INTRODUCTION

Modeling is an approach that helps us develop a better understanding of business situations. As a result, it helps us make better decisions. Thus, we don’t view modeling as an end in itself, but rather, as part of a broader process. In this chapter, we discuss the roles modeling plays in that broader process. We refer to this broader process generically as a problem-solving process, although specific instances could involve making forecasts, evaluating business opportunities, or allocating resources.

Any successful problem-solving process begins with recognition of a problem and ends with implementation of a proposed solution. All the work that comes between these two points is the problem-solving process. In some cases, this process is highly structured and planned, perhaps involving a large team working over several months; in other cases, it is informal and unstructured, perhaps involving only one person for a couple of hours. Modeling is just one of many tools or strategies that can be used within problem solving. An effective problem solver knows when and how to use modeling effectively within the broader context of effective problem solving.

Modelers can play different roles in the problem-solving process. Primarily, these roles are:

- **End user**
- **Team member**
- **Independent consultant**

When the entire team consists of one person, then problem owner (or client) and modeler are one and the same. We refer to this role as the *end-user* modeler. The end user is often a small-business owner or an entrepreneur, who has no staff and no budget for consultants. In large firms, many managers are also end users at times, when there is no time to brief the staff or bring in consultants, or when the problem is too sensitive to share with anyone else. The end user carries out all of the activities in problem solving: identifying a problem worthy of attention, developing a model, using the model to develop insights and practical solutions, and implementing the results. There is an enormous untapped potential for end-user modeling, because there are so many relatively small problems for which modeling can provide insight, and because there are so many end users who have (or can acquire) the spreadsheet and modeling skills necessary to develop useful models.

In addition to the end-user role, modelers are often assigned to the role of **team member** on an internal committee or task force. In many cases, the problem-solving process may have begun before the committee was formed, and the modeler may or may not have been part of that process. Although chosen for expertise in modeling, the team-member modeler’s role also requires good interpersonal and communication skills. A critical part of the work is communicating with nonmodelers on the team about the assumptions that go into
the model and the intuition behind the model’s results. Of course, the team-member mod-
er must also have the necessary technical skills to apply modeling successfully, but com-
munication skills are more important than for the end-user modeler.

A third role for the modeler is that of independent consultant. This role differs from
the role of team member because there is usually a client—someone who identifies the
problem and ultimately manages the implementation of any solution. The role of consult-
ant modeler also requires great communication and interpersonal skills. Despite being an
organizational outsider, the consultant modeler must understand the client’s problem
deeply and translate the client’s understanding of the problem into modeling terms. This
role also requires the ability to translate model insights back into a language the client can
understand, so that the client can proceed with implementing a solution.

This chapter describes a widely used problem-solving process and the role that mod-
eling plays in this process. We then report on research into how expert modelers approach
their work, and we draw some lessons for good modeling practice. Finally, we discuss the
role that creativity plays in modeling and problem solving and various ways that teams
and individuals can enhance their creativity.

THE PROBLEM-SOLVING PROCESS

While problem solving is an almost universal aspect of life, very few individuals follow a
structured approach to it. This could indicate that effective problem solving is instinctive and
intuitive and that the only way to improve in this area is through experience. We do not, how-
ever, subscribe to this point of view. In our experience, some degree of conscious attention
to the process pays off in improved results and efficiency, even for experienced modelers and
managers. This is especially true for problem-solving teams, where intuitive methods often
fail because what is intuitive to one member makes no sense to another. While the end-user
modeler can perhaps get by with short cuts, team members and independent consultants are
more effective when they carefully manage the problem-solving process.

The problem-solving process is often described as a sequential, step-by-step proce-
dure. While this makes for easy description, there is, in fact, no simple plan that represents
the universal problem-solving process. Moreover, when people look back on their own
problem-solving activities, they tend to recall more structure than was really there. Thus,
a sequential description of problem solving should not be taken at face value. Even experts
appear to jump around from one aspect of a problem to another as they attempt to formu-
late models. Any process must be flexible enough to accommodate different work styles,
unexpected discoveries and disappointments, and inevitable fluctuations in effort and cre-
ativity. The process we discuss below helps focus attention on some of the critical aspects
effective problem solving, without providing a straitjacket that will cramp a problem
solver’s style. Our description comes from what experts tell us, from what we observe, and
from what we have experienced in problem solving.

Defining Terms

We begin by making an important distinction between a problem and a mess. A mess is
a morass of unsettling symptoms, causes, data, pressures, shortfalls, opportunities, and so
on. A problem, on the other hand, is a well-defined situation that is capable of resolution.
Why do we need the concept of a mess when we are problem solving? The idea is simple:
problems do not come to us fully defined and labeled. Rather, we operate in a world full
of confusion: causes and effects are muddled, data exist but there is little relevant infor-
mation, problematic shortfalls or inadequacies appear alongside attractive opportunities,
and so on. Where are the problems in this mess? Identifying a problem in the mess is itself a creative act that will do much to determine the quality of any solutions we propose. In most situations, a number of problems could be extracted from a given mess. Which one we choose depends on our understanding of the situation and on our insight into where analysis and action could be most effective. Our first piece of advice on problem solving, then, is to recognize that defining the problem to be solved is a critical step in the process—one that deserves considerable attention.

One way to focus attention on the problem definition is to use a problem statement of the form “In what ways might . . . ?” Imagine the situation facing a manufacturing company whose costs are rising sharply due to increasing wages. Here are some possible problem statements the company could use:

- In what ways might we increase the productivity of our workforce?
- In what ways might we reduce the labor content of our products?
- In what ways might we shift our manufacturing to lower-cost regions?
- In what ways might we increase revenues to keep pace with costs?
- In what ways might we change our product line to maintain profit margins?

This is just a sample of the problem statements that could apply to a given situation. It should be obvious that the approach taken to resolving the “problem” will be very different depending on which of these statements is adopted. Our advice is to pay close attention to the problem definition, take any problem definition as tentative, and prepare to alter it if evidence suggests that a different problem statement would be more effective.

At any stage in the problem-solving process, there are two quite different styles of thinking: **divergent** and **convergent**. Divergent thinking stresses generating ideas over evaluating ideas. It involves thinking in different directions or searching for a variety of answers to questions that may have many right answers. Brainstorming, in which the evaluation process is strictly prohibited, promotes divergent thinking and allows many ideas to flourish at the same time, even ideas that contradict each other. Convergent thinking, on the other hand, is directed toward achieving a goal, toward a single solution, answer, or result. It involves trying to find the one best answer. In convergent thinking, the emphasis shifts from idea generation to evaluation: Which of these ideas leads to the best outcomes? In many cases, this evaluation is carried out using a model.

Why is this distinction between divergent and convergent thinking useful? One reason is that some individuals naturally prefer, enjoy, or are skilled at one or the other type of thinking. When working as end users, these individuals should be conscious of their preference or skill and take steps to ensure that they devote sufficient time and energy to the other approach. Good evaluators need to encourage themselves to generate more ideas; good idea generators need to encourage themselves to test their ideas thoroughly. Since end users do it all, they must ensure that the balance between divergent and convergent thinking is appropriate throughout the problem-solving process.

An understanding of these concepts is just as important to members of a problem-solving team. In this situation, each member can afford to specialize in their preferred thought process: idea generators can take a lead role in that phase, while strong evaluators can take a lead role when that becomes the primary activity of the group. But each type of person needs to understand their own strengths and the strengths of others on the team and needs to appreciate that the other types make an important contribution. Finally, teams work best when they are aware of which type of thinking they are stressing at each point in the process. It is disruptive and inefficient to have one member of a team evaluating
ideas during a brainstorming session; it is just as disruptive to have someone offering great new ideas during the preparation of a final presentation to the client.

**A Six-Stage Process**

We now describe a six-stage problem-solving process (Figure 2.1) that begins with a mess and ends with implementation of a solution. This process can be used to solve almost any problem, from the most immediate and well-defined (such as selecting a new supplier) to the most long-term and ill-defined (such as identifying a new corporate strategy). Since not all problem solving involves the use of formal models, we first describe the process in its most general form. Subsequently, we discuss how formal modeling fits within this

---

**FIGURE 2.1**
The Creative Problem-Solving Process

- **Exploring the mess**
  - **Divergent phase**
    - Search mess for problems and opportunities.
  - **Convergent phase**
    - Accept a challenge and undertake systematic efforts to respond to it.

- **Searching for information**
  - **Divergent phase**
    - Gather data, impressions, feelings, observations; examine the situation from many different viewpoints.
  - **Convergent phase**
    - Identify the most important information.

- **Identifying a problem**
  - **Divergent phase**
    - Generate many different potential problem statements.
  - **Convergent phase**
    - Choose a working problem statement.

- **Searching for solutions**
  - **Divergent phase**
    - Develop many different alternatives and possibilities for solutions.
  - **Convergent phase**
    - Select one or a few ideas that seem most promising.

- **Evaluating solutions**
  - **Divergent phase**
    - Formulate criteria for reviewing and evaluating ideas.
  - **Convergent phase**
    - Select the most important criteria. Use the criteria to evaluate, strengthen, and refine ideas.

- **Implementing a solution**
  - **Divergent phase**
    - Consider possible sources of assistance and resistance to proposed solution. Identify implementation steps and required resources.
  - **Convergent phase**
    - Prepare the most promising solution for implementation.

*(After Couger, *Creative Problem Solving and Opportunity Finding*)
overall framework. Throughout this section, we illustrate the stages of the process with the example of a pharmaceutical company whose blockbuster drug is due to come off patent in a year’s time.

The six stages in this process are:

■ Exploring the mess
■ Searching for information
■ Identifying a problem
■ Searching for solutions
■ Evaluating solutions
■ Implementing a solution

Divergent thinking tends to predominate early in this process, while convergent thinking comes to dominate later on, but there is a role for each type of thinking in every stage of the process.

The first stage of problem solving explores the mess. As we have said, problems do not appear to us in the form of well-posed problem statements. Rather, we find ourselves in various messes, out of which problems occasionally emerge. It often takes a special effort to rise above the press of day-to-day activities and begin a problem-solving process. In this sense, the most important aspect of this phase may be more psychological than intellectual. The divergent thinking in this phase involves being open to the flow of problems and opportunities in the environment; the convergent phase distills a specific problem out of the mess. During this phase, we ask questions such as the following:

■ What problems (or opportunities) do we face?
■ Where is there a gap between the current situation and the desired one?
■ What are the stated and unstated goals?

This stage will be complete when we have produced a satisfactory description of the situation and when we have identified (although not necessarily gathered) the key facts and data.

In our example, management in the pharmaceutical company is well aware that one drug has provided the bulk of profits over the past decade. Nevertheless, most of their day-to-day attention is devoted to tactical issues, such as resolving conflicts with suppliers or allocating R&D funds to the development of new drugs. As the date approaches on which their major drug loses its patent protection and alternative drugs can begin to compete, the managers gradually become more focused on the problem facing them. While the threat is obvious, the problem is not well defined. Each member of management probably explores this mess individually, in an informal way. They might make rough estimates of the magnitude of the threat (how much will profits fall when the patent expires?), and they might consider alternatives to improve outcomes (should I institute a cost-cutting program in manufacturing?). Eventually, management as a whole realizes the importance of the issue, and a task force is created to address it. All of this activity comes under the heading of exploring the mess.

The second stage searches for information. Here, we mean information in the broadest sense: opinions, data, impressions, published literature, and so on. This is a phase in which we cast about widely for any and all information that might shed light on what the problem really is. Examining the situation from many different points of view is an important aspect of this phase. We might survey similar companies to determine how they approach related problems. We might search the literature for related academic research. The search itself at this stage is divergent. Eventually, we begin to get a sense that some of the information is more relevant, or contains suggestions for solutions, or might other-
wise be particularly useful. This is the convergent part of this phase. In this stage, we should expect to be using diagnostic skills, prioritizing, and constructing diagrams or charts. During this phase, we ask questions such as the following:

- What are the symptoms and causes?
- What measures of effectiveness seem appropriate?
- What actions are available?

This stage will be complete when we have found and organized relevant data for the situation at hand and when we have made some initial hypotheses about the source of the problem and potential solutions.

The task force in our example holds several meetings to get to know each other and to get organized. They also hire a consultant to gather information and to bring an outside perspective to the discussion. The CEO charges the group to “find a strategy to deal with the patent situation,” but the task force recognizes this is not a problem statement, only a vague indication of senior management’s discomfort about the future of the company. The consultant, meanwhile, begins interviewing key managers inside the firm and gathering information externally. She collects information on general trends in the pharmaceutical industry, as well as case studies on the transition off patent for other drugs. A rough picture emerges as to the rate at which generics have invaded a market once patent protection has been lost. She also collects specific information on strategies that other market-dominating firms have used to limit their losses during similar transitions. The consultant interviews economists specializing in industry structure. Inside the firm, she interviews the scientists who develop new drugs, and she begins to formulate a picture of how the firm’s portfolio of new drugs will contribute to future revenues. If the problem-solving process is to work well here, a broad search for information must precede any effort to narrow in on a specific problem that can be resolved. However, even while this search goes on, the members of the task force are beginning to form opinions as to the real problem they face and solutions they prefer.

The third stage defines the problem. In the divergent portion of this phase, we might pose four or five candidate problem statements and try them on for size. We will eventually choose one of these statements, perhaps somewhat refined, as our working problem statement. As mentioned before, there is a significant benefit for any problem-solving group to having an unambiguous statement of the problem they are solving. This is not to say that we can’t modify or even replace one problem statement with another if the evidence suggests this is necessary. All problem statements should be viewed as tentative, although as time passes, the cost and risk of changing the problem statement increases. In this stage, we should be asking whether the situation fits a standard problem type, or whether we should be breaking the problem into subproblems. During this phase, we ask questions such as the following:

- Which is the most important problem in this situation?
- Is this problem like others we have dealt with?
- What are the consequences of a broad versus narrow problem statement?

This stage will be complete when we have produced a working problem statement.

The consultant to the pharmaceutical firm in our example holds a series of meetings with the task force to present and discuss her preliminary research. The group now has a shared understanding of the financial state of their own firm, as well as a general idea of the state of the industry. They discuss how other firms fared when major drugs came off patent and what strategies were used to smooth the transition. At this point, the consult-
The consultant leads an effort to define a problem statement around which the future efforts of the task force can be organized. In the discussion that ensues, two major points of view emerge. One group focuses on preserving the revenue-generating power of the patent drug as long as possible. They ask whether it would be possible to extend the patent, slow the introduction of generic competitors, or perhaps make an alliance with competitors that would share the profits from this category of drugs without significantly reducing its revenues. The other group is focused on a different issue: how to generate more revenue from other drugs now in the development pipeline. They ask whether the firm should increase its R&D spending, narrow its efforts to just the most promising drugs, or look for quicker ways to get regulatory approval. The consultant recognizes that no one is looking at reducing costs or shrinking the firm as possible strategies.

The task force has reached a critical stage in the problem-solving process. How they define the problem here will determine in large measure the solutions they eventually recommend. The consultant, recognizing this, makes an effort to have the group debate a wide range of problem statements. Here are some candidate problem statements they may consider:

- In what ways might we slow the decline in revenues from our patented drug?
- In what ways might we increase the chances of success of R&D on new products?
- In what ways might we increase market share for our existing products?
- In what ways might we resize the firm to match declining profits?
- In what ways might we develop more products with the same investment?
- In what ways might we partner with other firms?

Eventually, the task force comes to the conclusion that protecting the revenues from the existing drug is both difficult and risky. The most effective strategy probably involves developing a portfolio of new drugs as quickly and effectively as possible. Accordingly, they adopt the problem statement: “In what ways might we reduce the time to market for the six drugs currently under development?”

The fourth stage searches for solutions. Again, there is a divergent aspect to this phase, in which a deliberately open-ended search is conducted for good, even radical, solutions. Brainstorming or other creativity-enhancing techniques might be particularly useful, since the team has a well-considered problem statement to serve as a focal point for the creation of solutions. Prior to this point, it is premature to consider solutions. It can even be dangerous to do so, since superficially appealing solutions often gain support on their own, even if they solve the wrong problem. The convergent part of this phase involves a tentative selection of the most promising candidate solutions. The selection process must be tentative at this point, because criteria have not yet been established for a careful comparison of solutions. Nonetheless, there are costs to considering too many solutions, so some pruning is often necessary. During this phase, we ask questions such as the following:

- What decisions are open to us?
- What solutions have been tried in similar situations?
- How are the various candidate solutions linked to outcomes of interest?

This stage will be complete when we have produced a list of potential solutions and perhaps a list of advantages and disadvantages for each one.

Having decided to focus their efforts on improving the R&D process, our task force first forms a subcommittee composed mainly of scientists from the R&D division, along with a few business experts. The consultant conducts extensive interviews within the R&D
group to uncover inefficiencies and possible ways to improve the process of bringing drugs to market. The subcommittee eventually develops a list of potential solutions, along with an evaluation of their advantages and disadvantages. Three areas for potential improvement stand out:

- Hire outside firms to conduct clinical trials and develop applications for Food and Drug Administration (FDA) approvals. This will speed up the approval process, although it will also increase costs.
- Invest a higher percentage of the R&D budget in drugs with the most promise of winning FDA approval. This should reduce the time required for the most promising drugs to reach the market, but it may also reduce the number of drugs that do so.
- Focus the drug portfolio on drugs in the same medical category. This should help develop an expertise in just one or two medical specialties, rather than spreading efforts over many technical areas and markets.

The fifth stage evaluates solutions. This stage can be considered the culmination of the process, as it is here that a preferred solution emerges. Any evaluation of the candidate solutions developed in the previous phase requires a set of criteria with which to compare solutions. Usually, there are many criteria that could be relevant to the outcome; some divergent thinking is useful in this phase to ensure that all relevant criteria, even those that are not obvious, are considered. Once the most important criteria are identified, the various solutions can be evaluated and compared on each criterion. This can lead directly to a preferred alternative. More often, this process leads to changes—and improvements—in the solutions themselves. Often, an aspect of one solution can be grafted onto another solution, or a particularly negative aspect of a generally attractive solution can be removed once the weakness has been recognized. So this phase, while generally stressing convergent thinking, still involves considerable creativity. During this phase, we ask questions such as the following:

- How does this solution impact each of the criteria?
- What factors within our control could improve the outcomes?
- What factors outside our control could alter the outcomes?

This stage will be complete when we have produced a recommended course of action, along with a justification that supports it.

During this phase, our task force first develops a set of criteria with which to evaluate each of the previously proposed solutions. The overall goal is to ensure that the firm remains profitable into the future, even as the main drug goes off patent and its revenues are lost. However, it is difficult to anticipate how any one solution will impact profits directly. For example, how much additional profit will the firm realize if it saves two months in the development process for a particular drug? For this reason, each solution is measured against many criteria, and the results are synthesized by the task force. Here are some of the criteria they develop:

- R&D cost reduction
- Increase in market share
- Months of development time saved
- Increase in probability of FDA approval
After extensive discussion, the task force finally decides that the one most critical area for improvement is how R&D funds are allocated over time. In the past, the firm has generally been very slow to cancel development of any particular drug. Each drug has the passionate support of the scientists working on it, and the commitment of this group to its own drug has superseded the business judgment needed to recognize that other drug-development teams can make better use of scarce R&D resources. With a more business-oriented allocation process, fewer drugs will get increased R&D funding, but it is hoped, more drugs will come to market quickly.

The final stage implements the solution. This stage is included to remind us that a solution is useless if it cannot be implemented. Political resistance, departures from established tradition, and high personal cost or risk are some of the many reasons why apparently rational solutions cannot be implemented in real organizations. In the divergent portion of this phase, the problem-solving team will identify potential sources of resistance and support. As this phase proceeds and specific implementation plans for the proposed solution are developed, the thinking style turns from divergent toward convergent. In this stage, we should expect to be performing change management and focusing on communication. During this phase, we ask questions such as the following:

- What are the barriers to successful implementation?
- Where will there be support and motivation, or resistance and conflict?
- Are the resources available for successful implementation?

This stage will be complete when we have produced an implementation plan and executed enough of it to begin evaluating how well it is succeeding.

To implement its plan, the task force must first convince senior management to support the task force’s recommended solution. The consultant has a major role to play here, in developing an effective presentation and in convincing both scientists and executives that this solution will work. The task force’s role ends when it has won approval and has appointed a new committee to manage the implementation of the new R&D budget-allocation process. Of course, the problem-solving process does not really end here, as the new committee must carry the plan forward, monitor its impacts, modify it as needed, and solve a new set of problems as they arise. To this extent, no problem-solving process ever really ends; it just flows into a subsequent process.

Every successful problem-solving effort starts with a mess and concludes with an implemented solution. Sometimes, the cycle will be repeated more than once, so that the implementation itself creates a new situation and paves the way for follow-on problems to be identified. Nevertheless, the process passes through the stages we have outlined here. Knowledge of these stages is helpful in planning the overall tasks and resources, allocating effort, and setting expectations about progress. Within each stage, an awareness of the contributions from divergent and convergent thinking is helpful in balancing the need for creativity with the need for closure.

It is worth repeating that only rarely are these six stages followed in a strict sequence. Most problem-solving processes move back and forth from one stage to another, perhaps rethinking the problem statement while evaluating solutions, or returning to an information-gathering mode while searching for solutions. As in any creative endeavor, it is important for a problem-solving team (or individual) to remain flexible. That means remaining open to discoveries and to evidence that past work needs to be rethought.
Formal Modeling

The problem-solving process described above is generic in that it does not specifically address how formal modeling is used within the overall framework. Informal modeling, what is often called mental modeling, goes on constantly during problem solving. That is, problem solvers construct quick, informal mental models at many different points in the process. For example, when a potential solution is proposed, everyone on the team runs that idea through a mental model to get a quick first impression of its attractiveness. As an example, consider the following question: Would a tax on carbon emissions in developed countries significantly reduce global warming? What mental models do you use to evaluate this question? How do you think a tax would affect actual emissions of carbon? What would its impacts be on economic growth and quality of life? How would developing countries react to such a policy, and what would be the long-term impact on global temperature? Usually, when we consider questions like this, we use mental models to link causes (the tax) with their effects (changes in global temperature).

Mental models help us to relate cause and effect, but often in a highly simplified and incomplete way. Mental models also help us to determine what might be feasible in a given situation, but our idea of what is possible is often circumscribed by our personal experiences. Finally, mental models are always influenced by our preferences for certain outcomes over others, although those preferences may not be acknowledged or even understood. One of the sources of confusion and debate on topics such as global warming is that we all use different mental models, based on different assumptions and preferences for outcomes, and we have limited means of sharing those models because they are informal and hidden from view. So, while mental models may be useful, even necessary, they can also be extremely limiting. A common pitfall is to reject an unusual idea because it appears at first to be unworkable. Effective divergent thinking can help overcome this pitfall and allow unusual ideas to persist long enough to get a thorough hearing. But in some circumstances, mental models are simply not robust enough to provide sufficient insight, and formal models are called for.

Formal models provide the same kind of information as mental models. In essence, they link causes to effects and help us evaluate potential solutions. Once a set of potential solutions and a set of criteria have been identified, a formal model can be used to measure how well each solution performs according to the criteria. Formal models are undoubtedly costlier and more time-consuming to build than mental models, but they have the great advantage of making our assumptions, logic, and preferences explicit and open to debate.

Mental models were used extensively during the problem-solving process in our pharmaceutical company example. Every member of the task force was experienced in the industry, so each of them had developed mental models to think through the implications of the various proposals. For example, they each had some idea of the development and testing protocols for new drugs, the current process used to allocate R&D funds, and the profit streams new drugs typically generate. Using this experience, they were able to make rough, qualitative assessments of the impact the new R&D-allocation process would have on new-drug success, as well as the profit impact of introducing fewer drugs sooner. However, given the complexity of the drug-development process and the interaction of the various competing companies in the market, mental models would simply not support quantitative estimates of the overall profit impact of the proposed solution.

How could this company use formal modeling in the process? With a formal model, they could track the progress of each of the six drugs through the various stages of development. One of the key assumptions they need to agree on is how the new R&D process affects the completion time and probability of success at each stage. To this model, they
probably want to add a module that projects the introduction of competing products in each medical category. This requires discussion and agreement on a set of assumptions about the plans of their competitors. Finally, they can complete the model by adding a financial component to determine their profits under any scenario. Taken as a whole, this model projects a stream of new-drug introductions by the firm itself and its competitors, then determines the price and market share for each drug, and ultimately calculates the resulting profits. Unlike mental models, a formal model built along these lines can be used to analyze whether the firm can generate enough revenues from new drugs to offset the loss in revenues from its blockbuster drug.

THE REAL WORLD AND THE MODEL WORLD

We stated at the outset of this chapter that modeling is a tool or a strategy that is used within the broader context of problem solving. Now that we have described that broader context, we can focus more narrowly on modeling itself.

A model is an abstraction, or simplification, of the real world. It is a laboratory—an artificial environment—in which we can experiment and test ideas without the costs and risks of experimenting with real systems and organizations. Figure 2.2 is a schematic showing how modeling creates an artificial world. We begin in the real world, with a problem statement that is already a selection of the most important features from the confusion and complexity of the mess. If we determine that modeling is an appropriate tool, we then move across an invisible boundary into the model world.

In order to move into the model world, we abstract the essential features of the real world, leaving behind all the inessential detail and complexity. We then construct our laboratory by combining our abstractions with specific assumptions and by building a model of the essential aspects of the real world. This is the process of formulation. It is an exercise in simplifying the actual situation and capturing its essence, with a specific purpose in mind. The formulation process typically forces us to confront four features of a model:

- Decisions
- Outcomes
- Structure

![Figure 2.2: The Real World and the Model World](image)
Data

Decisions refers to possible choices, or courses of action, that we might take. These would be controllable variables, such as quantities to buy, manufacture, spend, or sell. (By contrast, uncontrollable variables such as tax rates or the cost of materials are not decision variables.) Outcomes refers to the consequences of the decisions—the performance measures we use to evaluate the results of taking action. Examples might include profit, cost, or efficiency. Structure refers to the logic and the mathematics that link the elements of our model together. A simple example might be the equation \( P = R - C \), in which profit is calculated as the difference between revenue and cost. Another example might be the relationship \( F = I + P - S \), in which final inventory is calculated from initial inventory, production, and shipments. Finally, data refers to specific numerical assumptions. That may mean actual observations of the real world (often called “raw” or “empirical” data), or it may mean estimates of key uncontrollable variables in the problem’s environment. Examples might include an interest rate on borrowed funds, the capacity of a manufacturing facility, or the first-quarter sales for a new product. (In Chapters 3 and 4, we examine the model-formulation process in more detail. In Chapter 5, we focus on how to build effective models using spreadsheets.)

Once it is built, we can use the model to test ideas and evaluate solutions. This is a process of analysis, in which we apply logic, often with the support of software, to take us from our assumptions and abstractions to a set of derived conclusions. Unlike formulation, which tends to be mostly an art, analysis is much more of a science. It relies on mathematics and reason in order to explore the implications of our assumptions. (In Chapter 6, we describe the major steps in this process. In Chapters 7 through 9, we elaborate on the major quantitative techniques for analyzing models.) This exploration process leads, hopefully, to insights about the problem confronting us. Sometimes, these insights involve an understanding of why one solution is beneficial and another is not; at other times, the insights involve understanding the sources of risk in a particular solution. In another situation, the insights involve identifying the decisions that are most critical to a good result, or identifying the inputs that have the strongest influence on a particular outcome. In each instance, it is crucial to understand that these insights are derived from the model world and not from the real world. Whether they apply to the real world is another matter entirely and requires managerial judgment.

To make the model insights useful, we must first translate them into the terms of the real world and then communicate them to the actual decision makers involved. Only then do model insights turn into useful managerial insights. And only then can we begin the process of evaluating solutions in terms of their impact on the real world. This is a process of interpretation, and here again, the process is an art. Good modelers can move smoothly back and forth between the model world and the real world, deriving crisp insights from the model, and translating the insights, modifying them as needed, to account for real-world complexities not captured in the model world.

This schematic description of the modeling process highlights some of the reasons why modeling can be a challenge to incorporate into problem solving. While powerful in competent hands, modeling is also somewhat esoteric. It involves deliberate abstraction and simplification of a situation, which appears to many people as a counterproductive exercise. Modeling requires a willingness to temporarily set aside much of the richness of the real world and to operate in the refined and artificial world of models and model insights. It also requires confidence that whatever insights arise in the model world can be translated into useful ideas in the real world. Additionally, it requires an ability to mix art with science in order to exploit the modeling process to its full potential. Until we have some experience with this process, we may be resistant and skeptical. And it is always easy to criticize a model as being too simple. In fact, good models are as simple as they
can possibly be. But this very simplicity can appear to be a fatal flaw to skeptics. Despite all this, modeling is one of the most powerful tools in the problem solver’s toolkit, simply because there is no more practical way to arrive at the insights modeling can provide.

LESSONS FROM EXPERT MODELERS

Perhaps the best way to become a good modeler is to serve an apprenticeship under an expert. Unfortunately, such opportunities are rare. Moreover, experts in all fields find it difficult to express their expertise or to teach it. While narrow, technical skills are relatively easy to teach (e.g., how to use the NPV function in Excel), expertise consists largely of craft skills that are more difficult to teach (e.g., what to include and exclude from the model). In the arts, there is a tradition of studio training, where a teacher poses artistic challenges to students and then coaches them as they work through the problems on their own. This is one way for students to acquire some of the difficult-to-articulate craft skills of the master. There is no comparable tradition in the mathematical fields; in fact, there is a long-standing belief that modeling cannot be taught, but must simply be acquired by experience.

An alternative to an apprenticeship under an expert is to study experts in a laboratory setting. Tom Willemain did this in a series of experiments with twelve expert modelers. He gave each expert a short problem description as it would come from a client and observed the subject working for one hour on the problem. The subjects were asked to think out loud so their thought processes could be recorded. Willemain’s results concerning the “first hour in the life of a model” are highly suggestive of some of the ingredients of good modeling practice.¹

Willemain was interested in determining the issues to which expert modelers devote attention as they formulate their models. He identified five topics important to modelers:

- problem context
- model structure
- model realization
- model assessment
- model implementation

Problem context refers to the situation from which the modeler’s problem arises, including the client, the client’s view of the problem, and any available facts about the problem. In this activity, the modeler tries to understand the problem statement as provided by the client and to see into the mess surrounding the problem statement.

Model structure refers to actually building the model itself, including issues such as what type of model to use, where to break the problem into subproblems, and how to choose parameters and relationships. In Figure 2.2, this is the process of moving into the model world, making abstractions and assumptions, and creating an actual model.

Model realization refers to the more detailed activities of fitting the model to available data and calculating results. Here, the focus is on whether the general model structure can actually be realized with the available data and whether the type of model under development will generate the hoped-for kinds of results.

Model assessment includes evaluating the model’s correctness, feasibility, and acceptability to the client. Determining the correctness of a model involves finding whether the model assumptions correspond well enough to reality. Feasibility refers to whether the

client has the resources to implement the developed model, whether sufficient data are available, and whether the model itself will perform as desired. Client acceptability refers to whether the client will understand the model and its results and whether the results will be useful to the client. In this phase, we can imagine the modeler looking from the model world back into the real world and trying to anticipate whether the model under construction will meet the needs of the client.

Finally, **model implementation** refers to working with the client to derive value from the model. This corresponds to the translation and communication activities in Figure 2.2.

One of the interesting observations Willemain made about his experts was that they frequently switched their attention among these five topics. That is, they did not follow a sequential problem-solving process, but rather, moved quickly among the various phases—at one moment considering the problem statement, at another considering whether the necessary data would be available, and at another, thinking through whether the client could understand and use the model. A second significant finding was that model structure, presumably the heart of a modeler’s work, received a relatively small amount of attention (about 60 percent of the effort) when compared to the other four topics. Finally, it turned out that experts often alternated their attention between model structure and model assessment. That is, they would propose some element of model structure and quickly turn to evaluating its impact on model correctness, feasibility, and acceptability. Willemain suggests that the experts treat model structuring as the central task, or backbone, of their work, but they often branch off to examine related issues (data availability, client acceptance, and so on), eventually returning to the central task. In effect, model structuring becomes an organizing principle, or mental focus, around which the related activities can be arrayed.

The experts in Willemain’s study also offered their own perspectives on the important qualities of an effective **modeler**, an effective **model**, and an effective **modeling process**. As for an effective modeler, they listed first in order of importance the modeler’s mindset: creativity, sensitivity to client needs, persistence, and so on. Second in importance was nontechnical expertise, including communication and teamwork skills. Listed third was technical expertise and fourth, knowledge of the industry or problem type involved in the work. It is very revealing that even expert modelers, who might be expected to value technical expertise most highly, cite the modeler’s mindset and nontechnical skills as being most important. This reinforces the notion that craft skills are every bit as important to the successful modeler as technical skills.

When evaluating the qualities of an effective model, the experts listed validity, usability, value to client, feasibility, and aptness for client’s problem—in that order. Validity refers to the technical correctness of the model: whether it is internally consistent, logical, and a faithful implementation of the modeler’s intentions. It is not surprising that this is an absolute requirement. But notice the importance of model usability and value to client: a perfectly valid model may still be of little value to the client. Again, a good model and modeler must understand the problem context and the needs of the client.

Finally, when asked to compare the five modeling topics listed above and rate them on their importance to an effective modeling process, the experts listed problem context, model assessment, model structure, and model realization—in that order. Understanding the problem context, or discovering the real problem, again outranks the more technical aspects of the process in these experts’ eyes.

The overall picture that emerges from this research is one in which craft skills are as essential to the effective modeler as technical skills. An effective modeler must understand the problem context, including the client, or modeling will fail. Likewise, a model that is technically correct but does not provide information the client can use, or does not gain the trust of the client, represents only wasted effort. Experts approach modeling with a general process in mind, but they move fairly quickly among the different activities, creating, testing, and revising constantly as they go. The experts appear to be comfortable with a high degree of
ambiguity as they approach the task of structuring a model. They do not rush to a solution, but patiently build tentative models and test them, always being ready to revise and improve.

**CREATIVITY IN MODELING**

Creativity is a subject that makes many people uncomfortable, possibly because they underestimate how common it is. Nevertheless, creativity is a vital ingredient in successful problem solving, as it is in good modeling. Our purpose in this section is to dispel some of the myths surrounding creativity and to offer some practical tools for encouraging the creativity of problem-solving teams and individuals.

We begin with some common myths about creativity. The first is that creativity is instinctive and cannot be learned. This is similar to the belief that great teachers, or great chefs, or great architects, are simply born to their craft, and no amount of study will turn an ordinary professional into an extraordinary one. The truth seems to be somewhat different. Creativity, in fact, is an activity that results from the ordinary thought processes of ordinary people. Moreover, virtually everyone’s creativity can be increased beyond its present level through training in the use of specific techniques.

Another common myth is that creative ideas arise in a flash of inspiration. Again, the truth is more mundane. All studies show that creative breakthroughs occur only after a considerable amount of time and effort has been expended. We need only read about the invention of the telephone, to which Alexander Graham Bell devoted decades of research before having a series of breakthroughs lead to success, to realize how critical it is to prepare the ground. While hard work is not a guarantee of creative breakthroughs, lack of hard work essentially rules them out. Louis Pasteur said this well: “Inspiration is the impact of a fact on a well-prepared mind.”

A third myth is that creative individuals are geniuses—that is, different from the rest of us. This is the hardest myth to dispel, partly because we tend to focus on the few really awesome breakthroughs (the discovery of relativity or the DNA helix), while overlooking thousands of truly creative ideas that arise around us all the time. We have somehow elevated creativity to the status of a rare gem, when in fact it is an everyday matter. William James said, “Genius, in truth, means little more than a faculty of perceiving in an unhabitual way.”

Creative individuals are different in some ways from average folk. They tend to display attributes we would expect—such as openness to new ideas, curiosity, independence, playfulness, impulsiveness, and risk taking. But they also display attributes that we do not traditionally attribute to them, such as discipline and perseverance. The widely-portrayed artist with great creativity but no discipline is truly a myth. Again, the biographies of the great inventors typically reveal years of toil and frustration punctuated by a few great insights. Truly creative breakthroughs are by their nature rare, but creativity is a characteristic everyone has and can improve.

**Barriers to Creativity**

What are some of the barriers to creativity? It is useful to distinguish perceptual barriers from emotional barriers. One perceptual barrier to creativity is stereotyping and labeling; that is, seeing the current situation as indistinguishable from some stereotypical situation, or labeling the current problem with a blanket label.

Another barrier is difficulty in isolating a problem. It is difficult to find creative solutions to a mess. Until we can isolate a problem from the confusion and distractions of the mess, it is almost impossible to focus our creativity.
A third barrier is adding artificial constraints to a problem. Many problem-solving teams have a hard time seeing beyond the current ways of doing business. Is the budget really fixed just because some higher manager has set budgets in the past, or can we make a case for expanded resources? Must we accept that each of our customers requires a personal sales call, or can our customers change their old habits and learn to order over the Internet? Every constraint limits the search for solutions. Every constraint diminishes the freedom of creative minds to explore.

A final perceptual barrier is an inability to see a problem from different points of view. Creative individuals seem to excel at holding many possible views of the problem, and even many possible solutions, in their head at the same time. This is one reason every step in the problem-solving process has a divergent phase, to encourage problem solvers to keep as many options open as long as possible. Some of these views or solutions may even contradistinct each other. Creativity is enhanced when multiple viewpoints and contradictions are encouraged and when premature focus on one viewpoint or solution is discouraged.

Creativity is also reduced by a number of emotional barriers. These include fear of making mistakes, intolerance of ambiguity, preference for judging ideas over generating them, inability to let ideas gestate, and a desire to succeed too quickly. To be creative, we need a certain degree of self-confidence. This involves a willingness to make mistakes, perhaps even to suggest silly solutions. It also involves a certain patience: a tolerance for ambiguity about what the real problem is and where a good solution might be found, the patience to let ideas percolate without knowing in advance which ones will pan out, and the confidence that success will come eventually. Finally, while an ability to evaluate ideas is critical to good problem solving, too strong a desire to judge ideas can hinder creativity. This last barrier is so important that we discuss it in detail in Chapter 3.

Techniques to Enhance Creativity

Many techniques have been developed to help individuals and groups to be more creative. While there is no guarantee of becoming highly creative by using these techniques, they are useful for freeing one’s thinking. Groups are particularly given to behaviors that discourage creative thinking, so creativity techniques for groups may be particularly important. We discuss here a small sample of techniques for individuals and groups.

**Boundary examination.** In every problem-solving process, there are implicit assumptions that set the boundaries for the analysis. Boundary examination is used to uncover those assumptions, to challenge them, and to expand or replace them as needed. Boundaries are not intrinsically good or bad, but they are certainly necessary. In fact, the stages we have outlined in this chapter are designed to limit the scope of the problem-solving process so that it can reach an effective conclusion. One of the primary failings of many problem solvers is an inability to focus on one well-defined aspect of the mess that can be resolved.

Boundary examination begins with a description of the problem as it is currently understood. Then the assumptions behind this problem definition are isolated, and each one is challenged in turn. For example: Should we ignore the actions of competitors in our analysis of a new product? What are the consequences of doing so? How would we include the actions of competitors if we chose to do so? Once each assumption has been challenged, the problem can be restated based on a deeper understanding.

**Force-field analysis.** This technique is used to identify the forces that might move the situation under examination toward the best possible state and those that might move it toward the worst possible state. This technique first helps to identify the goals toward
which we are working. Then it can stimulate creativity by identifying forces already at work in the situation—forces that will work with or against any proposed solution.

The first step in force-field analysis is to identify the goal to be reached. We next describe what the situation would be like in the worst possible case and the forces working to move the situation toward that outcome. Then we describe the best possible case and the forces moving the situation that way. For example, if the problem is to limit the impact of competing products on sales of our product, the worst possible state might involve a complete collapse of demand due to the introduction of a dominating product or due to product safety problems. The best possible case might arise if competitors fail to introduce any competing products or if the products they do introduce fail to gain customer loyalty.

These descriptions of extreme outcomes and the forces leading to them help to reveal the mental models behind our thinking. They also help to identify effective solutions, by revealing approaches that would strengthen the positive forces in play and weaken the negative ones.

**Interrogatories.** This method expands our view of a problem by asking five simple questions: Who, What, Where, When, and Why? These questions are helpful at almost any stage of the problem-solving process. They can help broaden our perspective and uncover hidden assumptions. In the example cited above, where the problem is to limit competitive inroads on our sales, we might ask:

- Who will buy our product if competitors offer a cheaper alternative?
- What qualities of the product we offer (for example, price, cost, or service) could we improve to reduce loss of business?
- Where can we most effectively place new advertising to expand our customer base?
- When can we expect competitors to introduce competing products?
- Why do existing customers purchase our product?

**Brainstorming.** Brainstorming is by far the best known of all creativity techniques. It is used when the goal is to generate a multitude of ideas, especially ideas outside the mainstream. The method works by separating idea generation from evaluation. In fact, evaluation is explicitly forbidden during brainstorming.

Usually, a group engages in a brainstorming session for an hour or so, under the guidance of a facilitator. The facilitator’s role is to encourage all members to participate, to help the group build on the ideas already generated, to record the ideas as they arise, and to remind the group of the rules in brainstorming. The essential rule is to accept all ideas—no matter how wild, dangerous, or outrageous—without evaluation. Any attempt to evaluate an idea, even to provide a positive comment, should be avoided. It is permissible—indeed, members are encouraged—to build on an idea by refining or extending it.

**Nominal group technique.** One of the drawbacks of brainstorming is that ideas are generated in public, so the group knows the author of each idea. This may inhibit creativity, since it is likely that some members of the group have higher positions of authority or higher status, so their ideas may be better received than others. Even without any overt evaluation of ideas, members can perceive (or even simply imagine) that sharing certain ideas may be dangerous to their reputations or careers.

The nominal group technique is used for the same purposes as brainstorming, but the ideas are initially generated in written form. Once each member has listed as many ideas as possible, the ideas are shared anonymously. For example, the facilitator might randomize the cards on which each member has recorded ideas and write down one from each
card in turn. Members are then encouraged to discuss the ideas, clarifying them and using them to stimulate new ideas, but not to evaluate them or make their authorship public. This public discussion is often followed by another round of writing and sharing.

Wildest idea. Groups are generally quite conservative in their approach to problem solving, preferring tried-and-true ideas to the truly creative. When it is necessary to break out of this bind, the wildest-idea technique can help.

The process begins with the first wild idea anyone can offer. The facilitator guides the group through an exploration of the idea, trying to vary it or extend it to better solve the problem at hand. While this process involves evaluation to some extent, the general tone should be kept positive, looking for the useful parts of a given idea and not rejecting it out of hand because it is impractical in some ways. Once the first idea has been fully explored, the group moves on to another wild idea—until an idea is found that offers a potential solution. Often, the solution adopted will share some features of several of the wild ideas generated in this session.

SUMMARY

Effective modeling takes place within a larger problem-solving process. Modeling can be useful both in finding a good solution and in facilitating communication as the solution is developed, refined, and implemented. Therefore, it is important to recognize the larger context in which modeling occurs. We organize the problem-solving process into six stages. At the outset, the “problem” is no more than an unstructured situation where there is some unsatisfied need, some goal (possibly unarticulated) waiting to be met, or some opportunity remaining unrealized. During the process, this initial unstructured mess is gradually transformed—first by gathering information, then by articulating a problem, and finally, by creating, evaluating, and implementing a solution. Although it’s convenient to describe these stages as if they were separate and occurred in a strict sequence, that is seldom the case. In fact, we can’t always identify the specific activities at each stage until after the fact. Nevertheless, every implemented solution comes about through some version of the problem-solving process. Generally speaking, the bigger the problem at hand or the larger the team working on it, the more important it is to use a structured problem-solving process.

Mental modeling is an essential tool in problem solving. A mental model allows us to trace the consequences of a course of action without actually implementing it. In that way, mental models save us the time and cost, not to mention the occasionally disastrous consequences, of actually trying out alternative solutions to a problem.

Formal models provide the same kind of benefits as mental models. A formal model is a laboratory within which we can search for the best solution, without incurring the time and cost of trial-and-error approaches. Formal models are costlier and more time-consuming to build than mental models, but they have the great advantage that they make our assumptions, logic, and preferences explicit. They also allow us to search among many more solutions than would otherwise be possible. Finally, an effective formal model can help communicate the reasoning behind a solution and in that way help to motivate an individual or organization to act.

Modeling involves abstracting the essential features of a situation and building a logical structure that mimics some aspects of the real world. We use the metaphor of the “model world” to emphasize the artificial nature of modeling and the need to be aware of whether we are reasoning about the real world or a simplified representation of it. An
effective modeler can comfortably move back and forth between the real world and the model world. Moving into the model world requires abstracting the essential features of the real world; moving back to the real world requires translating model insights into managerial insights.

Research on expert modelers has shown that they develop their models in a cyclic fashion, not in a predictable sequence of steps. Structuring the model provides a central focus, but experts frequently shift their focus to consider related issues, such as data availability or the needs of a client. Experts themselves consider it essential that a modeler possess nontechnical skills such as creativity, persistence, and sensitivity to the client’s needs. Thus, the craft skills of modeling, which are a major theme of this book, are vital for effective modelers.

Creativity is an essential ingredient in successful problem solving, just as it is in modeling. Creativity involves an element of play; likewise, effective modelers often seem to play with their models. Myths are common about creativity, and it is generally an uncomfortable subject. Creativity is, in fact, common among ordinary people, especially those who have immersed themselves in a problem. Moreover, creativity can be enhanced through self-awareness and the use of specific techniques, such as force-field analysis or brainstorming.

REFERENCES

For more information on problem solving, creativity in general, and specific creativity techniques, consult the following books:


EXERCISES

1. Refer to the Retirement Planning case.
   a. Explore the mess by answering the following questions:
      - What do we know?
      - What can we assume?
      - What could the results look like?
      - What information can be brought to bear?
      - What can we ask the client?
      - Are there any similar situations or problems?
   b. Formulate one or more problem statements.

2. Refer to the Draft TV Commercials case.
   a. Explore the mess by answering the following questions:
      - What do we know?
      - What can we assume?
      - What could the results look like?
      - What information can be brought to bear?
      - What can we ask the client?
Are there any similar situations or problems?

**b.** Formulate one or more problem statements.

3. Refer to the Icebergs for Kuwait case.
   **a.** Explore the mess by answering the following questions:
   - What do we know?
   - What can we assume?
   - What could the results look like?
   - What information can be brought to bear?
   - What can we ask the client?
   - Are there any similar situations or problems?

   **b.** Formulate one or more problem statements.

4. Refer to the Racquetball Racket case.
   **a.** Explore the mess by answering the following questions:
   - What do we know?
   - What can we assume?
   - What could the results look like?
   - What information can be brought to bear?
   - What can we ask the client?
   - Are there any similar situations or problems?

   **b.** Formulate one or more problem statements.