PART I

CHAPTER 1

Introduction

1.0 MODELS AND MODELING

A *model* is a simplified representation of reality. We use models all the time, although often we are not aware of doing so. Any map is a model of some part of the natural or human landscape. A decision to merge two companies is likely to be based on a model of how the combined companies will operate. Predictions that the U.S. Social Security program will go bankrupt are based on models, as are decisions to recommend evacuation in the face of a hurricane. Models, in fact, are a ubiquitous feature of modern life, and everyone is affected by them.

Modeling is the process of building and using models. Some models are built for a single purpose. For example, someone might build a simple spreadsheet model to test the impact of various investment alternatives on their personal tax liabilities. Other models are built by modeling experts to help a group of managers make a one-time decision. An example of this might be a consulting company that builds a model to value a potential acquisition target for a large corporation. Still other models are used repetitively, as part of everyday operations. State legislatures use models routinely, for instance, to forecast the annual budget surplus based on tax receipts collected to date.

Just as there are many different types of models and purposes for modeling, there are also many different types of modelers. *Professional modelers* often specialize in a particular industry or modeling method. Professional modelers work on airline-crew scheduling problems, marketing media-selection problems, and stock-option valuation problems. Other professionals specialize in particular tools, such as econometrics, optimization, or simulation. Also, millions of modelers build and use models as part of their jobs or in their personal lives but do not think of themselves as modelers. Most spreadsheet users probably fall into this category. We refer to these individuals as *end-user modelers*. End users often are professionals in a field other than modeling. They may be consultants, lawyers, accountants, marketing or financial analysts, plant managers, or hospital administrators. This book is designed to help end users

Modeling for Insight: A Master Class for Business Analysts, by Stephen G. Powell & Robert J. Batt

become more like professional modelers, without investing the time to acquire an advanced degree or serve an apprenticeship.

Modeling is used by different people in different circumstances for different purposes. Some modeling is routine, in that the problem is well structured and the procedure for getting from the problem to a solution is well understood. This would be the case, for example, in a consulting company where valuing corporations as possible takeover targets is a core part of the business. In this situation, the consulting company would have a well-developed procedure for modeling the future value of a target company. Essentially the same model structure would then be reused each time a new valuation was needed. The analyst's task in this case would not be to formulate the model from scratch but to identify the data inputs for the company in question and to carry out the analysis as prescribed in the procedure. Routine modeling efforts such as this are *not* this book's major focus, although some of the tools we discuss here can be used effectively in routine modeling.

The focus of this book is on modeling new and ill-structured problems from scratch when no existing procedure is available to follow. This aspect of modeling has received very little attention in existing books or courses. Some people claim that this most creative aspect of modeling cannot be taught but can only be learned through experience. We disagree. We know that real expertise in modeling requires both breadth and depth of experience and cannot be acquired *solely* from a book or course. However, that does not mean modelers cannot improve their skills in any way other than through experience. As with most skills, learning solely through experience does lead to improvement, but the rate of improvement is often very slow and bad practices can be learned just as well as good ones. Many people learn most effectively through a combination of experience and structured study. We believe the methods presented in this book can help you dramatically improve your modeling skills if you take the time to work through the chapters slowly and carefully and if you continue to practice and develop your skills after you complete the book.

1.1 WELL-STRUCTURED VERSUS ILL-STRUCTURED PROBLEMS

Problems come to the analyst from many sources and in many forms. Most problems can be dealt with adequately without great modeling skill. Typically, these are *well-structured* problems, such as preparing a budget for the coming year in a stable business or selecting the lowest cost vendor to supply raw materials. By a well-structured problem, we mean one in which

- The objectives of the analysis are clear
- The assumptions that must be made are obvious
- All the necessary data are readily available
- The logical structure behind the analysis is well understood

By contrast, in an *ill-structured* problem, few or none of the features listed above are present. Thus, in these problems, the objectives are unclear, the assumptions one should make are ambiguous, little or no data are available, and the necessary logical structure is not well understood. Here are several examples of ill-structured problems:

- Should the American Red Cross institute a policy of paying for blood donations?
- Should Boeing's next major commercial airliner be a small supersonic jet or a slower jumbo jet?
- Should an advertiser spend more money on the creative aspects of an ad campaign or on the delivery of the ad?
- How much should a mid-career executive save out of current income toward retirement?

Why is each of these problems ill structured? The Red Cross situation illustrates a problem in which objectives are unclear. As a nonprofit organization, the organization exists to serve the public, but it cannot at the same time run an unlimited deficit. And does the quality of the blood supplied by the Red Cross figure into the analysis? The Boeing problem illustrates a situation in which the assumptions one makes may heavily influence the outcome of the analysis. Should one assume, for example, that the company can only develop one new airliner or more than one? The advertiser's problem is difficult in part because no data are available that can suggest how the quality of ads might improve with the number of drafts chosen. Finally, the retirement problem illustrates a case where the precise objective is unclear and a logical structure must be constructed within which to carry out an analysis.

1.2 MODELING VERSUS PROBLEM SOLVING

Well-structured problems typically can be *solved*. A solution to a problem consists of qualitative or quantitative information that leaves no questions about the problem unanswered. In many cases, we can actually prove the solution is the only possible one. An algebra problem provides an extreme but illustrative example. Consider this one:

Solve the following system of equations for X and Y:

$$3X + 4Y = 18$$

$$9X + Y = 21$$

The solution to this problem consists of the values $X = 2$, $Y = 3$. Not only can we easily demonstrate that these values actually do solve the problem, we can prove this is the only solution to this problem. Once we have found these values for X and Y, nothing more needs to be said about the problem.

Unlike well-structured problems, ill-structured problems cannot be solved in this same sense because it is impossible to develop a solution that leaves no outstanding questions about the problem. Even more, one cannot demonstrate that any particular set of information actually constitutes a solution, much less prove that it is unique. Many problem solvers confuse well- and ill-structured problems. But ill-structured problems demand different methods than well-structured problems. Ill-structured problems do not have solutions in the same way that well-structured ones do, nor is an effective approach to a problem that is well structured likely to work for a problem that is ill structured.

The distinction we have made here between the two types of problems is fundamental to this book. It is also helpful to make a parallel distinction between trying to *solve* a well-structured problem and trying to *gain insight into* an ill-structured one. We refer to the former activity as *problem solving* and to the latter as *modeling*.

If ill-structured problems cannot be solved, how can we say anything useful about them at all? First, ill-structured problems can be *explored*. Exploring a problem involves making assumptions, formulating hypotheses, building a sequence of models, and deriving tentative conclusions, all with an inquiring mind and in a spirit of discovery. Problem exploration is a more creative and open-ended process than problem solving. It often reveals aspects of the problem that are not obvious at first glance. These discoveries can become useful insights.

Another useful approach modelers can bring to ill-structured problems is to develop a problem *structure* within which exploration can proceed. For example, clarifying the outcome measures, decisions, and uncertainties in ill-structured problems provides a type of structure for problem exploration. In some cases, simply asking what options we have in the situation can focus the discussion. In other cases, a more formal model structure, consisting, perhaps, of a decision tree or a cash-flow model, provides the necessary structure. Ultimately, an effective modeler can develop insights into the factors that make one course of action preferred to all others.

1.3 MODELING FOR INSIGHT

We use the word *insight* for any useful information that can be developed about an ill-structured problem. Insights come from many types of analysis, but they are almost always expressed in words, not numbers. Some insights can be developed by exploring different objectives for the problem. Other insights come from exploring trade-offs between various consequences of a particular course of action. (A trade-off occurs when changing a decision improves one objective but worsens another.) Still others come from developing an understanding of the factors critical to succeeding or achieving a plan. Finally, some insights come from analyzing the risks inherent in a decision.

Although creativity is a necessary ingredient in the search for insights, some insights can be identified rather routinely using the techniques we describe in this book. Our fundamental goal is to present procedures for approaching ill-structured problems that, although not leading to solutions, can reliably lead to insights. "Modeling for insight" is the phrase we use for the process of modeling ill-structured problems in order to gain understanding.

1.4 NOVICE MODELERS AND EXPERT MODELERS

When faced with an ill-structured problem, novice modelers typically focus on acquiring *data*, whereas expert modelers typically focus on developing a *model structure*. Why do experts behave so differently from novices? Does it make a difference?

Let's consider the Red Cross problem: Should the Red Cross pay for blood donations? Novices are likely to look for data, such as the number of pints of blood now being donated per year, the average surplus (profit) the Red Cross earns on each pint, or perhaps the percent of donated blood that is contaminated. Although these types of data may be valuable in the eyes of the modeler, especially if they are easy to acquire, focusing on finding data early in a modeling effort has many drawbacks. The most obvious of these drawbacks is that data collection takes time and (often) money, which are resources that are always scarce in modeling. Even worse, actually acquiring data can prematurely narrow the focus of the modeling effort or even reduce the creativity brought to the task. Finally, premature data collection may well turn out to be wasted effort if, as frequently happens, the data that are collected do not affect the results. The essential point to keep in mind about data collection is that *without at least a preliminary model in mind, there is no way to determine what data are really needed*. One of the fundamental tools we offer in this book is a way to determine the data that will be valuable in modeling ill-structured problems.

Data play a very different role in well-structured problems. These types of problems actually have answers, which are likely to depend on the data. For example, if we change any one of the six parameters in the system of equations discussed above, then $X = 2$, $Y = 3$ will no longer be the correct solution. However, in an ill-structured problem, it is unlikely the insights we are looking for are highly sensitive to the data in the problem. And when data are critical, understanding why this is the case itself generates insights. As we have pointed out, problem-solving methods that are effective for well-structured problems are not always effective for ill-structured ones. This is true of data as well: data are critical in well-structured problems but less so in ill-structured ones.

Expert modelers, not surprisingly, take a very different approach from that of novices when faced with an ill-structured problem. Experts rarely look for data early in a modeling effort. Instead, they build a model structure as a backbone for their thinking. In other words, they focus on the *relationships* between variables rather than on the values of those variables. They use the structure they create to ask questions, such as:

- Have I formulated the right problem?
- Will the approach I'm taking work out?
- Will this model help me answer the client's questions?
- Can this approach lead to a practical course of action?

This approach offers several advantages. First, a preliminary model structure can suggest which data will be most useful. Second, the modeler's creativity is most unfettered when data issues are moved to the background. Third, the structure-first approach uses time effectively, allowing the modeler to consider important aspects of the problem in general terms first without committing to any one approach.

To help you learn this approach to modeling, we address several problems in which little or no data are given. At times, we even exaggerate the scarcity of data to inculcate the desired attitude toward data. We have found that it is a useful discipline to learn to model without any data at all. If you can build a credible model structure when no data are available, you can certainly build one when some data are at hand.

1.5 CRAFT SKILLS IN MODELING

An expert modeler possesses several different types of skills. Certainly an expert must have a command of the field of study's technical underpinnings. For example, a marketing analyst must understand marketing very well to be a good modeler in that domain. But modelers need a range of skills that go beyond their domain expertise. For one thing, they need the skill to determine which problems are suitable for modeling. Then they must be able to abstract the essential features of the real problem. Finally, they must be skilled in translating model results into a form that is relevant and useful in the real world.

We refer to all the skills an expert modeler possesses beyond technical expertise as *modeling craft*. We know from experience that craft skills are essential to success in modeling, but craft skills are difficult to articulate. Many expert modelers, like experts in any field, have difficulty explaining how they do their work. Thus, craft skills have been underappreciated and rarely taught. This book, by contrast, is devoted to helping you learn the craft skills of modeling.

You can find many books that describe how models are used in a particular domain, such as marketing or finance, and even more that cover specific modeling tools, such as optimization, simulation, or statistics. But very few books deal in any detail with the essential craft skills of modeling. This is our task.

1.6 A STRUCTURED MODELING PROCESS

We find it effective to organize modeling into four stages:

1. **Frame the Problem:** Problems do not come neatly packaged, ready for solution. Rather, they emerge out of the confusion of daily life. The first critical skill you need to develop as a modeler is the ability to identify a problem suitable for modeling, including which aspects of the problem to include and exclude. This process is *problem framing* or problem formulation.
2. **Diagram the Problem:** Once you have framed a problem, you will find it is often effective to develop a high-level understanding through visualization. We use influence diagrams for this purpose. Influence diagrams allow you to work out the connections between inputs and outputs without precisely specifying the relationships involved. This freedom is essential to creative modeling.
3. **Build a Model:** A well-structured model is the heart of modeling for insight. Building such a model requires a sound problem frame and a well-thought-out influence diagram. Then you can employ the tools of spreadsheet engineering to develop a model that will serve as an effective laboratory for finding insights.
4. **Generate Insights:** Generating insights is the goal in modeling ill-structured problems. Although most of us recognize insights when we see them, no recipe is available for generating them. Insights come out of a deliberate process of exploring the behavior and implications of a model. To find them, you must translate model results into meaningful results for the real problem represented. Insights usually are expressed in words and graphs, so as an effective modeler, you will need to develop skills in communicating with these tools as well as with numbers and formulas.

1.7 MODELING TOOLS

Within this overall process, our approach uses six powerful modeling tools:

1. **Influence Diagrams:** A graphical approach to model formulation is often more effective than an algebraic or a numerical approach, especially early in problem formulation. *Influence diagrams*, the tool we use in this book, involve mapping inputs, outputs, and the relationships that connect them.

2. **Spreadsheet Engineering:** A model is a tool, or a means to an end, not the end itself. The end result may be a forecast, a decision, or an insight. For a model to serve as an effective tool, it must be solidly built and skillfully used. *Spreadsheet engineering* refers to a variety of methods for building and using models effectively.
3. **Parameterization:** All models include numerical inputs. These inputs are referred to in different contexts as data, parameters, decision variables, assumptions, or, simply, inputs. Many insights come from varying these inputs in an organized way. To perform this task effectively, both the input values and the relationships that depend on them must be formulated appropriately. This process is called *parameterization*.
4. **Sensitivity Analysis:** When the problem at hand is ill structured, the modeling process will not be used to generate a single numerical solution. Rather, modeling will be used to better understand the problem—that is, to generate insights. Many insights can be found by varying one or more aspects of the model in a structured manner. This process is referred to as *sensitivity analysis*.
5. **Strategy Analysis:** Models are often used to evaluate alternative courses of action. Sometimes, the alternatives are set in advance, but very often the modeling process itself leads to the creation of new alternatives or new combinations of alternatives. *Strategy analysis* refers to the process within modeling of evaluating individual alternatives or combinations of alternatives and of inventing new alternatives, all in an effort to improve the overall outcome of the decision process.
6. **Iterative Modeling:** Novices often begin a modeling project by trying to build the ultimate model right from the start. This approach can lead to confusion, errors, wasted time, and sometimes, to complete failure of the modeling effort. Experts, on the other hand, build a series of increasingly complex and informative models. This process is called *iterative modeling*, and it is one of the keys to modeling success.

1.8 SUMMARY

A model is a simplified representation of reality. This book focuses on modeling ill-structured problems, for which no solution exists. Ill-structured problems cannot be solved, but they can be explored for insights. Novices and experts approach ill-structured problems in very different ways. The approach we develop in this book is designed to help you acquire the skills of expert modelers quickly.

Expert modelers possess both technical and craft skills. To help you learn the essential craft skills, we have organized the modeling process into four stages and have identified six powerful modeling tools that we use repeatedly to generate insights. In the next chapter, we discuss the modeling process and these six modeling tools in more detail.