Table 1-1 Single-Point Estimates of the Cash Flows for PsychoCeramic Sciences, Inc.

	A	B	C	D	E	F	G
1					Discount	Net Present	Inflation
2	Year	Inflow	Outflow	Net Flow	Factor	Value	Rate
3	A	B	C	D = (B − C)	$1/(1 + k + p)^t$	D × (Disc. Factor)	
4	2000*	$0	$125,000	−$125,000	1.0000	−$125,000	0.02
5	2000	0	100,000	−$100,000	0.8696	−$86,957	0.02
6	2001	0	90,000	−$90,000	0.7561	−$68,053	0.02
7	2002	50,000	0	$50,000	0.6575	$32,876	0.02
8	2003	120,000	15,000	$105,000	0.5718	$60,034	0.02
9	2004	115,000	0	$115,000	0.4972	$57,175	0.02
10	2005	105,000	15,000	$90,000	0.4323	$38,909	0.02
11	2006	97,000	0	$97,000	0.3759	$36,466	0.02
12	2007	90,000	15,000	$75,000	0.3269	$24,518	0.02
13	2008	82,000	0	$82,000	0.2843	$23,310	0.02
14	2009	65,000	0	$65,000	0.2472	$16,067	0.02
15	2009	35,000		$35,000	0.2472	$8,651	0.02
16							
17	Total	$759,000	$360,000	$399,000		$17,997	
18							
19		*t = 0 at the beginning of 2000					
20							
21	**Formulae**						
22	**Cell D4**		= (B4 − C4) copy to D5:D15				
23	**Cell E4**		= 1/(1 + .13 + .02)^0				
24	**Cell E5**		= 1/(1 + .13 + .02)^1				
25	**Cell E6**		= 1/(1 + .13 + .02)^(A6 − 1999) copy to E7:E15				
26	**Cell F4**		= D4*E4 copy to F5:F15				
27	**Cell B17**		= Sum (B4:B15) copy to C17, D17, F17				

Therefore, we will assume that the triangular distribution will give us a reasonably good fit for the inflow variables.

The hurdle rate of return is typically fixed by the firm, so the only remaining variable is the rate of inflation that is included in finding the discount factor. We have assumed a 2 percent rate of inflation with a normal distribution, plus or minus 1 percent (i.e., ±1 percent represents ±3 standard deviations).

It is important to point out that approaches in which only the most likely estimate of each variable is used are equivalent to assuming that the input data are known with certainty. The major benefit of simulation is that it allows all possible values for each variable to be considered. Just as the distribution of possible values for a variable is a better reflection of reality than the single "most likely" value, the distribution of outcomes developed by simulation is a better forecast of an uncertain

Table 1-2 Pessimistic, Most Likely, and Optimistic Estimates for Cash Inflows for PsychoCeramic Sciences, Inc.

	Minimum	Most Likely	Maximum
Year	**Inflow**	**Inflow**	**Inflow**
2002	$35,000	$50,000	$60,000
2003	$95,000	$120,000	$136,000
2004	$100,000	$115,000	$125,000
2005	$88,000	$105,000	$116,000
2006	$80,000	$97,000	$108,000
2007	$75,000	$90,000	$100,000
2008	$67,000	$82,000	$91,000
2009	$51,000	$65,000	$73,000
2009	$30,000	$35,000	$38,000
Total	$621,000	$759,000	$847,000

future reality than is a forecast of a single outcome. In general, precise forecasts will be "precisely wrong."

Using CB to run a Monte Carlo simulation requires us to define two types of cells in the Excel® spreadsheet. The cells that contain variables or parameters that we make assumptions about are defined as *assumption cells*. For the PsychoCeramic Sciences case, these are the cells in Table 1-1, columns B and G, the inflows and the rate of inflation, respectively. As noted above, we assume that the rate of inflation is normally distributed with a mean of 2 percent and a standard deviation of .33 percent. Likewise, we assume that yearly inflows can be modeled with a triangular distribution.

The cells that contain the outcomes (or results) we are interested in forecasting are called *forecast cells*. In PsychoCeramic's case we want to predict the NPV of the project. Hence, cell F17 in Table 1-1 is defined as a forecast cell. Each forecast cell typically contains a formula that is dependent on one or more of the assumption cells. Simulations may have many assumption and forecast cells, but they must have at least one of each. Before proceeding, open Crystal Ball® and make an Excel® spreadsheet copy of Table 1-1.

To illustrate the process of defining an assumption cell, consider cell B7, the cash inflow estimate for 2002. We can see from Table 1-2 that the minimum expected cash inflow is $35,000, the most likely cash flow is $50,000, and the maximum is $60,000. Also remember that we decided to model all these flows with a triangular distribution.

Given the information in Table 1-2, the process of defining the assumption cells and entering the pessimistic and optimistic data is straightforward and involves six steps:*

1. Click on cell **B7** to identify it as the relevant assumption cell.
2. Select the menu option **Cell** at the top of the screen.
3. From the dropdown menu that appears, select **Define Assumption**. CB's **Distribution Gallery** is now displayed as shown in Figure 1-6. (Note: it is important that the

* It is generally helpful for the reader to work the problem as we explain it. If Crystal Ball® has been installed on your computer but is not running, select **Tools**, and then **Add-ins** from Excel®'s menu. Next, click on the **CB** checkbox and select **OK**. If the CB Add-In has not been installed on your computer, consult your Excel® manual and the CD-ROM that accompanies this book to install it.

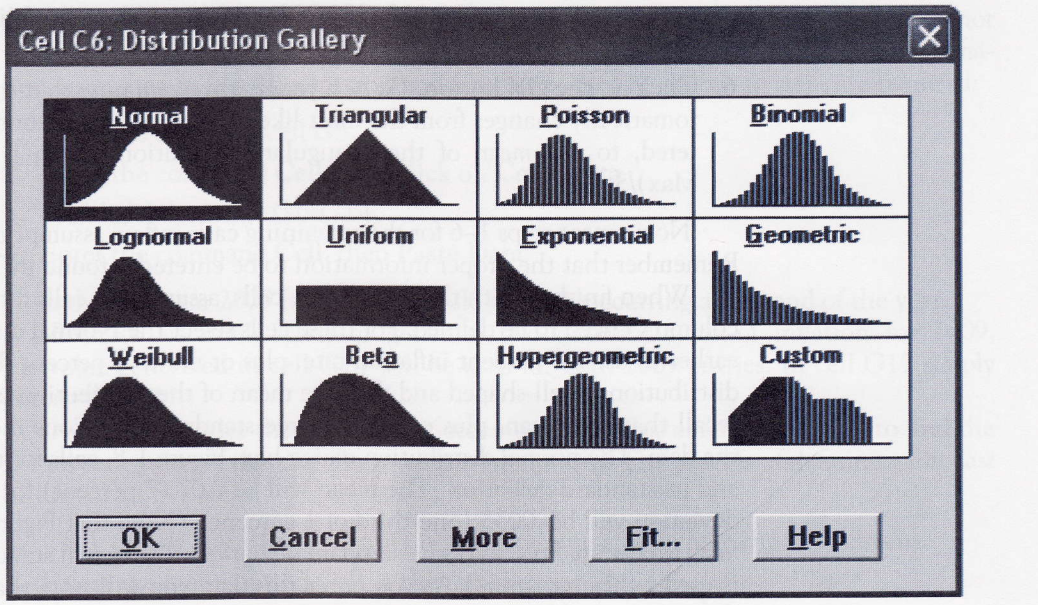

Figure 1-6 Crystal Ball® 2000 Distribution Gallery.

cell being defined as an assumption cell contain a numeric value. If the cell is empty or contains a label, an error message will be displayed during this step.)

4. CB allows you to choose from a wide variety of probability distributions. Double-click on the **Triangular** box to select it.

5. CB's Triangular Distribution dialog box is displayed as in Figure 1-7. In the **Assumption Name:** textbox at the top of the dialog box enter a descriptive label, for example, *Cash Inflow 2002*. Then, enter the pessimistic, most likely, and

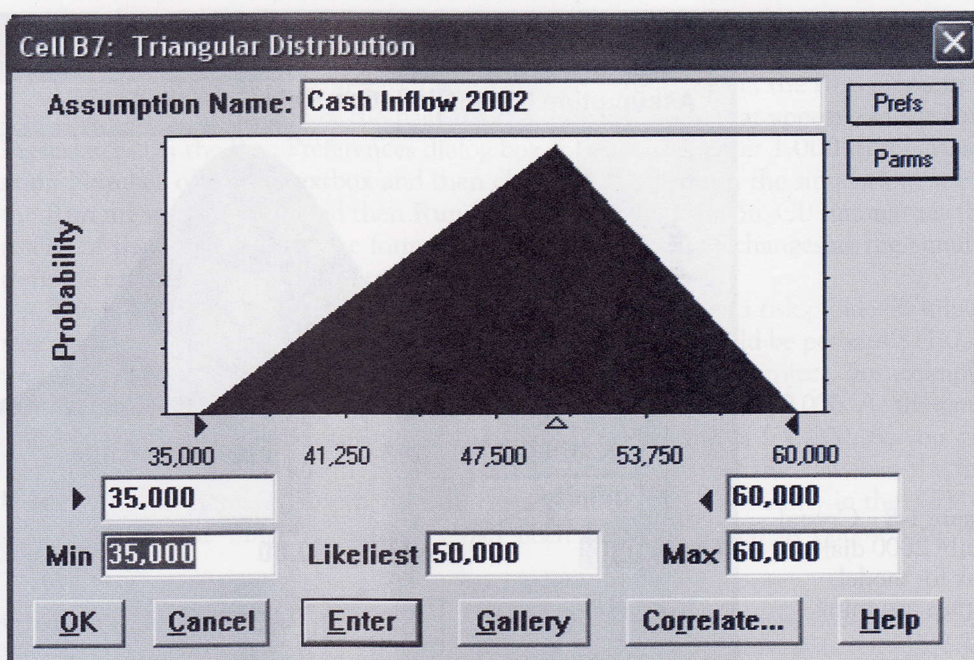

Figure 1-7 Crystal Ball® 2000 dialog box for model inputs assuming the triangular distribution.

optimistic costs of $35,000, $50,000, and $60,000 in the **Min**, **Likeliest**, and **Max** boxes, respectively.

6. Click on the **OK** button. (When you do this step, note that the inflow in cell B7 automatically changes from the most likely entry, or other number you might have entered, to the *mean* of the triangular distribution which is (Min + Likeliest + Max)/3.

Now repeat steps 1–6 for the remaining cash inflow assumption cells (cells B8:B15). Remember that the proper information to be entered is found in Table 1-2.

When finished with the cash inflow cells, assumption cells for the inflation values in column G need to be defined. For these cells select the **Normal** distribution. We decided earlier to use a 2 percent inflation rate, plus or minus 1 percent. Recall that the normal distribution is bell-shaped and that the mean of the distribution is its center point. Also recall that the mean, plus or minus three standard deviations includes 99+ percent of the data. The normal distribution dialog box, Figure 1-8, calls for the distribution's mean and its standard deviation. The mean will be 0.02 (2 percent) for all cells. The standard deviation will be .0033 (one-third of 1 percent). (Note that Figure 1-8 displays only the first two decimal places of the standard deviation. The actual standard deviation of .0033 is used by the program.) As you enter this data you will note that the distribution will show a mean of 2 percent and a range from 1 percent to 3 percent.

Notice that there are two cash inflows for the year 2000, but one of those occurs at the beginning of the year and the other at the end of the year. The entry at the beginning of the year is not discounted so there is no need for an entry in G4. (Some versions of CB insist on an entry, however, so go ahead and enter 2 percent with zero standard deviation.) Move on to cell G5, in the **Assumption Name:** textbox for the cell G5 enter *Inflation Rate*. Then enter .02 in the **Mean** textbox and .0033 in the **Std Dev** textbox. While the rate of inflation could be entered in a similar fashion for the following years, a more efficient approach is to copy the assumption cell G5 to G6:G14. Because the inflation rate is now a variable, we must change the formulae for column E as noted in Table 1-3. Since

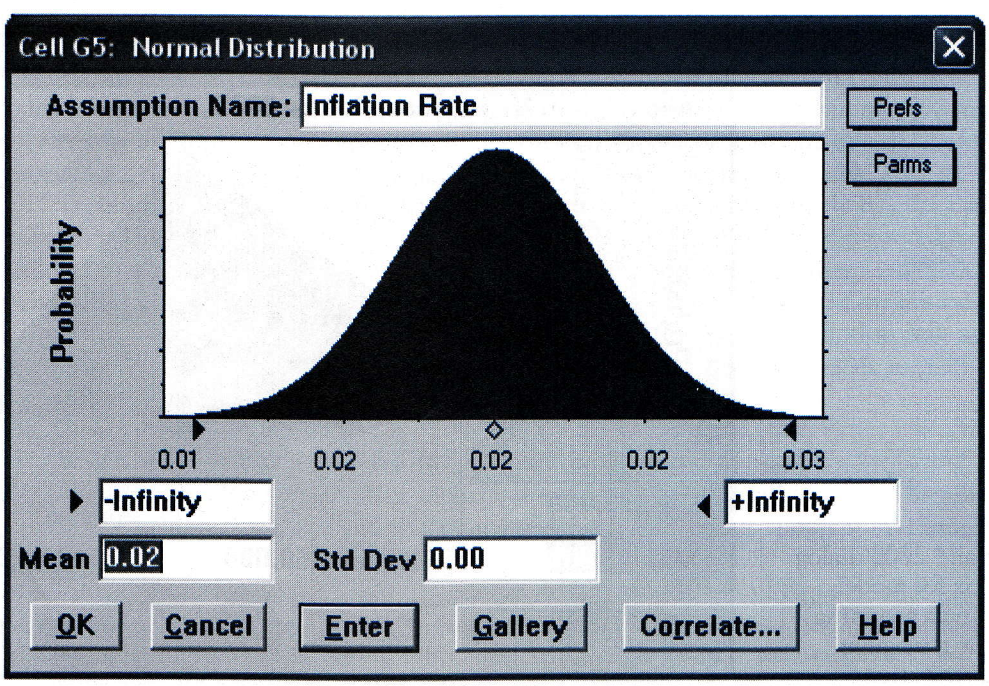

Figure 1-8 Crystal Ball® 2000 dialog box for model inputs assuming the normal distribution.

CB is an add-in to Excel®, simply using Excel®'s copy and paste commands will not work. Rather, CB's own copy and paste commands must be used to copy the information contained in both assumption and forecast cells. The following steps are required:

1. Place the cursor on cell **G5**.
2. Enter the command **Cell**, then click on **Copy Data**.
3. Highlight the range **G6:G14**.
4. Enter the command **Cell**, then **Paste Data**.

Note that the year 2009 has two cash inflows, both occurring at the end of the year.

Because we don't want to generate two different rates of inflation for 2009, the value generated in cell G14 will be used for both 2009 entries. In cell G15 simply enter **=G14**.*

Now we consider the forecast or outcome cell. In this example we wish to find the net present value of the cash flows we have estimated. The process of defining a forecast cell involves five steps.

1. Click on the cell **F17** to identify it as containing an outcome that interests us.
2. Select the menu option **Cell** at the top of the screen.
3. From the dropdown menu that appears, select **Define Forecast** . . .
4. CB's Define Forecast dialog box is now displayed. In the **Forecast Name**: textbox, enter a descriptive name such as *Net Present Value of Project*. Then enter a descriptive label such as *Dollars* in the **Units**: textbox.
5. Click **OK**. There is only one Forecast cell in this example, but in other situations there may be several. Use the same five steps to define each of them.

When you have completed all entries, what was Table 1-1 is now changed and appears as Table 1-3.

We are ready to simulate. CB randomly selects a value for each assumption cell based on the probability distributions which we specified and then calculates the net present value of the cell values selected. By repeating this process many times, we can get a sense of the distribution of possible outcomes.

To simulate the model you have constructed 1000 times, select the **Run** menu item from the toolbar at the top of the page. In the dropdown box that appears, select **Run Preferences**. In the Run Preferences dialog box that appears, enter **1,000** in the **Maximum Number of Trials** textbox and then click **OK**. To perform the simulation, select the **Run** menu item again and then **Run** from the dropdown menu. CB summarizes the results of the simulation in the form of a frequency chart that changes as the simulations are executed. See the results of one such run in Figure 1-9.

The frequency chart in Figure 1-9 is sometimes referred to as a risk profile. While in this particular case our best guess of the NPV for this project would be perhaps $11,000, we see that there is considerable uncertainty associated with the project. For example, the frequency diagram shows the project could yield a NPV below −$9,000. At the same time, we see that this same project could yield a NPV in excess of $30,000. As you can see, the amount of uncertainty increases as the width or range of the values in the frequency diagram increases. In other words, there would be less uncertainty in the NPV of this project if the range of outcomes had been $2,000–$15,000 as opposed to the

* You may wonder why we spend time with this kind of detail. The reason is simple. Once you have dealt with this kind of problem, and it is common in such analyses, you won't make this mistake in the real world where having such errors called to your attention may be quite painful.

Table 1-3 Three-Point Estimate of Cash Flows and Inflation Rate for PsychoCeramic Sciences, Inc. All Assumption and Forecast Cells Defined

Year	Inflow	Outflow	Net Flow	Discount Factor	Net Present Value	Inflation Rate
A	B	C	D = (B − C)	$1/(1 + k + p)^t$	× (Disc. Factor)	
2000*	$0	$125,000	($125,000)	1	($125,000)	0.02
2000	0	100,000	($100,000)	0.8696	($86,957)	0.02
2001	0	90,000	($90,000)	0.7561	($68,053)	0.02
2002	48,333	0	$48,333	0.6575	$31,780	0.02
2003	117,000	15,000	$102,000	0.5718	$58,319	0.02
2004	113,333	0	$113,333	0.4972	$56,347	0.02
2005	103,000	15,000	$88,000	0.4323	$38,045	0.02
2006	95,000	0	$95,000	0.3759	$35,714	0.02
2007	88,333	15,000	$73,333	0.3269	$23,973	0.02
2008	80,000	0	$80,000	0.2843	$22,741	0.02
2009	63,000	0	$63,000	0.2472	$15,573	0.02
2009	34,333		$34,333	0.2472	$8,487	
Total	$742,333	$360,000	$382,333		$10,968	
	*t = 0 at the beginning of 2000					
Formulae						
Cell D4		= (B4 − C4) copy to D5:D15				
Cell E4		= 1/(1 + .13 + G4)^0				
Cell E5		= 1/(1 + .13 + G5)^1				
Cell E6		= 1/(1 + .13 + G6)^(A6 − 1999)			copy to E7:E15	
Cell F4		= D4*E4 copy to F5:F15				
CellB17		= Sum(B4:B15) copy to C17, D17, F17				

range shown in the chart that goes from −9,289 to $30,772. And as we have stated before, as the level of uncertainty increases, so does the risk.

CB provides considerable information about the forecast cell in addition to the frequency chart including percentile information, summary statistics, a cumulative chart, and a reverse cumulative chart. For example, to see the summary statistics for a forecast cell, select **View** from the Forecast dialogue box toolbar and then select **Statistics** from the dropdown menu that appears. The Statistics view for the frequency chart (Figure 1-9) is illustrated in Figure 1-10.

Figure 1-10 contains some interesting information. Both the mean and median NPV resulting from the simulation are nicely positive and thus indicate a return above the hurdle rate of 13 percent (15 percent including inflation). There are, however, several negative outcomes, those showing a return below the hurdle rate. What is the like-

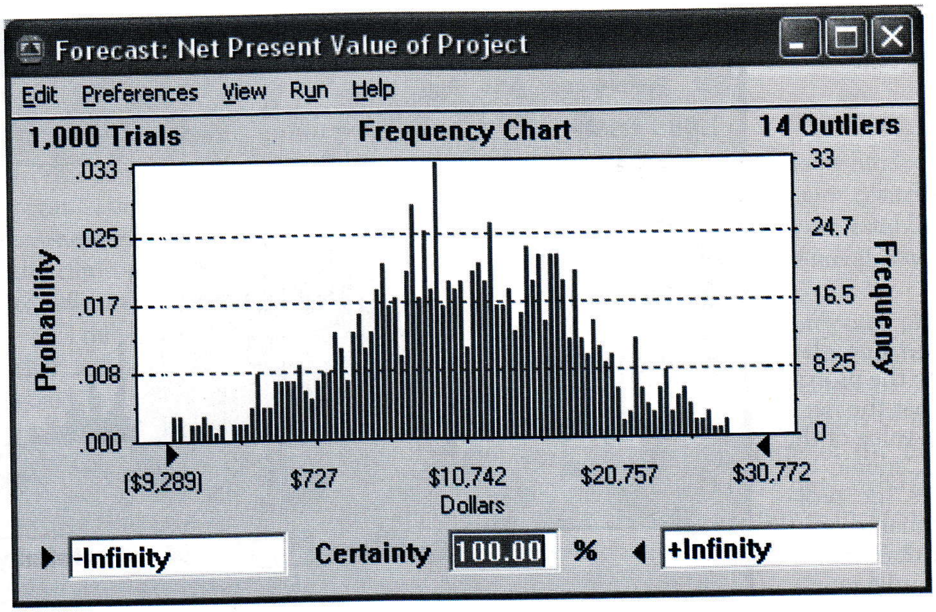

Figure 1-9 Frequency chart of the simulation output for net present value of Psycho-Ceramic Sciences, Inc. Project.

lihood that this project will achieve a positive NPV, and therefore produce a rate of return at or above the hurdle rate? With CB, the answer is easy. Using the display shown in Figure 1-9, erase *–Infinity* from the box in the lower left corner. Type **0** (or *1*) in that box and press **Enter**. Figure 1-9 now changes as shown in Figure 1-11. The boxes at the bottom of Figure 1-11 show that given our estimates and assumptions of the cash flows and the rate of inflation, there is a .90+ probability that the project will have an NPV between zero and infinity, that is, a rate of return at or above the 13 percent hurdle rate.

Even in this simple example the power of including uncertainty in project selection should be obvious. Because a manager is always uncertain about the amount of uncertainty, it is also possible to examine various levels of uncertainty quite easily using CB.

Forecast: Net Present Value of Project

Edit Preferences View Run Help

Cell F17 — Statistics

Statistic	Value
Trials	1,000
Mean	$10,772
Median	$10,697
Mode	---
Standard Deviation	$7,716
Variance	$59,538,051
Skewness	-0.08
Kurtosis	3.03
Coeff. of Variability	0.72
Range Minimum	($11,164)
Range Maximum	$35,755
Range Width	$46,919
Mean Std. Error	$244.00

Figure 1-10 Summary statistics of the PsychoCeramic Sciences, Inc. simulation.

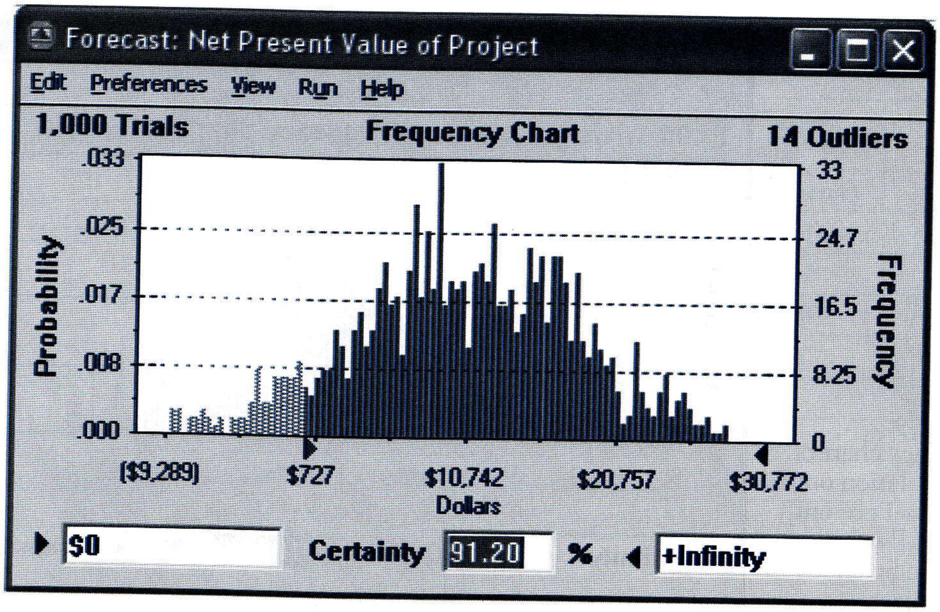

Figure 1-11 Calculating the probability that the net present value of the PsychoCeramic Sciences, Inc. project is equal to or greater than the firm's hurdle rate.

We could, for instance, alter the degree to which the inflow estimates are uncertain by expanding or contracting the degree to which optimistic and pessimistic estimates vary around the most likely estimate. We could increase or decrease the level of inflation. Simulation runs made with these changes provide us with the ability to examine just how sensitive the outcomes (forecasts) are to possible errors in the input data. This allows us to focus on the important risks and to ignore those that have little effect on our decisions. We strongly recommend the User Manual for users of CB (*Crystal Ball®* 2000 User Manual, 2000).

1.7 THE PROJECT PORTFOLIO PROCESS

The Project Portfolio Process (PPP) attempts to link the organization's projects directly to the goals and strategy of the organization. This occurs not only in the project's initiation and planning phases, but also throughout the life cycle of the projects as they are managed and eventually brought to completion. Thus, the PPP is also a means for monitoring and controlling the organization's strategic projects. On occasion this will mean shutting down projects prior to their completion because their risks have become excessive, their costs have escalated beyond their expected benefits, another (or a new) project does a better job of supporting the goals, or any of a variety of similar reasons. The steps in this process generally follow those described in Longman, Sandahl, and Speir (1999) and Englund and Graham (2000).

Step 1: Establish a Project Council

The main purpose of the project council is to establish and articulate a strategic direction for projects. The council will also be responsible for allocating funds to those projects that support the organization's goals and controlling the allocation of resources and skills to the projects. In addition to senior management, other appropriate members of the project council include: project managers of major projects; the head of the Project Management Office (if one exists); particularly relevant general managers, that is, those

1.6 CONFRONTING UNCERTAINTY—THE MANAGEMENT OF RISK

As we argue throughout this book, effective project management requires an ability to deal with uncertainty. The time required to complete a project, the availability and costs of key resources, the timing of solutions to technological problems, a wide variety of macroeconomic variables, the whims of a client, the actions taken by competitors, even the likelihood that the output of a project will perform as expected, all these exemplify the uncertainties encountered when managing projects. While there are actions that may be taken to reduce the uncertainty, no actions of a PM can ever eliminate it. Therefore, in today's turbulent business environment, effective decision making is predicated on an ability to manage the ambiguity that arises while we operate in a world characterized by uncertain information.

One approach that is particularly useful in helping us understand the implications of uncertain information is *risk analysis*. The essence of risk analysis is to make estimates or assumptions about the probability distributions associated with key parameters and variables and to use analytic decision models or Monte Carlo simulation models based on these distributions to evaluate the desirability of certain managerial decisions. Real-world problems are usually large enough that the use of analytic models is very difficult and time consuming. With modern computer software, simulation is not difficult.

A mathematical model of the situation is constructed and a simulation is run to determine the model's outcomes under various scenarios. The model is run (or replicated) repeatedly, starting from a different point each time based on random choices of values from the probability distributions of the input variables. Outputs of the model are used to construct statistical distributions of items of interest to decision makers, such as costs, profits, completion dates, or return on investment. These distributions are the *risk profiles* of the outcomes associated with a decision. Risk profiles can be considered by the manager when considering a decision, along with many other factors such as strategic concerns, behavioral issues, fit with the organization, and so on.

In the following section, using an example we have examined earlier, we illustrate how Crystal Ball® 2000 (CB), a widely used Excel® Add-In that is bundled with this book, can be used to improve the PM's understanding of the risks associated with managing projects.

Considering Uncertainty in Project Selection Decisions

Reconsider the PsychoCeramic Sciences example we solved in the section devoted to finding the discounted cash flows associated with a project. Setting this problem up on Excel® is straightforward, and the earlier solution is shown here for convenience as Table 1-1. We found that the project cleared the barrier of a 13 percent hurdle rate for acceptance. The net cash flow over the project's life is just under $400,000, and discounted at the hurdle rate plus 2 percent annual inflation, the net present value of the cash flow is about $18,000. The rate of inflation is shown in a separate column because it is another uncertain variable that should be included in the risk analysis.

Assume that the expenditures in this example are fixed by contract with an outside vendor so that there is no uncertainty about the outflows; there is, of course, uncertainty about the inflows. Suppose that the estimated inflows are as shown in Table 1-2 and include a minimum (pessimistic) estimate, a most likely estimate, and a maximum (optimistic) estimate. (In Chapter 5, "Scheduling the Project," we will deal in more detail with the methods and meaning of making such estimates.) Both the beta and the triangular statistical distributions are well suited for modeling variables with these three parameters, but fitting a beta distribution is complicated and not particularly intuitive.