Financial Modeling with Crystal Ball and Excel
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In Memory of Gerald Daniel Charnes, 1925–2005
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I wrote this book to help financial analysts and other interested parties learn how to build and interpret the results of Crystal Ball models for decision support. There are several books that exist to inform readers about Monte Carlo simulation in general. Many of these general books are listed in the References section of this book. This book focuses on using Crystal Ball in three main areas of finance: corporate finance, investments, and derivatives.

In 1982, University of Minnesota–Duluth Business School professor Henry Person introduced me to IFPS, computer software designed for financial planning, that we ran on VAX mainframe computers for an MBA class in quantitative methods. IFPS used a tabular layout for financial data similar to Excel’s, although it was more abstract than Excel’s because one had to print the data to see the layout in IFPS instead of working with Excel’s tabular display of the data on the screen. Gray (1996) describes what is evidently the latest, and perhaps final, version of this financial planning software. It is significant to me because IFPS included a Monte Carlo command that gave me my first glimpse of using a computer as a tool for financial risk analysis.

I was hooked. The next term, I took Henry’s class in discrete-event simulation based on Tom Schriber’s (1974) red GPSS textbook. I found the notion of system simulation fascinating. It made experimentation possible in a computer lab on models of real-world situations, just as the physical scale models of dams in the University of Minnesota–Twin Cities hydraulic laboratory made experimentation possible for the civil engineering professors during my days as an undergraduate student there. I saw many places where systems simulation could have been applied to the construction industry when I worked as a field engineer, but was unaware at the time of what simulation could accomplish.

More graduate school beckoned. After a year of teaching finance at the University of Washington in Seattle, I returned to the Twin Cities to eventually earn my doctorate in what became the Carlson School of Management. There I met David Kelton in 1986. His coauthored textbook, now in print as Law and Kelton (2000), got me started on my dissertation research that was done largely at the Minnesota Supercomputer Institute, where I ran FORTRAN programs on Cray supercomputers and graphed the resulting output on Sun workstations. It is amazing to me that anyone can do the same tasks today faster and more easily by using Crystal Ball on a personal computer. I wish that I had had today’s version of the personal computer and Crystal Ball available to me when I worked as an economic analyst at a Fortune 50 banking conglomerate in 1985.
As assistant professor in the management sciences department at the University of Miami in Coral Gables, Florida, I taught simulation to systems analysis and industrial engineering students in their undergraduate and graduate programs. When I moved to the University of Kansas in 1994, I had hopes of offering a similar course of study, but learned quickly that the business students here then were more interested in financial risk analysis than systems simulation. In 1996, I offered my first course in risk analysis at our suburban Kansas City campus to 30 MBA students, who loved the material but not the software we used—which was neither IFPS nor Crystal Ball.

I heard many complaints that term about the "clunky software that crashed all the time," but one student posed an alternative. She asked if I had heard of Crystal Ball, which was then in use by a couple of her associates at Sprint, the Kansas City–based telecommunications company. I checked it out, and the more I read in the Crystal Ball documentation, the more convinced I became that the authors were influenced by the same Law and Kelton text that I had studied in graduate school.

At the 1997 Winter Simulation Conference, I met Eric Wainwright, chief technical officer at Decisioneering, Inc. (DI), and one of the two creators of Crystal Ball, who confirmed my suspicions about our shared background. Thus began my friendship with DI that led to creation of Risk Analysis Using Crystal Ball, the multimedia training CD-ROM offered on the DI Web site. That effort, in collaboration with Larry Goldman, Lucie Trepanier, and Dave Fredericks, was a wholly enjoyable experience that gave me reason to believe—correctly—that the effort to produce this book would also be enjoyable.

About the same time I met Eric, I had the good fortune to work with David Kellogg at Sprint. His interest in Crystal Ball and invitation to present a series of lectures on its use as a decision support tool led to my development of training classes that were part of the Sprint University of Excellence offerings for several years. I am grateful to David and all the participants in those classes over the years for their helping me to hone the presentation of the ideas contained in this book. I am also grateful to Sprint and Nortel Networks for the financial support that led to development of the real options valuation tool described in Chapter 13. Other consulting clients will go unnamed here, but they also have influenced the presentation.

Microsoft Excel has become the lingua franca of business. Business associates in different industries and even some in different divisions of the same company often find it difficult to communicate with each other. However, virtually everyone who does business planning uses Excel in some capacity, if not exclusively. Though not always able to communicate in the same language, businesspeople around the globe are able to share their Excel spreadsheets. As with everything in our society, Excel has its critics. Yet the overwhelming number of users of this program make it foolish to deliberately shun its use.

My main criticism of Excel is obviated by use of the Crystal Ball application. Excel is extremely versatile in its ability to allow one to build deterministic models in many different business, engineering and scientific domains. Without Crystal Ball, it
is cumbersome to use Excel for stochastic modeling, but Crystal Ball’s graphical input and output features make it easy for analysts to build stochastic models in Excel.

In the 1970s, Jerry Wagner and the other founders of IFPS had a dream of creating software that would dominate the market for a computerized, plain-language tool for financial planning by executives. In the meantime, Microsoft Excel came to dominate the market for financial planning software. The combination of Excel, Crystal Ball, and OptQuest provides a powerful way for you to enhance your deterministic models by adding stochastic assumptions and finding optimal solutions to complex real-world problems. Building such models will give you greater insight into the problems you face, and may cause you to view your business in a new light.

**ORGANIZATION OF THIS BOOK**

This book is intended for analysts who wish to construct stochastic financial models, and anyone else interested in learning how to use Crystal Ball. Instructors with a practical bent may also find it useful as a supplement for courses in finance, management science, or industrial engineering.

The first six chapters of this book cover the features of Crystal Ball and OptQuest. Several examples are used to illustrate how these programs can be used to enhance deterministic Excel models for stochastic financial analysis and planning. The remaining seven chapters provide more detailed examples of how Crystal Ball and OptQuest can be used in financial risk analysis of investments in securities, derivatives, and real options. The technical appendices provide details about the methods used by Crystal Ball in its algorithms, and a description of some methods of variance reduction that can be employed to increase the precision of your simulation estimates. All of the models described in the book are available on the accompanying CD-ROM, as is a link to a Web site from which a trial version of Crystal Ball may be downloaded. The contents of each chapter and appendix are listed below:

Chapter 1 provides an overview of financial modeling and risk analysis through Monte Carlo simulation. It also contains a discussion of risk management and the benefits and limitations of Crystal Ball.

Chapter 2 describes how to specify and interpret Crystal Ball forecasts, the graphical and numerical summaries of the output measures generated during simulation. A retirement portfolio is used for an example.

Chapter 3 takes a helicopter view of building a Crystal Ball model. It starts out with a simple, deterministic business planning Excel model, and then shows you how to add stochastic assumptions to it with Crystal Ball. The chapter also contains a discussion of possible sources of error in your models and how they can be controlled.

Chapter 4 contains a deeper look at specifying Crystal Ball assumptions. It describes Crystal Ball’s basic distributions and shows you how to select distributions using historical data and/or your best expert judgment. The chapter also describes how to use, estimate, and specify correlations between assumptions in a Crystal Ball model.
Chapter 5 covers the use of decision variables in detail. A decision variable is an input whose value can be chosen by a decision maker. Decision variables enable you to harness the power of Crystal Ball and OptQuest to find optimal solutions. A first look at real options is included in this chapter.

Chapter 6 lists and explains the runtime options available in Crystal Ball as well as how and when to use them.

Chapter 7 discusses the relative merits of using the concepts of net present value and internal rate of return in deterministic and stochastic models. Examples include capital budgeting in finance and customer lifetime value in marketing.

Chapter 8 describes how to add stochastic assumptions to pro forma financial statements, then perform sensitivity analyses using tornado charts and Crystal Ball sensitivity charts.

Chapter 9 presents examples of using Crystal Ball to construct single- and multiperiod portfolio models. It also compares the Crystal Ball results for a single-period model to the analytic solution in a special case where an analytic solution can be found.

Chapter 10 discusses Value at Risk (VaR) and its more sophisticated cousin, Conditional Value at Risk (CVaR), the relative merits of VaR and CVaR, and how they are used in risk management.

Chapter 11 describes how to simulate financial time series with Crystal Ball. It covers random walks, geometric Brownian motion, and mean-reverting models, as well as a discussion of autocorrelation and how to detect it in empirical data.

Chapter 12 shows how to create Crystal Ball models for financial option pricing, covering European, American, and exotic options. It includes a model to demonstrate how to simulate returns from option strategies, using a bull spread as an example. It also shows how to use Crystal Ball to evaluate a relatively new derivative security, a principal-protected instrument.

Chapter 13 concludes the main body of the text with a discussion of how Crystal Ball and OptQuest are used to value real options. It also contains a brief review of the literature and some applications of real options analysis.

Appendix A contains short descriptions of each available Crystal Ball assumption. Each description includes the assumption’s parameters, probability mass or density function, cumulative distribution function, mean, standard deviation, and notes about the distribution and/or its usage.

Appendix B provides a brief description of how Crystal Ball generates the random numbers and variates during the simulation process.

Appendix C describes some variance reduction techniques, methods by which an analyst changes a model to get more precise estimates from a fixed number of trials during a simulation.

Appendix D provides information on downloading the Crystal Ball software and Excel files that are used in this book.

Appendix E contains citations for the references in the text to academic and practitioner literature relating to financial modeling and risk analysis. A glossary is also included.
For their conversations and help (unwitting, by some) in writing this book I would like to thank: Chris Anderson, Bill Beedles, George Bittlingmayer, David Blankinship, Eric Butz, Sarah Charnes, Barry Cobb, Tom Cowherd Jr., Riza Demirer, Amy Dougan, Bill Falloon, Dave Fredericks, Larry Goldman, Douglas Hague, Emilie Herman, Steve Hillmer, Mark Hirschey, Joe B. Jones, David Kellogg, Paul Koch, Mike Krieger, Chad Lander, Michael Lisk, Howard Marmorstein, Samik Raychaudhuri, Catherine Shenoy, Prakash Shenoy, Steve Terbovich, Michael Tognetti, Lucie Trepanier, Eric Wainwright, Bruce Wallace, and Laura Walsh. Special thanks go to Suzanne Swain Charnes for help with editing and time taken to indulge my interest in Crystal Ball over the years.

I enjoyed writing this book, and hope that it helps you learn how to build stochastic models of realistic situations important to you. I will appreciate any feedback that you send to jcharnes@ku.edu.

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Lawrence, Kansas 2006
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Professor Charnes holds PhD (1989), MBA (1983), and Bachelor of Civil Engineering (1980) degrees from the University of Minnesota. Before earning his doctorate, he worked as a surveyor, draftsman, field engineer, and quality-control engineer on numerous construction projects in Minnesota, Iowa, and Maryland. He has served as president of the Institute for Operations Research and the Management Sciences (INFORMS) College on Simulation, and proceedings coeditor (1996) and program chair (2002) for the Winter Simulation Conferences.
Life is stochastic. Although proponents of determinism might state otherwise, anyone who works in business or finance today knows quite well that future events are highly unpredictable. We often proceed by planning for the worst outcome while hoping for the best, but most of us are painfully aware from experience that there are many risks and uncertainties associated with any business endeavor.

Many analysts start creating financial models of risky situations with a base case constructed by making their best guess at the most likely value for each of the important inputs and building a spreadsheet model to calculate the output values that interest them. Then they account for uncertainty by thinking of how each input in turn might deviate from the best guess and letting the spreadsheet calculate the consequences for the outputs. Such a “what-if” analysis provides insight into the sensitivity of the outputs to one-at-a-time changes in the inputs.

Another common procedure is to calculate three scenarios: best case, worst case and most likely. This is done by inserting the best possible, worst possible, and most likely values for each key input, then calculating the best-case outputs when each input is at its best possible value; the worst-case outputs when each input is at its worst possible value; and using the base case as the most likely scenario. Scenario analysis shows the ranges of possibilities for the outputs, but gives no idea of the likelihood of output values falling between the extremes.

What-if and scenario analysis are good ways to get started, but there are more sophisticated techniques for analyzing and managing risk and uncertainty. This book is designed to help you use the software programs Crystal Ball and Excel to develop financial models for risk analysis. The spreadsheet program Excel has dramatically changed financial analysis in the past 30 years, and Crystal Ball extends the capability of Excel by allowing you to add stochastic assumptions to your spreadsheets. Adding stochastic assumptions provides a clearer picture of the possibilities for each of the outputs of interest. Reading this book and following the examples will help you use Crystal Ball to enhance your risk analysis capabilities.

Throughout the book, I use the word *stochastic* as a synonym for *random* or *probabilistic*, and as an antonym for *deterministic*. The majority of spreadsheet models in use today are deterministic, but every spreadsheet user knows at some level that there is a degree of uncertainty about each of the inputs to his or her models.
Crystal Ball enables you to use a systematic approach to account for uncertainty in your spreadsheet models.

The first six chapters of this book demonstrate how to use Crystal Ball. The remainder of the text provides examples of using Crystal Ball models to help solve problems in corporate finance, investments, and financial risk management. The appendices provide technical details about what goes on under the hood of the Crystal Ball engine.

This chapter is an overview of financial modeling and risk analysis. Some example applications are listed below where these tools provide insights that might not otherwise come to light, and you get a glimpse of how straightforward it is to assess financial risk using Crystal Ball and Excel. For a simple model that is already built and ready to run, we will interpret the output and analyze the model’s sensitivity to changes in its inputs. The chapter concludes with a discussion of the benefits and limitations of risk analysis with Crystal Ball and Excel.

**FINANCIAL MODELING**

For the purposes of this book, financial modeling is the construction and use of a spreadsheet depiction of a company’s or an individual’s past, present, or future business operations. To learn more about deterministic financial modeling, see Proctor (2004), Sengupta (2004), or Koller, Goedhart, and Wessels (2005). For each situation where we wish to use a stochastic model, we begin with a deterministic Excel model, then add stochastic assumptions with Crystal Ball to generate stochastic forecasts. By analyzing the stochastic forecasts statistically, we can make inferences about the riskiness of the business operations described by the model. The risk analysis process became much easier and more widely available with the introduction of Crystal Ball to the marketplace in 1987.

**RISK ANALYSIS**

The first recorded instances of risk analysis are the practices of the Asipu people of the Tigris-Euphrates valley about 3200 B.C. (Covello and Mumpower 1985). The Asipu would serve as consultants for difficult decisions such as a proposed marriage arrangement, or the location of a suitable building site. They would list the alternative actions under consideration and collect data on the likely outcomes of each alternative. The priest-like Asipu would interpret signs from the gods, then compare the alternatives systematically. Upon completion of their analysis, they would etch a final report to the client on a clay tablet, complete with a recommendation of the most favorable alternative (Oppenheim 1977).

According to the *Oxford English Dictionary* (Brown 2002), the term risk analysis means the “systematic investigation and forecasting of risks in business and commerce.” The word risk comes through French, Latin, and Italian from
the Greek word *rhiza*, in reference to sailors navigating among cliffs. Note that although some authorities believe that *risk* is derived from the Arabian word *rizq*, meaning “subsistence” it is difficult to explain how this meaning developed into that of “danger” (Klein 1967). If you bought this book to help you analyze business problems, I will bet that you have no trouble seeing the connection between the risks of managing a business and the perils of navigating a sailing vessel around cliffs and barely submerged rocks that can damage the hull and sink the ship.

Imagine an ancient Greek mariner piloting a ship as it approaches a cliff or point of rocks in uncharted waters. Another sailor is on lookout in the crow’s nest at the top of the mast to give the earliest possible warning about how far down into the water an outcrop from the cliff might be. A navigator nearby with sextant and compass is keeping track of where the ship has been and the direction in which it’s headed. His lookout warns him at the first sign of trouble ahead, but it is up to the pilot to decide how wide to take the turn around the cliff. Cutting the corner too close can save time but might sink the ship. Veering far from the edge is safer, but adds costly travel time.

In navigating a strait between two cliffs, the pilot’s decision is even more difficult. Being too far from one cliff can mean being too close to the opposing cliff. The pilot must weigh the risks, use judgment and instinct to carefully choose a course, and then hope for the best as vessel and crew proceed through the strait.

It is the pilot’s job to take all of the available information into account and decide how best to sail the ship in uncharted waters. The pilot wants a clear analysis of all the dangers and opportunities that lie ahead, in order to decide whether the potential time savings of the ship’s chosen course outweigh the disastrous consequences of hull damage. Even though the ship may have been through many different straits in the past, the pilot needs a systematic investigation and forecasting of the risks associated with the planned course through each new strait encountered during the voyage.

If you are running a business (or are an analyst helping to run a business), you are often in situations conceptually similar to those facing the pilot of a sailing vessel in uncharted waters. You know where your business has been, and you are always on the lookout for dangers and opportunities on the horizon. You operate in an environment fraught with uncertainty. You know that future circumstances can affect you and your business greatly, and you want to be prepared for what might happen. In many situations, you need to weigh the favorable and unfavorable consequences of some decision and then choose a course of action. Similar to a ship pilot, it is your job to decide how best to navigate the straits of your business environment. What do you do?

Fortunately, mathematicians such as Simon LaPlace and Blaise Pascal developed the fundamental underpinnings of risk analysis in the seventeenth century by devising the mathematical methods now used in probability theory (Ore 1960). From these precepts came the science of statistics. “What?” you ask, “I studied probability and statistics in college and hated every minute of them. I thought I was done with that stuff. How can it help me?”
In short, probability and statistics help you weigh the potential rewards and punishments associated with the decisions you face. This book shows you how to use Crystal Ball to add probabilistic assumptions and statistical forecasts to spreadsheet models of a wide variety of financial problems. In the end, you still must make decisions based on your best judgment and instincts, but judicious use of the methods of probability and statistics that we go through in this book will help you in several ways.

The modeling process described here enables you to investigate many different possibilities, hone your intuition, and use state-of-the-art software tools that are extremely beneficial for managing risk in dynamic business environments. The risk analysis process forces you to think through the possible consequences of your decisions. This helps you gain comfort that the course of action you select is the best one to take based on the information available at the time you make the decision. Risk analysis is the quantification of the consequences of uncertainty in a situation of interest, and Crystal Ball is the tool for carrying it out.

**MONTE CARLO SIMULATION**

Risk analysis using Crystal Ball relies on developing a mathematical model in Excel that represents a situation of interest. After you develop the deterministic model, you replace point estimates with probability distribution assumptions and forecast the distribution of the output. The forecasted output distribution is used to assess the riskiness of the situation.

For simple models, the output distribution can be found mathematically to give an analytic solution. For example, consider the simple cost equation

\[
\text{(Total Cost)} = \$100 + 15 \times (\text{Quantity Produced}),
\]

where (Quantity Produced) is modelled as a normal probability distribution with mean, \(\mu = 50\), and standard deviation, \(\sigma = 10\), and we want to know the probability that (Total Cost) is greater than \$900. We don’t need Crystal Ball for this situation because we can easily obtain an analytic solution.

A result in probability theory holds that if a random variable \(X\) follows the normal distribution with mean, \(\mu\), and standard deviation, \(\sigma\), then the random variable \(Y = a + bX\) will also be normally distributed with mean, \(a + b\mu\), and standard deviation, \(b\sigma\). Therefore, we can easily determine that (Total Cost) is normally distributed with mean, \(100 + (15 \times 50) = \$850\), and standard deviation, \(15 \times 10 = \$150\). Using a table of cumulative probabilities for the standard normal distribution, or using the Excel function \(=1-\text{NORMDIST}(900,850,150, \text{TRUE})\), we can find that the probability is 36.94 percent that (Total Cost) is greater than \$900. See the file Analytic.xls for these calculations, along with a Crystal Ball model that validates the solution.
In practice however, it is easy to find situations that are too difficult for most analysts to solve analytically. For example, consider a simple situation where unit sales, $S$, follow the Poisson distribution with mean 10; price, $P$, is lognormally distributed with mean $50 and standard deviation $10; variable cost percentage, $V$, has the beta distribution with parameters minimum = 0%, maximum = 100%, alpha = 2, and beta = 3; and fixed cost, $F = $100. Then profit, $\pi$, is calculated as

$$\pi = SP(1 - V) - F$$ (1.1)

in the Profit.xls model shown in Figure 1.1. The stochastic assumptions in Profit.xls are shown in Figure 1.2. For this model, it is easy to obtain a forecast distribution for profit with Crystal Ball and find the probability of making a positive profit to be approximately 76 percent (Figure 1.3), but it is not so easy to determine the distribution mathematically and obtain the probability of positive profit by analytic solution.

Further, Crystal Ball enables us do sensitivity analysis very easily. The sensitivity chart in Figure 1.4 shows that most of the variation in profit arises from the Assumption $V$, the variable cost percentage. If we are able to control this variable, then the model shows that we can reduce the variation of profit by reducing the variation in $V$. If this variable is beyond our control, the chart indicates that we should work first on $V$ when we are fine-tuning the model by improving our estimates of the assumption variables.

With Crystal Ball, we obtain an approximate solution using Monte Carlo simulation to generate the output distribution. One of the features of Monte Carlo
is that the more simulation trials we run, the closer is our approximation to the true distribution. The technique of Monte Carlo simulation has been used for this purpose for many years by scientists and engineers working with large and expensive mainframe computers. In combination with today’s small and inexpensive personal computers, Crystal Ball and Excel bring to everyone the ability to run Monte Carlo simulations on a PC.

In statistics, one of the earliest uses of simulation (albeit without a computer), was that by the mathematical statistician William S. Gossett, who used the pen name “Student” to conceal his identity and appease his employers at Guinness brewing company. To verify his mathematical derivations, Gossett repeatedly drew random samples of numbers from a bowl, wrote them down, and painstakingly made his calculations. The results he obtained were within the tolerances expected from an experiment involving random sampling. Gossett’s sampling experiments are conceptually similar to what we do on computers today, but Crystal Ball does for us in seconds what must have taken Gossett weeks or months to do by hand in his day.
**FIGURE 1.3** Forecast distribution for the simple profit model. The certainty of 75.74 percent for the range from 0.00 to infinity is the Crystal Ball estimate of the probability of positive profit, $Pr(\pi > 0)$ for the model specified by Expression 1.1.

**FIGURE 1.4** Sensitivity chart for the simple profit model. The input variables (assumptions) $P$, $S$, and $V$ are listed from top to bottom in decreasing order of their impact on the output variable (forecast), profit.
The term *Monte Carlo* originated in a conversation between two mathematicians employed by Los Alamos National Laboratory as a code word for their secret work on the atomic bomb (Macrae 1992). John von Neumann and Stanislaw Ulam applied Monte Carlo methods to problems involving direct simulation of behavior concerned with random neutron diffusion in fissionable material (Rubinstein 1981). The name was motivated by the similarity of the computer-generated results to the action of the gambling devices used at the casinos in the city of Monte Carlo in the principality of Monaco. The term caught on and is now widely used in finance, science, and engineering.

**RISK MANAGEMENT**

When analyzing risk with the methods presented in this book you will be able to quantify the consequences of uncertainty by answering three main questions:

1. What can happen?
2. How likely is it to happen?
3. Given that it occurs, what are the consequences?

All good managers go through a process by which they consider these questions somehow, even if subconsciously. By taking the time to answer the questions in quantifiable terms, you will develop deeper insight into the problems you face.

Risk analysis is part of a broader set of methods called *risk management*, which also seeks to find answers to three main questions:

1. What can be done?
2. What options are available?
3. What are the associated trade-offs in terms of costs, benefits, and risks?

It is your job as a manager or analyst to identify what can be done and what options are available, but once you have done so, the methods in this book will help you investigate the associated trade-offs in terms of costs, benefits, and risks.

Risk analysts often claim that much of the benefit of using Crystal Ball comes just from going through the process used to develop and fine-tune their models. The risk analysis process helps you develop insights into a problem more quickly than you would without it. In a sense, the intent of this book is to help save you some of the time and tuition you might otherwise pay in the school of hard knocks to reach good decisions.

**BENEFITS AND LIMITATIONS OF USING CRYSTAL BALL**

This section describes some of the benefits and the limitations of using Crystal Ball and Excel for risk analysis. When it is applicable, diligent use of these tools yields
deeper insight and understanding that will lead to better decision making. However, the tools have their limits as described below.

**Benefits**

- Careful study of the situation being modeled usually reveals the key input factors that lead to success. Sometimes it will become obvious what these factors are during model building. However, Crystal Ball has built-in sensitivity analysis tools to help identify the key input factors.
- As mistakes are costly, it is better to evaluate before implementation. A valid model of a situation can help save much time and expense compared to experimenting with aspects of the actual situation to see what happens. This book is intended to help you build valid models.
- Computer hardware and software make simulation easy. Until recently, the use of Monte Carlo simulation was limited to those who had access to large mainframe computers and the expertise to program them. Today’s personal computers have the same computational horsepower as yesterday’s mainframes. Crystal Ball has been developed over the years to make the addition of stochastic inputs and the calculation of output statistics as easy as possible.
- Realistic situations can be analyzed with relatively simple models. While many realistic situations have a host of potential complications, most often just a few of these have the greatest effect on the outputs. Crystal Ball’s sensitivity analysis features help you identify the effects of the factors having the greatest impact.
- Risk analysis can be a convincing agent for change. For those who understand the modeling process and the output produced by Crystal Ball, experimenting with the model can demonstrate very well the impact of changes to the system. If you have earned the buy-in of key decision makers, the model can be a powerfully persuasive tool.

**Limitations**

- Validity of the input data is essential. As with any other computer program, the output is only as good as the input. The aphorism “garbage in, garbage out” will always be true for Crystal Ball models as it will be for every computer program.
- If you can’t model it, you can’t simulate it. Your ability to build Crystal Ball models is subject to the limitations of Excel. If you cannot build an Excel spreadsheet to represent the situation, then you cannot use Crystal Ball for simulation. Fortunately, the hundreds of functions built into Excel make it very versatile, and Crystal Ball allows you to use Excel’s VBA capabilities if necessary for specialized purposes.
- Risk analysis requires expert insight to make decisions. Crystal Ball will not make decisions for you. It will help you gain insight into the problem, but you must still reach conclusions and make decisions based on your judgment and intuition about the situation you are analyzing.