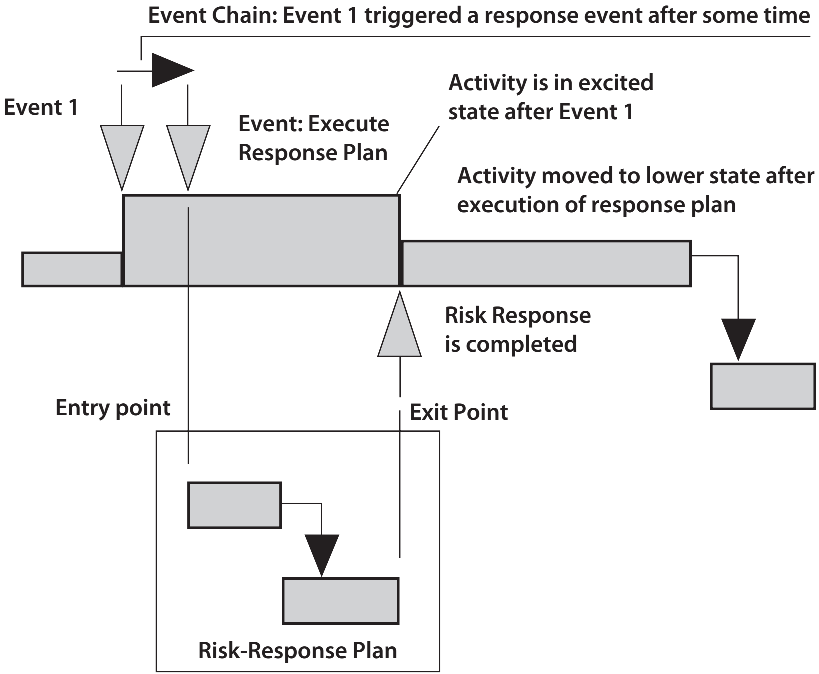


Figure 17-9. Execution of Response Plan

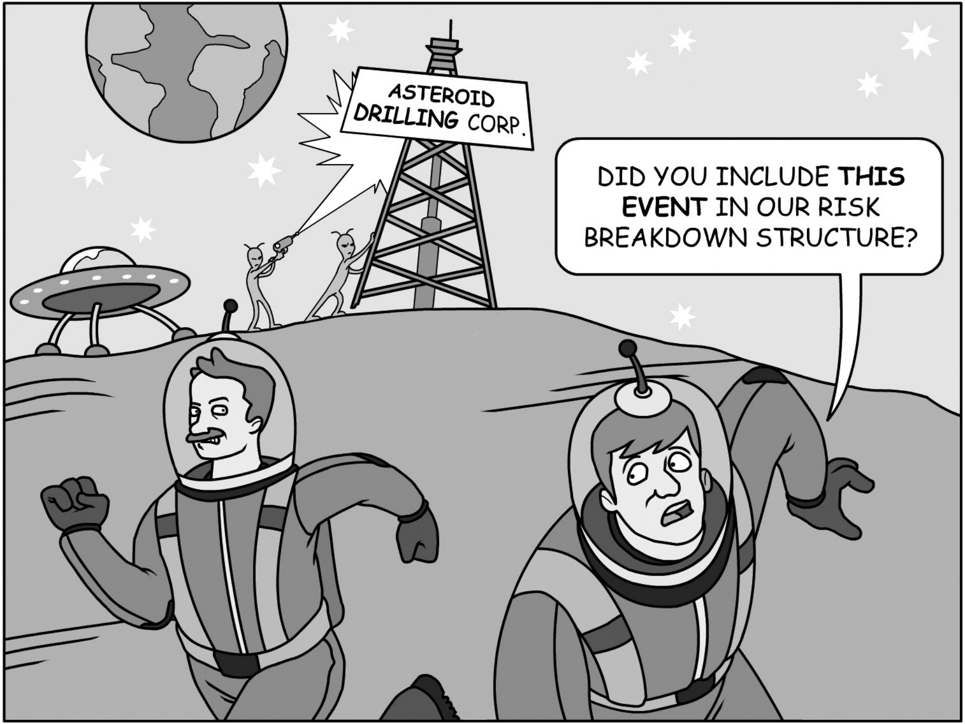


Figure 17-10. How Long Will It Take to Drill a Hole in the Asteroid?

Table 17-1. Risks Associated with Drilling into an Asteroid

	Risk	Probability	Impact
1	Problem with landing on the asteroid or delay with finding a drilling site	20% 40%	Delay of 4 hours Delay of 2 hours
2	Problem with drilling in unknown geological conditions	25%	Restart drilling

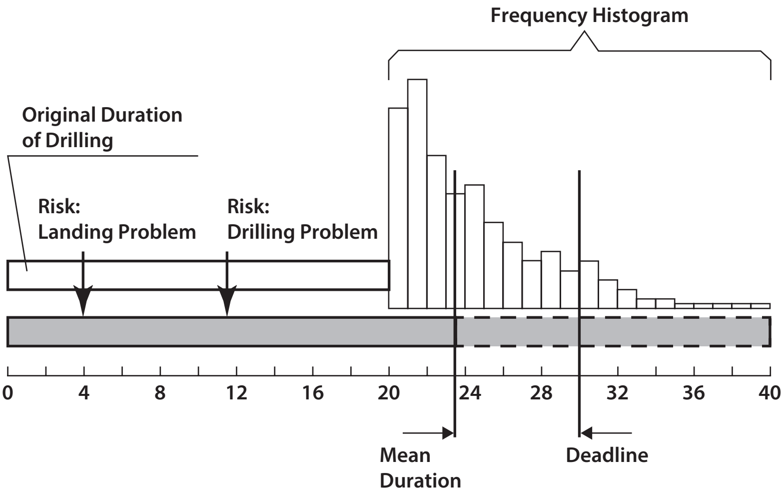


Figure 17-11. Project: Drilling a Hole in the Asteroid

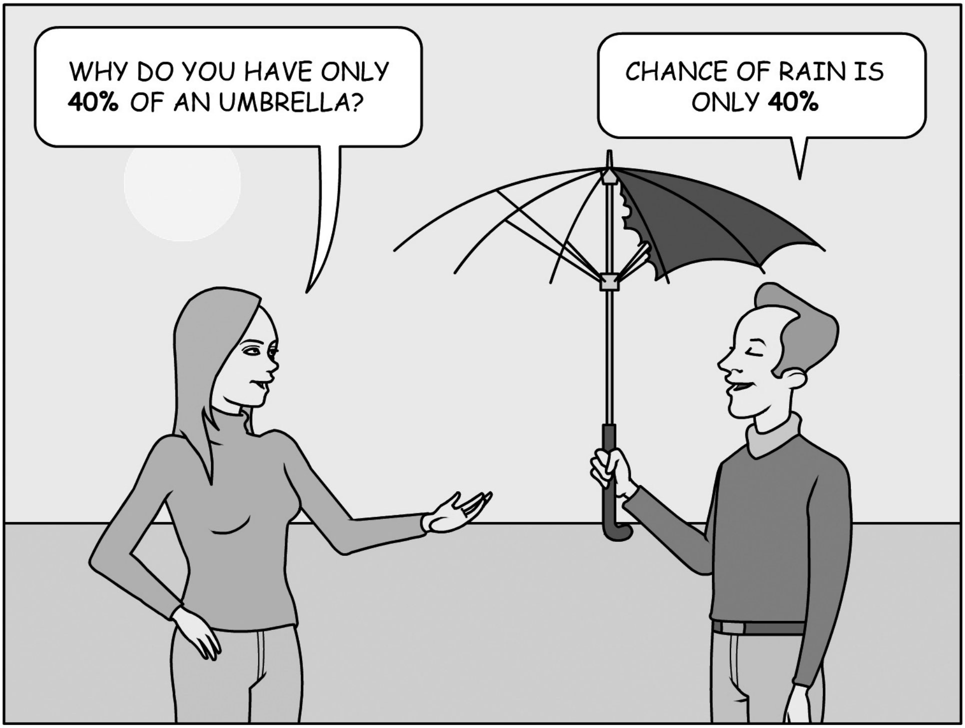


Figure 18-1. What Is the Probability of Rain?

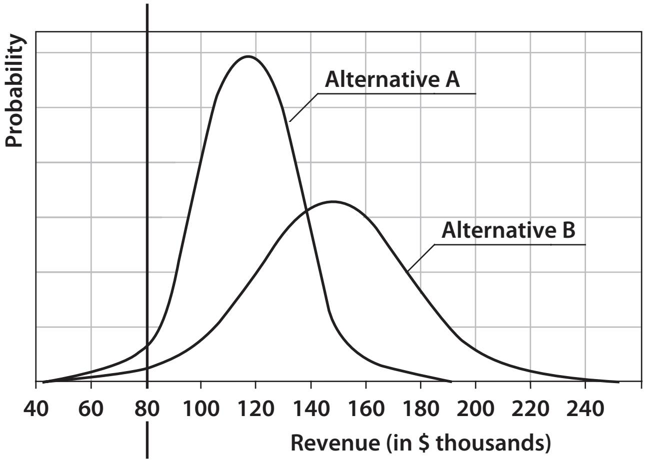


Figure 18-2. Comparison of Two Project Alternatives

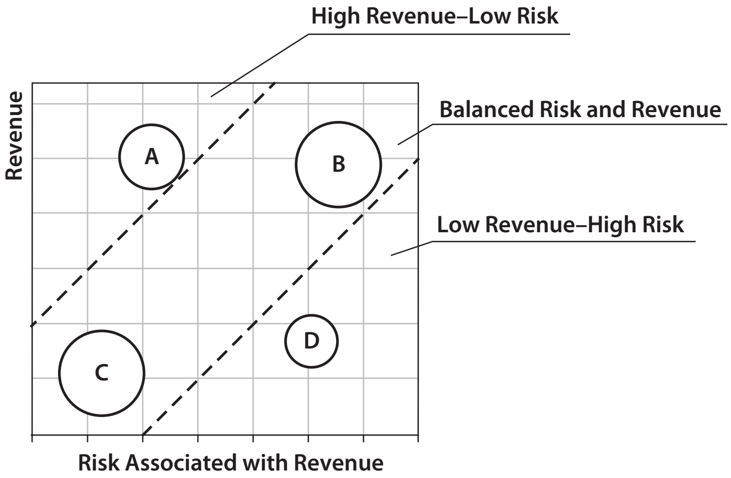


Figure 18-3. Risk vs. Return Chart

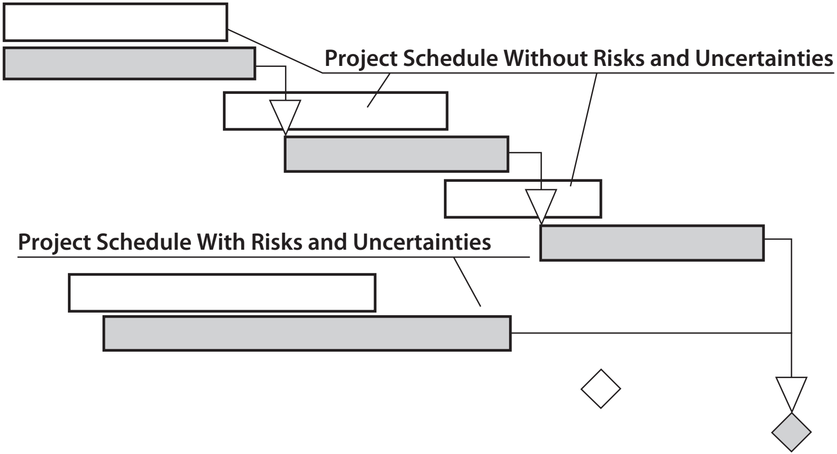


Figure 18-4. Gantt Chart that Combines Schedules with and without Risks

Table 18-1. Example of the Report Table: Comparison of Revenue for Two Projects

	Project A	**Project B**
Deterministic (no risks and uncertainties)	$100,000	$120,000
With risks (low estimate)	$70,000	$100,000
With risks (mean)	$115,000	$150,000
With risks (high estimate)	$150,000	$200,000

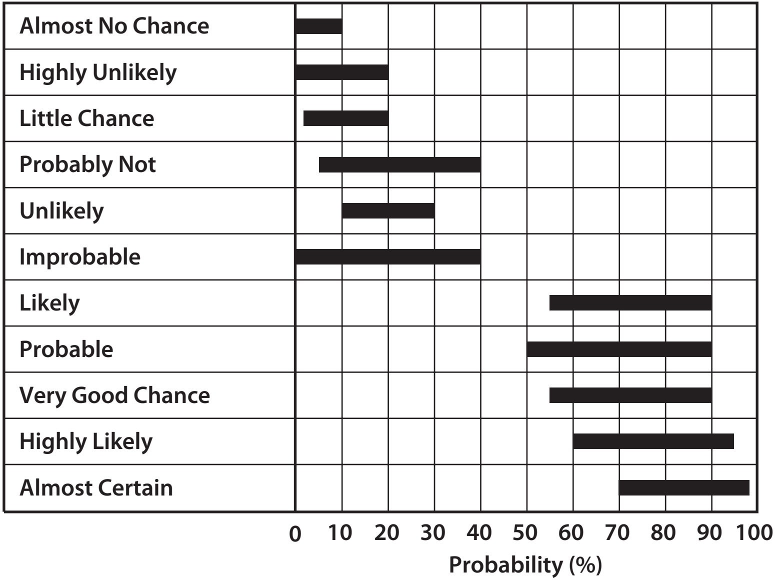


Figure 18-5. Perception of Verbal Definition of Uncertainty

Table 19-1. Decision-Making Criteria and Their Relative Weights

	Criterion	Importance	Weight
1	Cost	Very important	10
2	Quality	Very important	10
3	Safety	Very important	10
4	Low maintenance	Important	6
5	Community relationship	Not very important	3
6	Customer satisfaction	Not very important	3

Table 19-2. Score Calculation for Two Alternatives

			Alternative A		Alternative B	
	Criterion	**Weight**	**Rating**	**Score**	**Rating**	**Score**
1	Cost	10	0.5	$0.5 \times 10 = 5.0$	0.1	$0.1 \times 10 = 1.0$
2	Quality	10	0.5	$0.5 \times 10 = 5.0$	1.0	$1.0 \times 10 = 10.0$
3	Safety	10	1.0	$1.0 \times 10 = 10.0$	0.8	$0.8 \times 10 = 8.0$
4	Low maintenance	6	0.2	$6 \times 0.2 = 1.2$	0.2	$6 \times 0.2 = 1.2$
5	Community relationship	3	0.5	$3 \times 0.5 = 1.5$	0.5	$3 \times 0.5 = 1.5$
6	Customer satisfaction	3	1.0	$1.0 \times 3 = 3.0$	0.8	$0.8 \times 3 = 2.4$
	Total Score			25.7		24.1

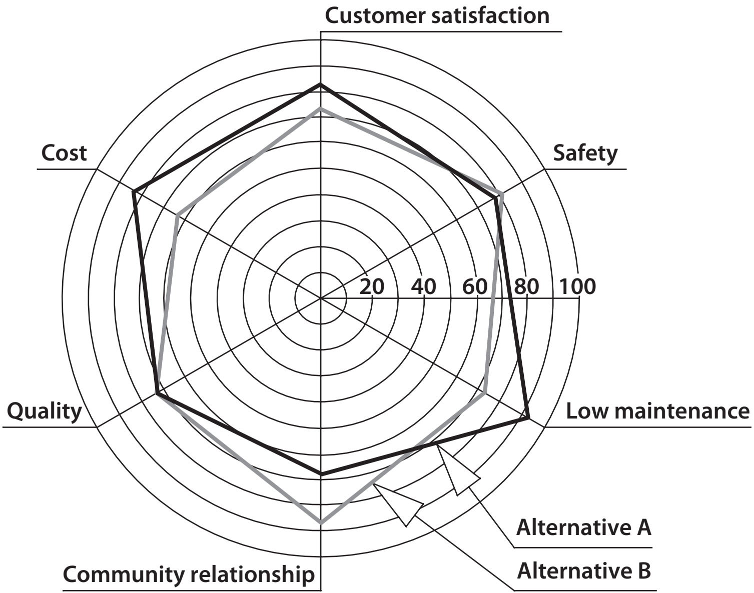


Figure 19-1. Radar Chart Used to Compare Strategies against Multiple Objectives

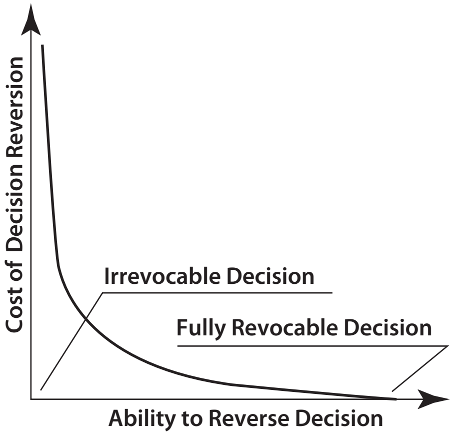


Figure 20-1. Cost of Decision Reversal

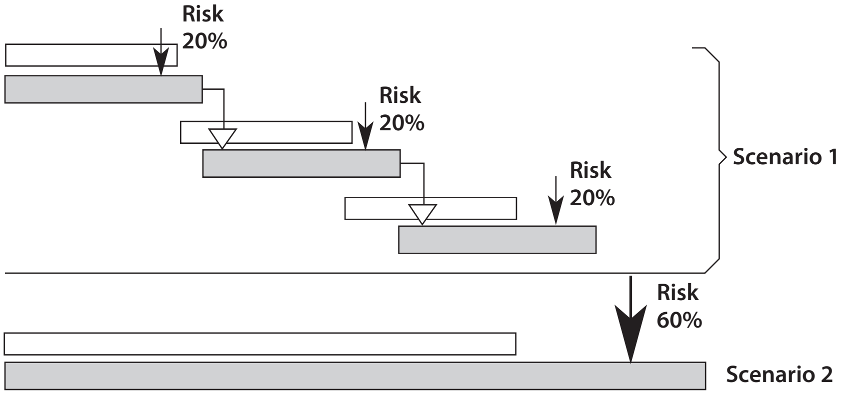


Figure 20-2. Quantitative Analysis of Two Project Scenarios

Table 20-1. Results of Quantitative Analysis: Duration of Project in Days

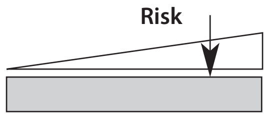
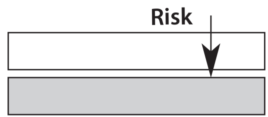
	Risk most likely occurs at the end of the activity (triangular distribution for moment of risk) 			**Risk most likely occurs at the end of the activity (triangular distribution for moment of risk)** 		
	Low Estimate (P10)	Mean	High Estimate (P90)	Low Estimate (P10)	Mean	High Estimate (P90)
Scenario 1: 3 tasks, 20 days each	60	68	80	60	66	78
Scenario 2: 1 task, 60 days	60	84	115	60	78	110

Figure 21-1. Flooding in Northwest New Orleans and Metairie after Hurricane Katrina (Credit: U.S. Coast Guard, 2005)

Figure Concl. Aerial View of ITER Site in 2018 (Credit: Oak Ridge National Laboratory, 2018)

Appendix A: Risk and Decision Analysis Software

The following risk and decision analysis software products widely used in project management can help you implement the processes described in this book. Please note that we did not perform detailed evaluations of each software and therefore cannot make specific recommendations. Each product has its unique set of the features, and every customer has its unique set of requirements. We also do not guarantee that this list is comprehensive, as we did not include all available software.

All software within a category is listed in alphabetical order.

Quantitative Project Risk Analysis Software

	Software	**Company**	**Comment**
1	Deltek Acumen Risk	Deltek www.deltek.com	Monte Carlo cost and schedule risk analysis; includes risk register and integration with other scheduling software
2	Full Monte	Barbecana www.barbecana.com	Monte Carlo cost and schedule risk analysis for Microsoft Project and Oracle® Primavera
3	Primavera Risk Analysis	Oracle www.oracle.com	Monte Carlo cost and schedule risk analysis for OraclePrimavera
4	RiskyProject	Intaver Institute www.intaver.com	Monte Carlo risk analysis; includes advanced risk register and integration with other scheduling software

(*cont.*)

(*continued*)

	Software	Company	Comment
5	Safran Risk	Safran www.safran.com	Monte Carlo cost and schedule risk analysis; includes risk register and integration with other scheduling software
6	Tamara	Vose Software www.vosesoftware.com	Monte Carlo cost and schedule risk analysis

Enterprise Risk Management Software

	Software	Company	Comment
1	Active Risk	Sword Active Risk www.sword-activerisk.com	Comprehensive enterprise risk management focused on project risk management
2	BWISE	Bwise www.bwise.com	General purpose enterprise risk management
3	Enablon	Wolters Kluwer www.enablon.com	General purpose enterprise risk management
4	ETQ Enterprise Risk Management	ETQ www.etq.com	General purpose enterprise risk management
5	Intelex Enterprise Risk Management	Intelex www.intelex.com	General purpose enterprise risk management
6	IRIS Intelligence	IRIS Intelligence www.irisintelligence.com	Enterprise risk management focused on project risk management
7	LogicManager Enterprise Risk Management	LogicManager www.logicmanager.com	General purpose enterprise risk management
8	MetricStream Enterprise Risk Management	MetricStream www.metricstream.com	General purpose enterprise risk management
9	Resolver Enterprise Risk Management	Resolver www.resolver.com	General purpose enterprise risk management
10	RiskyProject Enterprise	Intaver Institute www.intaver.com	Enterprise project risk management; includes project scheduling, plus advanced quantitative and qualitative risk analysis

Other Decision and Risk Analysis Software Used in Project Management

	Software	Company	Comment
1	@RISK	Palisade www.palisade.com	Monte Carlo simulation to Microsoft® Excel. Can be used for project management, as well
2	Analytica	Lumina Decision Systems www.lumina.com	Visual tool for creating, analyzing, and communicating decision models; created using influence diagrams.
3	CrystalBall	Oracle www.oracle.com	Monte Carlo simulation software for Excel
4	Decision Frameware	Decision Frameworks www.decisionframeworks.com	Set of decision analysis software tools
5	DPL	Syncopation Software www.syncopation.com	Desktop tool for decisions; includes influence diagrams, decision tree analysis, Monte Carlo simulation, and sensitivity analysis
6	SmartOrg	www.smartorg.com	Modeling, evaluating, forecasting, and managing the business opportunities in projects and portfolios
7	TreeAge	TreeAge Software www.treeage.com	Decision tree and influence diagram, sensitivity analysis, Bayes's revision, Monte Carlo simulation, and multi-attribute analysis

Appendix B: Heuristics and Biases in Project Management

The following is not a comprehensive list, although it does include the most relevant heuristics and biases that apply to project management. Some psychological effects mentioned in this book, such as the creativity block, are not included, to avoid repetition. If you glance through the list from time to time, that will refresh your memory and give you some ideas about how you should think while you manage your projects.

The discipline of psychology helps us look at our actions from a fresh point of view. When we showed this list to managers who were not familiar with cognitive biases, most recognized the mental pitfalls that had tripped them up in the past. We hope this list will help you avoid some of these pitfalls.

It is difficult to come up with definitive classifications for heuristics and biases in project management. Many biases are related to each other and may affect our behavior in various ways. Nevertheless, we have grouped all the biases into a few logical categories. Within each category, the biases are presented in alphabetical order. Note that a few fundamental psychological concepts, such as selection perception, and some heuristics have a number of biases associated with them.

Behavioral Biases and Biases Related to Perception

Ascription of Causality—The tendency to ascribe causation even when the evidence suggests only correlation. Managers may think that a project succeeded because they created and managed a risk list. Correlations between a project's success rate and the presence of a risk list are not enough to conclude that a risk list led to the positive result.

Bias Blind Spot—The tendency not to see your own cognitive biases (Pronin et al. 2002). Even if people know their own cognitive biases, they do not invariably compensate for them. Knowledge of this bias is important for both project management training and education.

Biased Covariation Assessment—The tendency not to examine all the possible outcomes when making a judgment regarding a correlation or an association. We may focus on only one or two possibilities, while ignoring the rest. This bias affects a project manager's ability to analyze correlation and causation in a project.

Choice-Supportive Bias—The tendency to remember positive attributes as having been part of the chosen option rather than of the rejected option. For example, research participants were asked to make a choice between two options. Later, in a memory test, participants were given a list of positive and negative features. Positive features were more likely to be attributed to the chosen option, while negative features were more likely to be attributed to the rejected option (Mather and Johnson 2000). This bias is related to the selection of project alternatives and reviews of the results of decision analysis.

Congruence Bias—A bias that occurs as a result of a decision-maker's reliance on direct testing of a given hypothesis while neglecting indirect testing. Hampered by this bias, decision-makers are often unable to consider alternative hypotheses. This bias is related to generation and evaluation of creative project alternatives.

Elimination-by-Aspect Heuristic—A heuristic in which people eliminate a potential choice from a plurality of choices if it does not satisfy certain conditions (Tversky 1972). It manifests itself when project managers select project alternatives based on multiple criteria.

Escalating Commitment—The tendency to invest resources in failing projects with a very small chance of recovery (McCray et al. 2002). This behavioral trap is related to the sunk-cost effect.

Experiential Limitations—Inability or unwillingness to look beyond the scope of past experiences or rejection of the unfamiliar. This bias serves as a creativity block that occurs when project managers may discard good ideas because they do not fit into a familiar pattern.

Failure to Consider Alternatives—A tendency to evaluate and consider only a single course of action. It occurs when project managers attempt to reduce efforts during the evaluation of alternatives. It is often the result of sufficient information about one particular suggested course of action along with insufficient information about alternatives. This bias is related to the congruence bias.

Focusing Effect—A bias that occurs when decision-makers place too much importance on a single aspect of an event or process. For example, a software project manager believes the software's quality is associated only with the number of software defects. In reality, though, the notion of software quality, along with the quality of the software code, involves the quality of the documentation, user interface, packaging, and support.

Hyperbolic Discounting—The tendency to prefer smaller payoffs to larger ones when the smaller payoffs come sooner in time than the larger. For instance, a project manager may prefer a $500,000 NPV project now to one with a $1 million NPV several years from now. However, given the choice of the same $500,000 NPV project five years from now and the $1 million NPV six years from now, most project managers would choose $1 million in six years.

Illusion of Control—The tendency of decision-makers to believe they can control or influence outcomes over which they in fact have no influence. For example, when rolling dice in craps, people tend to throw stronger for high numbers and softer for low numbers. Similarly, sometimes project managers plan projects under the assumption that they can control most processes, which in reality they cannot.

Impact Bias—The tendency of a decision-maker to believe that if a negative event occurs, it takes longer to recover emotionally from the event than it actually does. In project management this is related to the analysis of risk impacts.

Inconsistency—The inability or unwillingness to apply the same decision criteria in similar situations. Consistency is one of the fundamental principles of the project decision analysis process.

Inertia—An unwillingness to change thought patterns that we have used in the past, when faced with new circumstances. Project managers often follow the same practices in a new environment, such as project size, industry, organizational structure, and so on. In many cases, this can be inappropriate and may lead to problems.

Information Bias—The tendency to seek information even when it cannot possibly affect a decision. In organizations, management sometimes requires more reports and analysis than strictly necessary. Value-of-information analysis will help to mitigate a negative effect of this bias.

Invisible Correlations—The inability to see correlations because they are not expected to be related. In project management, this inability is often related to a correlation between an individual's motivation, beliefs, experience, and preferences and the ultimate project results.

Lexicographic Heuristic—The tendency of people to apply the following process to make a choice between alternatives strategies: (a) rank the order attributes; (b) select the option rated highest on the most important attribute; (c) if a tie, go to the next attribute (Tversky 1969). This heuristic is called lexicographic because a similar algorithm is used to order words in dictionaries. The heuristic manifests itself when project managers select project alternatives based on multiple criteria.

Omission Bias—The tendency to judge potentially harmful actions as worse than equally harmful inactions (omissions). Project managers may believe that new product development is riskier than continuing to maintain an existing product that is losing sales, even if the costs of both project alternatives are the same.

Outcome Bias—The tendency to evaluate a decision by its final outcome instead of the quality of the decision at the time it was made. If a decision results in a negative outcome, this does not mean that decision was wrong, because the decision was made based on the best possible information at the time. This bias manifests itself in the review of project decisions.

Planning Fallacy—The tendency to underestimate the duration of project activities. Project managers may eliminate factors that they perceive are not related to the project. Moreover, they may discount multiple improbable high-impact risks because each one is so unlikely to happen. The planning fallacy is one of the fundamental biases related to estimations in project management.

Post-Purchase Rationalization—A bias that occurs when people have invested a lot of time, money, or effort in something and try to convince themselves that the expenditure must have been worth it. It may affect the analysis of projects during reviews.

Prospect-Theory-Related Biases:

- **Endowment Effect**—The tendency of decision-makers to place a higher value on objects they own than on objects they do not. It explains why people rarely exchange a product they have already purchased for a better product. It can manifest in project management in choices related to replacing existing products, tools, and services (Kahneman et al. 1990).
- **Loss Aversion**—The tendency of decision-makers to prefer avoiding losses versus acquiring gains. In project management this bias is associated with risk aversion and risk tolerance which may occur when decision-makers evaluate possible project gains and loses.
- **Pseudocertainty Effect**—The inclination to make risk-averse choices if the expected outcome is positive, but to make risk-seeking choices to avoid negative outcomes (Tversky and Kahneman 1981; Slovic et al. 1982). Actual choices can be affected by simply reframing the descriptions of the outcomes. Project managers will prefer to take a risk and buy a component if they receive a free unit for every three purchased instead of buying all four components with a 25% discount.

- **Zero-Risk Bias—**The preference for reducing a small risk to zero over a greater reduction in a larger risk. Individuals may prefer small benefits that are certain to large ones that are uncertain. Project managers sometimes prefer to avoid a small risk completely rather than significantly mitigate a larger one.

Recognition Heuristic—When making a judgment between two items when only one of the items is recognized, the recognized item will be considered to have a higher criterion value (Goldstein and Gigerenzer 1999). This heuristic manifests itself when project managers select project alternatives based on multiple criteria.

Repetition Bias—A willingness to believe what we have been told most often and by the greatest number of different sources. Repetition bias is related to the exposure-memory effect and can lead to wrong assessments of business situations in project management.

Selective Perception—The tendency for expectations to affect perception. Sometimes selective perception is referred to as "What I see is what I want to see." These are several biases related to selective perception:

- **Confirmation Bias—**The tendency of decision-makers to seek out and assign more weight to evidence that confirms a hypothesis, and to ignore or give less weight to evidence that could discount the hypothesis. This can lead to statistical errors. This bias is related to estimations and evaluations of alternatives in project management.
- **Disconfirmation Bias—**The tendency for decision-makers to extend critical scrutiny to information that contradicts their prior beliefs (Lord et al. 1979). This bias is also related to the confirmation bias.
- **Premature Termination of Search for Evidence—**The tendency to accept the first alternative that looks as if it might work.
- **Professional Viewpoint Effect—**The tendency to look at things according to the conventions of a decision-maker's profession, forgetting any broader point of view. For example, project management professionals may not fully apply methodologies and tools that originated from operations research.
- **Selective Search of Evidence—**The tendency to gather facts that support certain conclusions while disregarding other facts that support different conclusions.

Similarity Heuristic—Relates to how people make judgments based on similarity. Thinking by similarity is one of the fundamental mental strategies of project managers, who usually analyze project issues by comparing them with previously corrected problems. Over time, a project manager's past experiences will allow his or her use of the similarity heuristic to be highly effective, quickly choosing the corrective actions that will likely reveal the problem's source. Similar approaches are used by software programmers, doctors, police investigators, and other professionals.

Source Credibility Bias—The tendency to reject information if a bias exists against the person, organization, or group that is the source of the information. The opposite effect is the tendency to accept information uncritically from trusted sources. In project management this can lead to a sampling bias, when too much faith is placed in certain information while other information is rejected (Skinner 2009).

Status Quo Bias—The inclination of decision-makers to prefer that things stay relatively the same (Samuelson and Zeckhauser 1988). This bias is similar to the omission bias and is related to the endowment effect. It explains why ineffective project management procedures often are not changed and why outdated technology is not replaced.

Student Syndrome—The tendency of people to wait until a deadline is near to start to fully apply themselves to a task (Goldratt 2002). The bias is named after the way many students tend to put off doing their papers until the night before they are due. The bias is related to estimation of project activity duration. A similar effect is Parkinson's Law, which states that the demand upon a resource always expands to match the supply of the resource (Parkinson 2018). Particularly, work expands to fill the time available for its completion. It is also strongly related to procrastination.

Sunk-Cost Effect—The tendency to make a choice considering the cost that has already been incurred and cannot be recovered (sunk cost). Sunk costs affect the decisions made due to the loss-aversion effect. Sunk costs may cause cost overruns and may also lead to investment in a project that now has no value. This effect is related to the escalating commitment bias.

Wishful Thinking—The formation of beliefs and decision-making according to what might be pleasing to imagine instead of by appealing to evidence or applying rationality. For example, a project manager often makes estimates based on positive results he or she wants to achieve instead of what is possible to achieve. Wishful thinking is related to the optimism bias.

Biases in Estimation of Probability and Belief

Ambiguity Effect—The tendency to prefer options with known probabilities and to avoid options in which missing information makes the probability seem unknown. In project management is it important to collect information for all selected alternatives.

Anchoring Heuristic—The tendency to rely on one trait or piece of information when making decisions. The following are biases related to the anchoring heuristic:

- **Insufficient Adjustment**—The tendency of decision-makers to "anchor" on a current value and make insufficient adjustments for future effects. In project management this bias often manifests itself in the estimation of uncertainties. A project manager frequently does not allow for sufficient adjustment after making three-point estimates of an activity's duration or cost.
- **Overconfidence in Estimation of Probabilities**—A tendency to provide overly optimistic estimates of uncertain events. Decision-makers tend to set the ranges of probability too low and to remain overconfident that these ranges will include true values. Overconfidence is most likely after a series of project successes, and it can lead to risk-taking.
- **Overestimating the Probability of Conjunctive Events**—If an event is composed of a number of elementary events, the probability of the elementary events should be multiplied to come up with the probability of a main event. For example, say the probability of task completion is 80%. If the project consists of three tasks, the probability of project completion will be ($0.8 \times 0.8 \times 0.8$), or 51.2%. People tend to overestimate the probability of the main event because the probability of elementary events serves as an anchor.

Availability Heuristic—The tendency to make judgments about the probability of events' occurring by how easily these events are brought to mind. The following are biases related to the availability heuristic:

- **Illusory Correlations**—The tendency to overestimate the frequency with which two events occur together. In project management the bias manifests itself in the analysis of relationships between two or more parameters—for example, whether the geographic location of a supplier is related to the quality of its products.
- **Vividness**—The tendency of people to recall events that are unusual or rare, vivid, or associated with other events such as major issues, successes, or failures. As a result, assessment of probabilities for project risks can be wrong.

Optimism Bias—The tendency to be overly optimistic about the outcome of planned actions. This bias manifests itself in project planning and forecasting. Project managers often overestimate the probability of successful project completion and underestimate the probability of negative events. The optimism bias is also related to wishful thinking.

Representativeness Heuristic—A heuristic according to which people estimate probability by judging how representative the object, person, or event is of a certain category, group, or process. The following are biases related to the representativeness heuristic:

- **Conjunction Fallacy**—An unwanted appeal to more detailed scenarios. This fallacy can lead to a "preference for details." If, for example, a project manager must select one project from a number of proposals, he or she may tend to pick those proposals with the most detail, even though they may not have the best chance of success.
- **Gambler's Fallacy**—The belief that a successful outcome is due after a run of bad luck (Tversky and Kahneman 1971). In project management, corrective actions as a response to certain issues and problems are often not taken because project managers believe that the situation will improve itself.
- **Ignoring Base-Rate Frequencies**—The tendency of people to ignore prior statistical information (base-rate frequencies) when making assessments about probabilities. In project management this bias can manifest itself in the estimation of probabilities and forecasting. For example, what is the probability that a new component from a supplier is defective? Project managers can make estimates based on recent testing where most components were defective. However, they may ignore the fact that historically 99% of the components from this supplier have been problem-free.
- **Ignoring Regression to Mean**—The tendency to expect extreme events to be followed by similar extreme events. In reality, extreme events most likely will be followed either by an extreme in the opposite way or by an average event. Project managers should not expect extraordinary performances from a team or individuals for every project because of the regression to mean, or the tendency to be average.

Memory Biases and Effects

Context Effect—Memory is dependent on context of the environment. Out-of-context memories are more difficult to retrieve than in-context memories. For example, the recall time and accuracy for a project-related memory will be lower when a manager is at home, and vice versa.

Exposure Effect—People can express an undue liking for things merely because they are familiar with them. The more often we read about a certain method or principle, the more we like it. This effect is used in the advertisement industry. For example, a project manager may like certain project management software just because it is advertised more often in an industry journal.

False Memory—A memory of an event that did not happen or a distortion of an event that did occur, as influenced by externally corroborated facts. Often, project managers simply forget important information and lessons learned.

Generation Effect—People will recall information better if it is generated rather than simply read. If a project manager experienced a certain issue and actually dealt with it, he or she will remember it better than if he or she merely read about it. The generation effect can be a strategy for learning.

Hindsight Bias (the "I Knew It All Along" effect)—The tendency to see past events as being more predictable than they actually were. The possible explanation of this bias is that events that actually occur are easier to recall than possible outcomes that did not occur. This bias manifests in the review of project decisions.

Misinformation Effect—A memory bias that occurs when misinformation affects people's reports of their own memory. If people read an inaccurate report about a project and are asked to recall their own experience about the project, the report will distort their memory about the project (Roediger et al. 2001).

Peak-End Rule—The heuristic according to which people judge their past experiences almost entirely on how they were experienced at their peak (pleasant or unpleasant) and how they ended. Other information is discarded, including net pleasantness or unpleasantness and how long the experience lasted. In project management this heuristic is important in project reviews because project stakeholders may not remember all necessary project details (Kahneman et al. 1999).

Picture Superiority Effect—Concepts and ideas are more likely to be remembered if they are presented as images rather than as words (Paivio 1971; 2006). This effect is important for presentation and interpretation of project information, as for example in the results of project decision analysis.

Zeigarnik Effect—Project managers may remember tasks in progress better than recently completed ones (Zeigarnik 1967).

Social and Group Biases

Attribution Biases—Biases that affect attribution, or the way we determine who or what was responsible for an event or action. Understanding of attribution biases is important for project human resource management. Attribution biases include:

- **Egocentric Bias**—The tendency of people to claim more responsibility for the results of a joint action than an outside observer would.
- **False Consensus Effect**—The tendency of decision-makers to overestimate the degree to which others agree with them. If members of a

group reach a consensus and it is not disputed, they tend to believe that everybody thinks the same way. Therefore, if nobody expresses a contrary opinion in a team meeting, project managers will believe that everybody agrees on the course of action.

- **Fundamental Attribution Error** (also called the Correspondence Bias or Overattribution Effect)—The tendency of people to overemphasize personality-based explanations for behaviors observed in others while underemphasizing the role and power of situational influences on the same behavior. People tend to judge what a person does based more on what "kind" of person he or she is than on the social and environmental forces at work on that person.
- **Outgroup Homogeneity Bias**—People see members of their own group as being relatively more varied than members of other groups.
- **Self-Fulfilling Prophecy**—A prediction that, once made, actually causes itself to become true. In other words, a false statement may lead people to take actions that will ultimately result in fulfillment of the prophecy. For example, a project manager expresses a concern that resources are not sufficient for the project. When resources are not given to him, he perceives all problems with the project as a result of limited resources. In J. K. Rowling's novel *Harry Potter and the Order of the Phoenix,* a prophecy was made shortly before Harry's birth that the one with the power to destroy Voldemort would be born shortly. To protect himself, Voldemort attempted to kill Harry while he was an infant, but his curse backfired on him, transferring some of his powers to Harry. In fact, this power transfer is a response to the prophecy. The prophecy was only "true" because Voldemort believed it.
- **Self-Serving Bias**—The tendency to claim responsibility for successes rather than failures. The self-serving bias results in the better-than-average effect and also in overconfidence. For example, project managers of a successfully completed project might say, "I did it because I am highly experienced." Project managers of a failed project might say, "The clients did not provide good specifications, and we did not have the necessary resources."
- **Trait-Ascription Bias**—The tendency of people to view themselves as relatively variable in terms of emotion, personality, and behavior while viewing others as much more predictable. This may be because people are able to observe and understand themselves better than others. This bias may lead to stereotypes and prejudice. The bias manifests itself in project team communication. This bias is similar to outgroup homogeneity bias on the group level.

Bandwagon Effect (Groupthink)—The tendency to do (or believe) things because many other people do (or believe) the same. The effect manifests itself in project teams when project managers and team members feel reluctant to express different points of view.

Ingroup Bias—The tendency of people to give preferential treatment to people they perceive to be members of their own groups, even if the group they share is random or arbitrary (such as having the same birthday). Ingroup bias is an important factor related to communication within project teams.

Polarization Effect—The tendency for group discussions to lead to amplified preferences or inclinations of group members. If a project team member already has an opinion about a certain issue (e.g., new product design), as a result of the meeting he or she may hold a much stronger opinion about this issue. People on both sides can move farther apart, or polarize, when they are presented with the same mixed evidence.

Appendix C: Risk Templates

Generic Risk Template #1

This is the basic set of risks in this Risk Breakdown Structure, adopted from the *PMBOK Guide* (Project Management Institute 2018). We recommend using as a very generic risk template when you identify risks in all types of projects.

Risk	Examined
Technical	
Requirements	☐
Technology	☐
Complexity and interfaces	☐
Performance and reliability	☐
Quality	☐
Safety	☐
External	
Subcontractor	☐
Components	☐
Legal and regulatory environment	☐
Market	☐
Customer relationship	☐
Site specific issues	☐
Weather and other environmental factors	☐
Organizational	
Project dependencies	☐

(*cont.*)

(*continued*)

Risk	Examined
Resources	
Personnel resources	☐
Material resources	☐
Funding	☐
Prioritization	☐
Project Management	
Estimating	☐
Planning	☐
Controlling	☐
Communication	☐

Generic Risk Template #2

Here is another generic risk template, which has separate external and internal issues. It can be useful for construction projects where external issues play very big role.

Risk	Examined
External	
Environment	
Weather	☐
Natural environment	☐
Site specific issues such as facility and infrastructure availability	☐
Local services and support	☐
Political environment	☐
Legal environment	☐
Community and social environment	☐
Cultural environment	☐
Market	
Competition	☐
Demand	☐

(*cont.*)

(*continued*)

Risk	**Examined**
Labor conditions such as labor cost and availability	☐
Material and fuel cost, quality, and availability	☐
Financial conditions such as interest rates and inflation	☐
Vendor and supplies availability	☐
Seasonal and cyclical factors affecting the market	☐
Internal	
Organization	☐
Organizational culture	☐
Decision profile including attitude toward risk	☐
Organizational experience in the project area	☐
Overall organizational stability, including financial situation	☐
Organizational structure	☐
Organizational ownership and management	☐
Organizational performance related to particular projects	☐
Public relationship	☐
Labor relationship	☐
Vendor/Subcontractor Relationship	
Quality of supplies and materials	☐
Issues related to delivery, installation, and implementation of supplies and materials	☐
Subcontractor relationship	☐
Acquisition and procurement process maturity	☐
Customer Relationship	
Level of requirement definition	☐
Requirement uncertainties	☐
Requirement complexity	☐
Level of customer involvement	☐

(*cont.*)

(*continued*)

Risk	Examined
Technology	
Technology availability and maturity	☐
Technology limits	☐
Technology complexity	☐
Resources (Personnel)	
Personnel skill set	☐
Personnel performance	☐
Personnel experience for specific project	☐
Personnel availability, including availability of business experts	☐
Project Management	
Project management process maturity	☐
Project manager experience	☐
Issues related to project schedule development	☐
Issues related to estimation of project activities	☐
Issues related to project scope definition	☐
Quality and Safety	
Overall quality objectives	☐
Issues related to quality standards	☐
Safety policy, standards, and procedures	☐

Risk Template for Software Development Project

Here is another risk template, which can be useful for IT related projects, particularly for the software development projects. Risk categories in this template are associated with Rational Unified Process workflows (Kruchten 2003).

Risk	Examined
Business Modeling and Requirements	
Clear business objectives	☐
Requirements gathering	☐

(*cont.*)

(*continued*)

Risk	Examined
Requirements review	☐
Requirements changes	☐
Requirements acceptance	☐
Contract	☐
Analysis and Design	
Architecture	☐
Technology capability	☐
New technology	☐
Requirements interpretation and analysis	☐
Design	☐
Implementation	
Coding	☐
Unit testing	☐
Integration	☐
Modification	☐
Quality Control	
Evaluation	☐
Testing	☐
Acceptance testing by the client	☐
Deployment and Maintenance	
Deployment	☐
Maintenance	☐
Installation and packaging	☐
Upgrade and growth	☐
Configuration and Change Management	
Configuration management, including build process	☐
Change management process	☐
Changing scope or objectives	☐

(*cont.*)

(*continued*)

Risk	Examined
Project Management	
Project management process maturity	☐
Senior management commitment	☐
Client involvement	☐
Technical performance	☐
Cost management	☐
Environment	
Development environment	
Software and tools	☐
Hardware	☐
Organizational environment	
Management skills	☐
Organizational stability	☐
Organizational experience in the particular project	☐
External relationship	☐
Subcontracting and outsourcing	☐
Resources	
Resource availability	☐
Resource usage	☐
Resource performance	☐
Resource turnover	☐
Other environment	
Natural environment	☐
Site specific issues such facility and infrastructure availability	☐
Political and legal environment	☐
Community, cultural, and social environment	☐

Appendix D: Multi-Criteria Decision-Making Methodologies

This appendix lists some methods for multi-criteria decision-making that can be useful in project and portfolio management. These methods are employed mostly for selecting projects within a portfolio, as well as for making important project decisions. Each of these methods has its own strengths and weaknesses (see Linkov et al. 2006a).

Selecting methodologies and tools for multi-criteria decision-making should be part of the decision analysis process within your organization. It would be better to use this approach for many problems within a portfolio rather than for one particular problem. A number of off-the-shelf software tools can be used for the various methods. In particular, some methodologies are implemented as part of project portfolio management software.

Method	Short Description	References
Analytic Hierarchy Process (AHP)	• Develop a hierarchy that includes decision alternatives and criteria. • Perform pair-wise comparison to establish consistent priorities for different criteria. Input data for pairwise comparison is an expert judgment. • Calculate overall score for different alternatives and rank them according to score.	Anderson et al. 2015; Saaty and Vargas 2014
Goal Programming	A linear programming approach to multi-criteria decision problems whereby the objective function is designed to minimize deviation from goals	Anderson, et al. 2015; Schniederjans 2012
Multi-Attribute Utility Theory	1. Derive single-attribute functions for project parameters, such as project duration and cost. 2. Combine single-attribute utility functions to create multi-attribute utility function. 3. Perform consistency check to verify that multi-attribute utility function actually represents decision-maker's preferences.	Goodwin 2014; Keeney and Raiffa 1993
Simple Multi-Attribute Rating Technique (SMART)	1. Construct value trees, which represent decision-making criteria. 2. Define value functions, which represent relationships between criteria (e.g., project cost vs. project value). 3. Determine weights for all criteria. Compute overall value (score) for each alternative. 4. Perform sensitivity analysis to determine how sensitive value is to the selected weights.	Goodwin 2014