Sensitivity Analysis

Sensitivity analysis is an important step in decision analysis. It helps you gain insight into the nature of decision problems, saving time and simplifying the analysis by avoiding undue modeling complexity. In this chapter, we will demonstrate the use of Sensitivity by performing a sensitivity analysis on a decision about a new product introduction.

In most analyses, only a few critical variables account for most of the uncertainty in the value measure. These variables are prime candidates for inclusion in the decision tree. Sensitivity identifies these critical variables.

The Sensitivity program is almost always linked with models written in a spreadsheet or programming language. For our example, we use an Excel spreadsheet model called New Product that calculates the financial implications related to introducing a new product in an existing market.

New Product Example

The Excel spreadsheet for the new product introduction model, New Product, is called Newprod.xls and can be found in the Super95 folder (Windows) or the Supertree folder (Macintosh).

The spreadsheet is divided into three sections. The top section contains the parameters used in the evaluation, the middle section contains the calculations, and the bottom section contains income and cash flow statements.

The variables section of the New Product spreadsheet is shown below in Figure 2.1. Column A contains descriptive labels for the variables, column B contains the values of each variable used in the calculations, column C contains the range names of the corresponding cell in column B. Columns D, E, and F contain the low, base, and high value of each variable respectively. Column G contains the index used in the formula in Column B (Value in Use) to choose the right value from columns D, E, and F (Low, Base, and High). Finally, columns I and J contain a description of the variable and its units.

CONSTANTS

VARIABLES						
Description	Value in Use Range Name	Low	Base	High	Units/Notes
Market share	35% mktshr	10%	35%	50%	peak market share
Market growth rate	2% mktgr	1%	2%	4%	annual compound growth rate
Price	2.4 price	$1.44	$2.40	$3.12	dollars per pound
Start year	1998 inityr	1997	1998	1999	year sales start

Figure 2.1

The remaining structure of the model is straightforward. The calculations depicted in Figure 2.2 are based on several assumptions: market growth of 2% per year; the new product introduction in 1998; market share growth for three years, flattening out at a peak value, and eventually beginning to decline; sufficient production equipment installed to meet the peak demand; all prices and costs growing with inflation. Figure 2.2 shows the first few columns of the calculations and income and cash flow sections of the spreadsheet. Results are shown to 2003, although the full spreadsheet continues for 20 years, to 2015 in column V.

New Product Example

CALCULATIONS								
Year	1996	1997	1998	1999	2000	2001	2002	2003
Market (million of pounds)	120	122	125	127	130	132	135	138
Market Share (%)	0%	0%	12%	23%	35%	35%	35%	35%
Volume (millions of pounds)	0	0	15	30	45	46	47	48
Revenue ($ million)	0.0	0.0	35.0	71.3	109.1	111.3	113.5	115.8
Variable Cost ($ million)	0.0	0.0	18.9	38.6	59.1	60.3	61.5	62.7
Fixed Cost ($ million)	0.0	0.0	6.0	6.0	6.0	6.0	6.0	6.0
Total machines	0	0	1	2	4	4	4	4
New machines	0	0	1	1	2	0	0	0
Capital Cost ($ million)	0.0	0.0	8.0	8.0	16.0	0.0	0.0	0.0
Undepreciated capital ($ million)	0.0	0.0	6.4	11.3	21.5	16.5	12.7	9.8
Tax depreciation ($ million)	0.0	0.0	1.6	2.8	5.4	4.1	3.2	2.4
Book depreciation ($ million)	0.0	0.0	1.6	2.8	5.4	4.1	3.2	2.4
Note: in this simple example, tax=book=declining balance depreciation								
Working capital ($ million)	0.0	0.0	4.2	8.6	13.1	13.4	13.6	13.9
Discount factor	1.00	0.93	0.86	0.79	0.74	0.68	0.63	0.58

INCOME AND CASH FLOW STATEMENT (US $ million)								
	1996	1997	1998	1999	2000	2001	2002	2003
Revenue	0.0	0.0	35.0	71.3	109.1	111.3	113.5	115.8
Variable Cost	0.0	0.0	18.9	38.6	59.1	60.3	61.5	62.7
Fixed Cost	0.0	0.0	6.0	6.0	6.0	6.0	6.0	6.0
Book Depreciation	0.0	0.0	1.6	2.8	5.4	4.1	3.2	2.4
IBIT	0.0	0.0	8.4	23.9	38.6	40.9	42.8	44.6
Taxes	0.0	0.0	3.4	9.5	15.5	16.3	17.1	17.8
Net Income	0.0	0.0	5.1	14.3	23.2	24.5	25.7	26.8
Capital Expense	0.0	0.0	8.0	8.0	16.0	0.0	0.0	0.0
Change in Working Capital	0.0	0.0	4.2	4.5	4.9	0.8	0.8	0.8
Cash Flow	0.0	0.0	-5.5	4.6	7.7	27.9	28.1	28.4
Cum Cash Flow	0.0	0.0	-5.5	-0.9	6.8	34.7	62.8	91.2
Disc Cash Flow	0.0	0.0	-4.8	3.7	5.7	19.0	17.7	16.6
Cum Disc Cash Flow	0.0	0.0	-4.8	-1.1	4.6	23.6	41.3	57.9

VALUE MEASURE
NPV (US $million) $152

Figure 2.2

Cell B80 contains the NPV (net present value) for the new product.
The sensitivity analysis will determine how sensitive this value is to
the uncertainty in the variables listed in the parameters section of
the spreadsheet. (NPV is a way of reducing a set of financial results
spread out over years to a single value today.)

Entering the Problem

To start the Sensitivity program, choose Sensitivity from the Windows Start menu or double-click the Sensitivity icon on the Macintosh. The main Sensitivity screen will appear and you can begin using the program. The menu bar at the top of the screen controls the options. There is also a toolbar for common menu items.

Base, Low, and High Values for Variables

The next step is to assemble the data for the analysis.

Sensitivity requires three values for each variable: base, low, and high. The base value is the median value of the possible range of values for the variable. In other words, for peak market share, there should be a 50 percent chance that the actual peak market share will turn out higher and a 50 percent chance it will turn out to be lower. This will usually be the value that you already have in the spreadsheet.

Similarly, the low value represents a 10 percent chance that the actual peak market share will turn out to be lower (or equal to) and a 90 percent chance that it will turn out to be higher. The high value represents a 10 percent chance that the actual peak market share will turn out to be higher and a 90 percent chance that it will turn out to be lower.

If you use these guidelines, all the variations will have the same meaning (80 percent probability of being within the range), and you can readily compare the importance of the uncertainty in the variables.

Linking to the Spreadsheet Model

The spreadsheet calculates the impact of variations in individual variables on the value measure. In the new product introduction example, the value measure is NPV.

To link Sensitivity to the spreadsheet model, select the Enter or Change Model command from the Structure menu:

1. Enter the name of the spreadsheet program (Excel, in this case) and click OK. Possible responses are Basic, Excel, IFPS, Lotus, Powersim, Quattro.

Entering the Problem

2. Click the Locate button to locate the spreadsheet (Super95 folder, newprod.xls). A dialog box will appear to enable you to open your spreadsheet—the spreadsheet is not opened at this point, but Sensitivity captures the information required to locate it.

3. To respond to the prompt Result name or cell address you can enter either the cell address *B80* or the Range name *NPV*. We suggest you use the range name because it is easier to read and remains constant even with manipulation of the spreadsheet.

4. To respond to the prompt Column in which to store results, you can enter the name of an empty column of the spreadsheet. For the New Product spreadsheet, *AA* is a good choice.

5. Automatic program call enables you to choose between two different modes of calling Excel. (The default is Automatic program call. The consequences of this choice are discussed in the Evaluation section of this chapter.)

The final line (resulting endpoint expression) is a shorthand expression created by Sensitivity for the information on the screen. E denotes Excel, the $ signs are separators, and next is the spreadsheet name and location. NPV is the range name (or cell address) for the cell containing the value measure, and AA denotes the empty spreadsheet column where results are temporarily stored.

When you are done entering all the information, the completed dialog box should look like the one in Figure 2.3. Click OK.
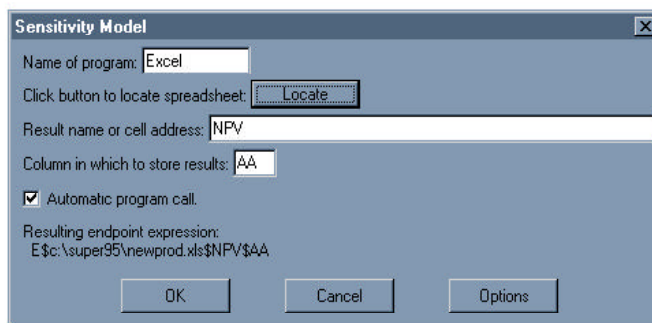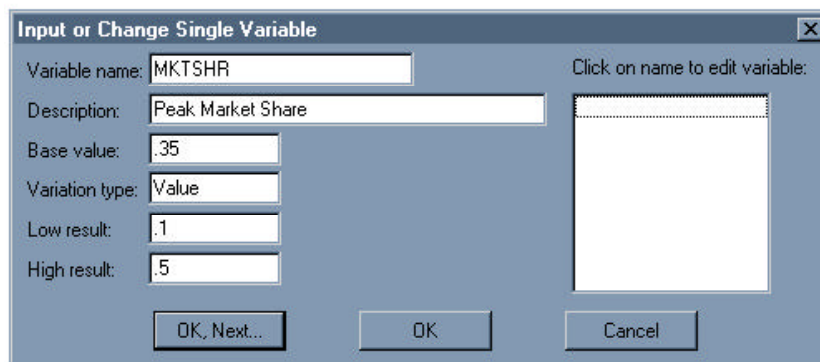

Figure 2.3

Entering the Problem

Inputting Variable Ranges

The next step is to enter the data. Choose the Input or Change Single Variable Data... command from the Structure menu. For the first variable entered, Sensitivity will request a descriptive name to use to label the output; enter *New Product Introduction Example*. (We have supplied typical values for entries here and below, but you can use others if you would like to experiment.)

Name the first variable *MKTSHR*, the range name in the spreadsheet for the peak market share value. Add a description, the base value, and designate the sensitivity type *VALUE*, to allow the high and low values to be directly input (as opposed to being calculated). The completed dialog box is shown in Figure 2.4.

Figure 2.4

Click the OK, Next... button and input information for MKTGR, the market growth rate. Designate the variation type *ADDITIVE*, meaning that the high (.02) and low (-.01) modifiers will be added to the base value (.02), producing a swing from .01 to .04. Figure 2.5 shows the display:

Entering the Problem

Figure 2.5

You can then click OK, Next... to move to the next variable, which is price. The variation type is *MULTIPLICATIVE*; the high (1.3) and low (0.6) modifiers will be multiplied by the base value (2.40) to produce 3.12 and 1.44 in this case.

Figure 2.6

The list of names under "Click on Name to Edit Variable:" indicates all variables that you have entered so far. Double-clicking a name in this list will recall the data for that variable.

Now that all variables have been entered, click OK and the Show Sensitivity Data screen appears.

Entering the Problem

Reviewing the Input Data

You can also select Show Sensitivity Data... from the Structure menu or from the toolbar. The screen will show the first three variables in Figure 2.7. To create interesting outputs, we have entered variations for ten additional variables. You can continue to enter all the variables listed in Figure 2.7 or you can open the file NEWPROD.ASN where all the variables have been entered for you.

Show Sensitivity Data

Sensitivity name: New Product Introduction Example
Model Name: E$c:\super95\newprod.xls$NPV$AA

VARIABLE	DESCRIPTION	BASE	TYPE	LOW	HIGH	STATUS
MKTSHR	Peak Market Share	.35	VAL	.1	.5	OLD
MKTGR	Market Growth Rate	.02	ADD	−.01	.02	OLD
PRICE	Price	2.4	MUL	.6	1.3	OLD
INITYR	Year Sales Start	1991	VAL	1990	1992	OLD
GROWTH	Years from Start to Peak	3	VAL	3	5	OLD
LIFE	Years from Start to Decline	11	VAL	7	15	OLD
DECLINE	Years in Decline	5	VAL	4	10	OLD
VARCOST	Unit Cost	1.3	ADD	−.2	.3	OLD
FIXCOST	Fixed Cost	6	MUL	.8	1.25	OLD
CAP	Machine Capacity	15	VAL	13	17	OLD
CAPCOST	Cost per Machine	8	VAL	7	10	OLD
WCCAP	Working Capital/Sales	.12	VAL	.1	.15	OLD
INFLRATE	Inflation Rate	.04	VAL	0	.08	OLD

Excel options:
  Open linked spreadsheets.

Figure 2.7

Note that in the last column, Sensitivity shows the status of each variable as new or old. New means that you have not yet evaluated or run the spreadsheet model to determine the sensitivity to that variable. Old means that the model has been evaluated for the variable indicated. This can save time if you add new variables or change the input data, because you need only evaluate the new ones.

Entering the Problem

Importing Variable Data

You can save time when entering the variables by using the Import Variable Data command from the Structure menu. (This option is valid for Excel spreadsheets only.) To do so, follow the two steps below.

1. Create a range name for the section of your spreadsheet containing the input variables. The first line of this spread-sheet must contain columns with the words,

    Description—contents of column, describe the variable

    Name—the range name for the Value in Use cell

    Low—the low value for the variable

    Base—the base value for the variable

    High—the high value for the variable

    The NewProd.xls file has a range called RD_inputtable (A22:L38) defined that contains the input data.

2. Choose Import Variable Data from Sensitivity's Structure menu.

    –   Accept the default name RD_inputtable

    –   Locate the spreadsheet.

    –   Enter a descriptive name such as "New Product Introduction Example."

    –   The Sensitivity Model dialog box appears. Enter "NPV" as the result name and "AA" as the column to store results. Note that the spreadsheet has already been located. Click OK and the Show Sensitivity Data screen appears.

Evaluating and Analyzing Sensitivities

Evaluating

The sensitivity data are now ready to be evaluated. Sensitivity establishes a base case by running the model once with all variables set to base values. Then it runs the model with each variable set first to its high value and then to its low value.

If you chose the automatic program call when naming the model for evaluation earlier in this section, Sensitivity will do all the work for you—this is recommended. If you chose the manual program call, Sensitivity will provide instructions on how to leave Sensitivity, run Excel, return to Sensitivity, and pick up the answers.

The first time you run Sensitivity, you may need to specify where the application Excel is located. You can do this by selecting the Enter or Change Model command from the Structure menu and clicking the Options button. You should then click the Locate button and locate the application.

After this is done, choose Evaluate Sensitivity from the Evaluate menu. Sensitivity will warn that you are about to embark on a possibly time-consuming process. (The example spreadsheet is small and only 13 variables are to be varied, so the evaluation should take less than a minute.) Answer *Yes*.

Analyzing the Results

After Sensitivity indicates all models are run (screen says "Total of 27 models run"), you can review the results.

To analyze the results, select Plot Results... from the Analyze menu, responding to the questions as shown in the dialog box in Figure 2.8.

The horizontal axis in Figure 2.8a shows NPV. The vertical bar cutting through the horizontal bars shows the base value of 152. The horizontal bars show how the model result (NPV) changes as each variable changes. You can see that as peak market share varies from .10 to .50 (the input numbers), NPV swings from 21 to 230.
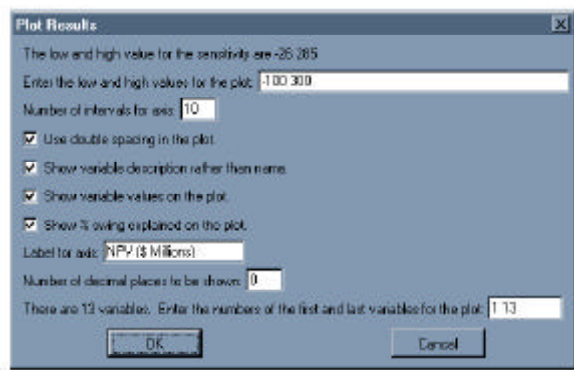
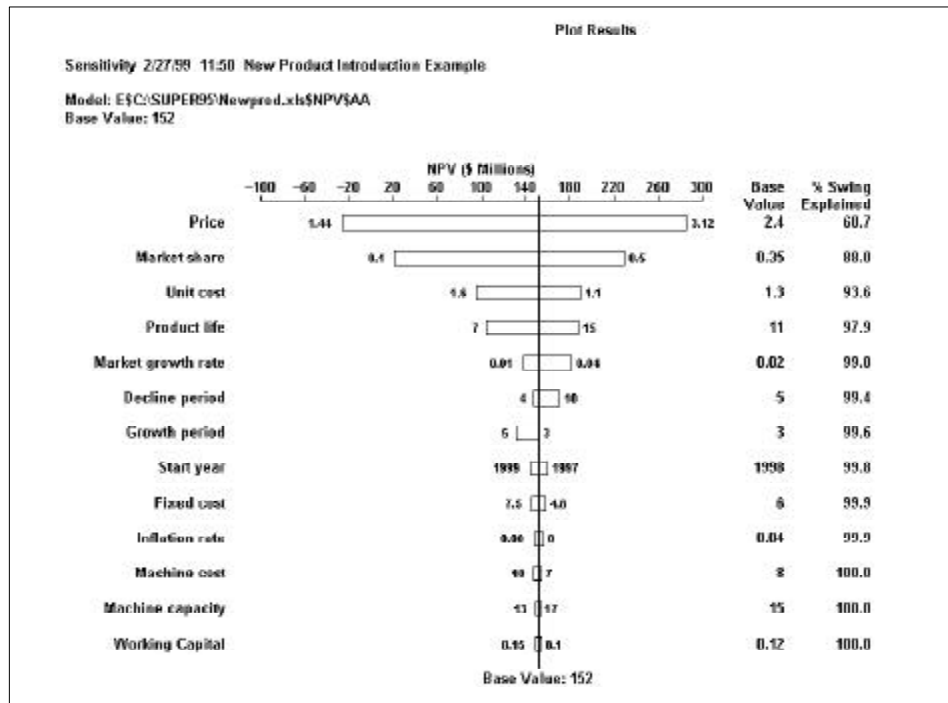# Evaluating and Analyzing Sensitivities

Figure 2.8

Figure 2.8a

Evaluating and Analyzing Sensitivities

To view the graphic data in tabular form, select List Results... from the Analyze menu to obtain the display shown in Figure 2.9.

List Results

Model: E$C:\SUPER95\Newprod.xls$NPV$AA

Base Value: 152
Sensitivity 2/27/99 11:53 New Product Introduction Example

Description	Base	Sens Type	Low Value	High Value	Low Result	High Result	Swing	% Swing Explained
Price	2.4	Value	1.44	3.12	–26	285	311	60.7
Market share	0.35	Value	0.1	0.5	21	230	209	88.0
Unit cost	1.3	Value	1.1	1.6	190	95	95	93.6
Product life	11	Value	7	15	105	187	83	97.9
Market growth rate	0.02	Value	0.01	0.04	138	181	43	99.0
Decline period	5	Value	4	10	147	171	23	99.4
Growth period	3	Value	3	5	152	131	21	99.6
Start year	1998	Value	1997	1999	160	144	16	99.8
Fixed cost	6	Value	4.8	7.5	158	145	13	99.9
Inflation rate	0.04	Value	0	0.08	156	148	8	99.9
Machine cost	8	Value	7	10	154	147	7	100.0
Machine capacity	15	Value	13	17	149	153	5	100.0
Working Capital	0.12	Value	0.1	0.15	154	149	4	100.0

Figure 2.9

The table summarizes all the information pertinent to the analysis and, in the swing column, shows the range in the value measure for each variable. The swing is typically the high result minus the low result, although it could be low minus base or high minus base if one of these quantities is larger.

Evaluating and Analyzing Sensitivities

Deciding Which Variables Are Critical

The purpose of sensitivity analysis is to identify uncertainties critical to planning and decision-making. In the sensitivity analysis above, it is evident that price and peak market share are the dominating uncertainties. Of lesser importance are the uncertainties in unit cost and years from start to decline. The uncertainty in the remaining variables can, for all practical purposes, be ignored.

Determining the most important variables is critical to building a manageable Supertree decision tree model. Instead of having a tree with 13 nodes (one for each variable), we now can create a tree with between 2 and 4 nodes. That may not seem like much of an accomplishment, until we realize that if each of the 13 nodes had 3 branches, there would be 3^{13} or 1,594,323 paths through the tree.

Additional information about this important topic can be found in the textbook *Decision Analysis for the Professional.*