

---

# **Decision Analysis for the Professional**

**Peter McNamee  
John Celona**

**Supertree and Sensitivity  
Software**

THIRD EDITION

**SmartOrg, Inc.**

2440 Sand Hill Road • Menlo Park • CA 94025-6900

[www.smartorg.com](http://www.smartorg.com)

# Decision Analysis for the Professional

Peter McNamee

John Celona

Copyright © 2001 by SmartOrg, Inc. All rights reserved. No part of this book may be reproduced, stored in retrieval system, or transcribed in any form or by any means without the prior written permission of the publisher, SmartOrg, Inc.

Printed in the United States of America

000000000000

ISBN 0-00000-000-0

Publisher: SmartOrg, Inc.

Editors: Mimi Campbell, Bill Roehl, Mary Story

Typography and Layout: Don Creswell and T/D Associates

Cover Design: Rogodino & Associates

---

Excel is a registered trademark of Microsoft Corporation. Supertree and Sensitivity are registered trademarks of SmartOrg, Inc.

# Supertree and Sensitivity Software

## Why Software is Useful

---

Analyzing large trees by hand is tedious and prohibitively time consuming. Imagine a tree with five nodes, each with three branches. There are  $3^5 = 243$  paths through this tree. First you would have to draw the tree, then you would have to obtain the 243 values to place at the end of each path for the value measure, and then you would have to perform the roll-back or roll-forward to obtain the expected value of the tree. Probability distribution graphs would need to be created from these data. And any changes in input data would require repeating all the calculations.

Thus, to use decision analysis successfully and routinely, a computer is essential. Three tasks are required of the computer:

- Calculate the value used for the value measure. In today's business world, this value is usually calculated by a spreadsheet.
- Iterate the calculation and record the results for all the paths through the decision tree.
- Perform the decision analysis tasks such as tree roll-back, plotting the probability distribution, displaying the evaluated tree, obtaining value of information and control, and the like.

In this document, we will show how the twin programs Sensitivity (for deterministic sensitivity analysis as described in Chapter 6) and Supertree (for probability and decision tree analysis) can be used to evaluate the examples used in this book.

To obtain a student version of these programs, go to the website [www.supertree.net](http://www.supertree.net).

In the first instance of the use of any of the Supertree or Sensitivity functions, the user interface will be completely displayed and reference made to the relevant sections of the book. In subsequent uses of a function, only important features of the user interface will be referred to.

## Computer Setup ---

Supertree and Sensitivity are two separate programs intended for use on a personal computer. They require a PC running Windows 95 or later with a minimum of 8 megabytes of RAM and 3 megabytes of free space on the hard disk.

To start a Supertree or Sensitivity session, go to the Programs option in the Start menu of Windows. Choose the folder Supertree 95 and either the Supertree or Sensitivity icon.

Each program has a Help menu which accesses a complete description of the program's features.

## Positronics (Chapter 2) ---

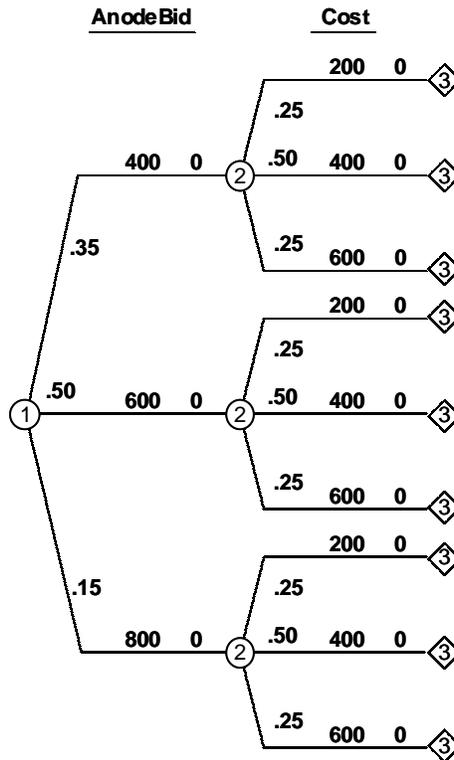
Figure 2-9 is a completed probability tree for the first pass analysis of the Positronics case. To analyze this tree, we will enter it into the Supertree program.

To prepare the tree for entry into Supertree, it is necessary to make some modifications, as shown in Figure A-1. The following four elements have been added to the tree to make it suitable for entering into Supertree:

- A new type of node has been added—the endpoint node (shown as a  $\hat{a}$ ). This is the node Supertree uses to assign a value to a scenario or path through the tree. Usually this node corresponds to a deterministic node in the influence diagram—Profit, in the Positronics case. All paths through the tree must terminate on the right in an endpoint node.
- The nodes have been numbered. Here, Anode's bid is node number 1, Positronics' cost is node number 2, and the endpoint node is node number 3. Node numbers in Supertree must be positive integers. Making the numbers increase from left to right in the tree helps you remember the structure while analyzing the tree.
- Each chance node has been given a node name, AnodeBid and Cost. In Supertree, the node name not only describes the node, but is also a variable that takes on as a value the outcomes of the node. Thus, the node names are variables that can be used by the endpoint node (value model) to calculate a value for each path through the tree. For instance, Supertree will give the variable Cost a value of 200, 400, or 600 depending on the path through the tree being evaluated. Node names in Supertree must begin with a letter and be composed of letters, digits and the underscore ( `_` ) character.
- A reward of \$0 has been assigned to each branch of the chance nodes and appears to the right of the outcomes on the branches. (In hand-drawn trees, they usually appear under the branches.) Rewards are quantities added to the values at the endpoints

Figure A-1

Positronics Tree Ready for Entry into Supertree



and are a quick way to represent the benefits (costs if negative) associated with a particular branch. By convention, rewards are normally not shown explicitly when they are zero.

In Supertree, you build the tree node by node, using the Input or Change Node Data option from the Structure menu. Supertree will first ask you for a descriptive name to be used in labeling output; enter\* *Positronics Tree #1*. Supertree then asks you for the number of the node (enter *1*) and the type of the node (enter *Chance*). Use the mouse or the Tab key to move from field to field to enter the data for the node as shown in Figure A-2. Click OK, Next... to enter the information for node 2 as shown in Figure A-2.

You need only type the first few letters of many entries in Supertree. When you press the Tab key or click on another entry field, Supertree will complete the entry for you. For instance, when entering the type of node, you could type *c* and Supertree would fill out the full *Chance* entry when you went to another field. If you are in doubt as to the possible entries in a field, enter a question mark (?).

\*User entry for computer dialog boxes will be shown in italics.

Figure A-2

Entry Screens for AnodeBid, Cost, and Profit Node

The figure displays three sequential dialog boxes for defining nodes in a decision tree model.

**Decision/Chance Node Data, Node Number 1**

- Node type:  Probabilities depend on nodes:
- Number of branches:  Outcomes depend on nodes:
- Node name:
- Table of outcomes:
 

Probability	Outcome	Reward	Successor Node
<input type="text" value=".35"/>	<input type="text" value="400"/>	<input type="text" value="0"/>	<input type="text" value="2"/>
<input type="text" value=".50"/>	<input type="text" value="600"/>	<input type="text" value="0"/>	<input type="text" value="2"/>
<input type="text" value=".15"/>	<input type="text" value="800"/>	<input type="text" value="0"/>	<input type="text" value="2"/>
- Buttons: , ,

**Decision/Chance Node Data, Node Number 2**

- Node type:  Probabilities depend on nodes:
- Number of branches:  Outcomes depend on nodes:
- Node name:
- Table of outcomes:
 

Probability	Outcome	Reward	Successor Node
<input type="text" value=".25"/>	<input type="text" value="200"/>	<input type="text" value="0"/>	<input type="text" value="3"/>
<input type="text" value=".50"/>	<input type="text" value="400"/>	<input type="text" value="0"/>	<input type="text" value="3"/>
<input type="text" value=".25"/>	<input type="text" value="600"/>	<input type="text" value="0"/>	<input type="text" value="3"/>
- Buttons: , ,

**Endpoint Data, Node Number 3**

- Name of program:
- Expression:
- Nodes upon which endpoint depends:
- Resulting endpoint expression:  $B\$(500-Cost)*(500<AnodeBid)$
- Buttons: , ,

Before entering node 3 (the endpoint node), we need to decide how to use the endpoint to place values at the end of the tree. We could type in numbers directly, but this works only for very small trees. In this case, we will use Supertree's capability for evaluating an endpoint expression using Basic syntax. We can use numbers, operators, and node name variables in this expression. (Use Supertree's Help menu and refer to the Basic Interface topic for details.)

The equation for profit was shown in the Profit node (Figure 2-8). The proposed bid is \$500,000, and the value is  $(500 - \text{Cost})$  if Positronics wins the bid. So, we could write the endpoint as follows:

$$(500 - \text{Cost}) \quad (\text{A-1})$$

However, what happens when Anode bids less than Positronics? Positronics loses the bid and does not get the profit described in Equation A-1. To model this, we can use a programmer's trick. In Basic (and in other programming languages), we can write a relational expression that compares two values with such operators as  $<$  (less than),  $=$  (equal to),  $<=$  (less than or equal to), etc. The result of this operation is either "true" (with a result of 1) or "false" (with a result of 0).\*

We can describe whether or not Positronics wins the bid with the expression  $(500 < \text{AnodeBid})$ . This expression is true (equals 1) if AnodeBid is greater than 500 and false (equals 0) if AnodeBid is less than or equal to 500. If we multiply  $(500 - \text{Cost})$  by this expression, we will zero out profits in the cases where Positronics loses the bid. Putting these together in a single expression, we obtain:

$$(500 - \text{Cost}) * (500 < \text{AnodeBid}) \quad (\text{A-2})$$

This expression will yield the profit values shown before. The last information needed for node 3 is that it depends on nodes 1 and 2, which means it needs the values of the variables AnodeBid (node 1) and Cost (node 2) to calculate values. This information was already in the influence diagram (Figure 2-5) in which the Profit node was influenced by the Anode Bid node and by the Positronics Cost node. "Depends on" in Supertree is the same as "is influenced by" in influence diagram language.

We can now enter node 3 into Supertree. Use the Input or Change Node Data command from the Structure menu, enter 3 for the node number and *Endpoint* for the node type. Enter *Basic* for the name of the program—the entry *Basic* indicates that an expression will be entered in Basic syntax. Enter the data as in Figure A-2. At the bottom of the dialog box, Supertree will display its summary of the endpoint expression—the B records the fact that Basic syntax is used and the \$ separates the B from the formula.

Once we have entered the structure of the tree, it must be evaluated by choosing the Evaluate Tree option from the Evaluate menu. The Evaluate Tree option uses the endpoint node(s) to find the values associated with each path through the tree. While this task is trivial in this case, for

---

\*In almost every computing language, true is equal to 1. In Basic, true is equal to -1. Supertree violates this Basic rule by taking true equal to 1 in Basic syntax expression.

Figure A-3

Plotting a Cumulative Distribution

**Plot Distribution**

Present order of nodes: 1 2  
 New order of nodes: 1 2  
 Node at which to plot the probability distribution: 1

Type of Plot:  
 Cumulative  
 Histogram  
 10/50/90 Bars

Distributions to Plot:  
 Single  
 Multiple

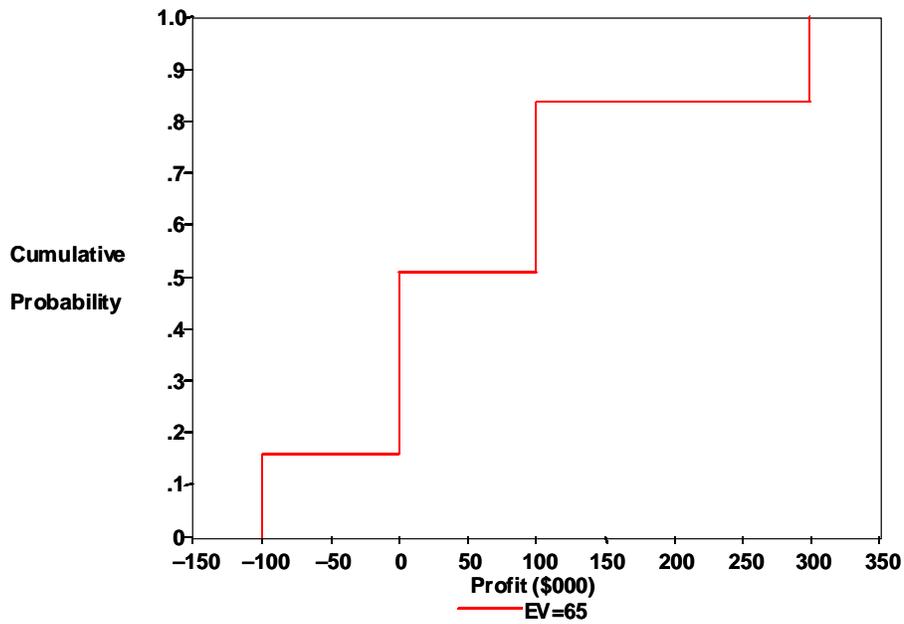
Label for axis: Profit (\$000)

OK Cancel

**Plot Distribution**

Smallest and largest values encountered are: -100 300  
 Lower and upper limits for display: -150 350  
 Number of intervals for axis: 10  
 Number of decimal places shown: 0

OK Cancel



trees with hundreds or thousands of paths and for models that take many seconds to run, evaluation is a major, time-consuming task.

Before evaluating the tree, Supertree checks that the structure and input are consistent and sensible (from a computer's point of view). However, Supertree gives the user considerable latitude in describing the tree and using endpoints; as a result, we could enter a tree and model that cause Supertree to encounter an error during the evaluation, resulting in an error message.

*Analyzing the Tree:* Now that the tree has been evaluated, we will determine what information can be drawn from it. First, we will examine how the component uncertainties have translated into uncertainty on the value of ultimate interest to the decision-maker. If we go to the Analyze menu of Supertree and choose the Plot Distribution option, Supertree will ask for information to specify the plot desired (Figure A-3).

We will leave the order of nodes the same for now by pressing the Tab key without entering anything in the field (we will see the usefulness of node reordering later) and then enter 1 for the node at which to plot the probability distribution. This will cause the overall probability distribution for the entire tree to be displayed. Select a cumulative plot and a single distribution. (Multiple distributions show the individual distributions at each branch of the selected node.) Enter *Profit (\$000)* for the label for the axis.

When we are through we click the OK button to process the information. Supertree then displays the smallest and largest values in the distribution, suggested limits for the plot, and other plot specifications. We can accept these by clicking the OK button or we can enter other specifications, as shown in Figure A-3. The resulting plot appears at the bottom of Figure A-3.

Using the Histogram choice of the Plot Distribution option from the Analyze menu is another way to represent the probability distribution for the venture's value. In a histogram plot, the horizontal (value) axis is divided into a number of equal-sized ranges or bins. The height of the bar drawn for each bin is the probability (vertical axis) that the value falls in the bin. For Supertree, a value is in a bin if it is greater than or equal to the lower bound of the bin and less than the upper bound of the bin (less than or equal to for the rightmost bin). The input data for the histogram (Figure A-4) are similar to those for the cumulative plot.

We can see the rollback process through the Display Tree option of the Analyze menu. The data entry screen for the Display Tree option appears in Figure A-5. As in Plot Distribution, Supertree asks for the order of nodes and then requests the number of the first and last nodes to be drawn. For very large trees, drawing the whole tree takes a prohibitive amount of time and computer memory and would add little, if any, insight. Finally, Supertree asks whether we wish scale the drawing.

If all we wished to see was the expected value of the tree, we could choose the Rollback Tree option from the Analyze menu and see the results in Figure A-6.

Figure A-4

Plotting a Histogram

**Plot Distribution**

Present order of nodes: 1 2  
 New order of nodes: 1 2  
 Node at which to plot the probability distribution: 1

Type of Plot:  
 Cumulative  
 Histogram  
 10/50/90 Bars

Distributions to Plot:  
 Single  
 Multiple

Label for axis: Profit (\$000)

OK Cancel

**Plot Distribution**

Smallest and largest values in distributions are: -100 300  
 Enter lower and upper limits for display: -100 400  
 Number of bins for data on this range: 5  
 Maximum probability on vertical axis: 0.4  
 Number of decimal places shown: 0

OK Cancel

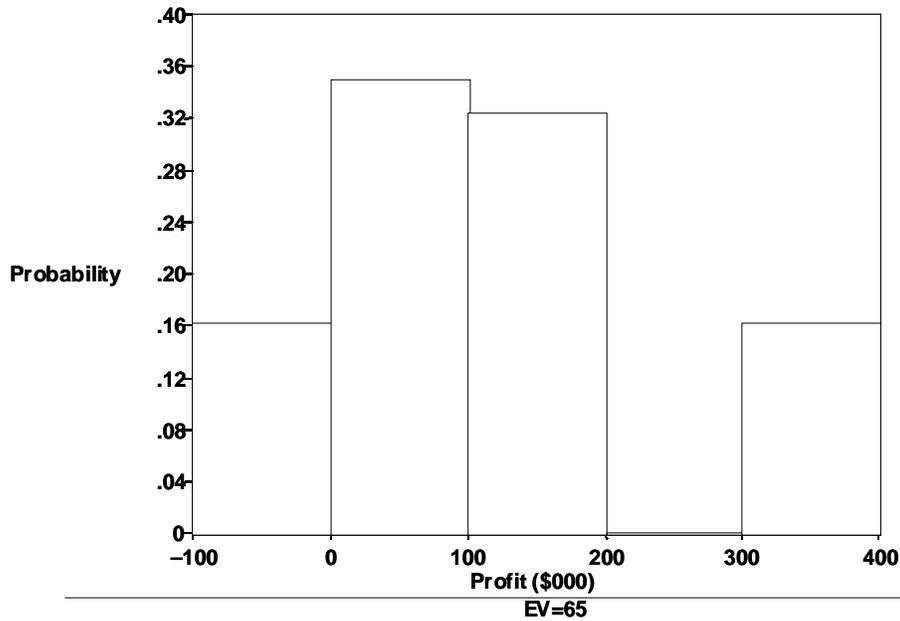
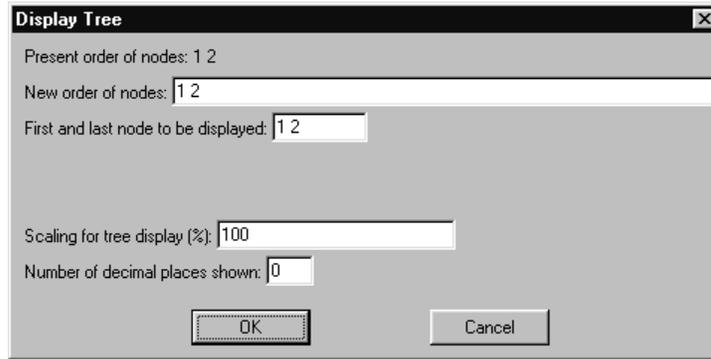


Figure A-5

Displaying the Tree

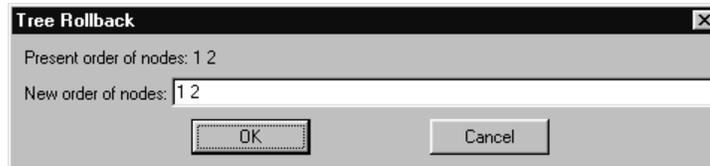


**Expected Value: 65**

Probs	Anode	Bid	Exp Val	Probs	Cost	Exp Val
.350	400	0	0	.250	200	0
				.500	400	0
.500	600	100	100	.250	600	0
				.250	200	300
.150	800	100	100	.500	400	100
				.250	600	-100
				.250	200	300
				.500	400	100
				.250	600	-100

Figure A-6

Rolling Back the Tree



**Expected Value: 65**  
**Tree Rollback Positronics Tree #1**

Figure A-7

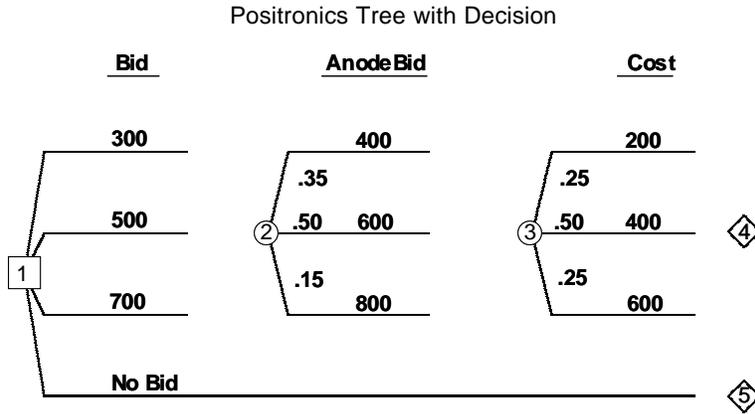


Figure A-8

Migrating from First to Second Tree

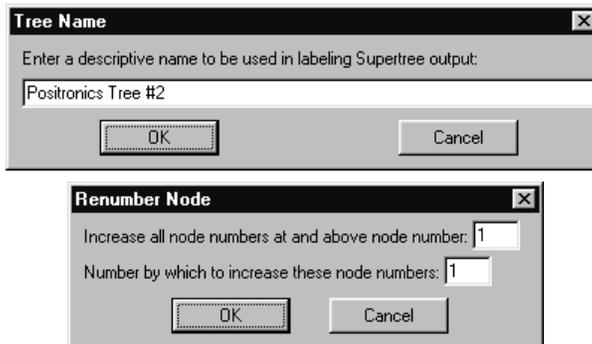


Figure A-9

The Bid Node

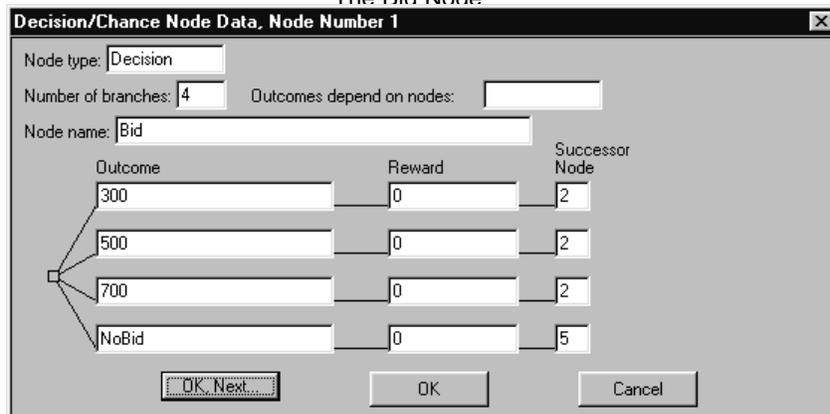


Figure A-10

Tree Data—Schematic Tree

Tree name: Positronics Tree #2

Node 1 Bid	Node 2 AnodeBid	Node 3 Cost	Node 4	Node 5
300 2	.35 400 3	.25 200 4	B\$(Bid-Cost)*(Bid<AnodeBid)	0
500 2	.50 600 3	.50 400 4		
700 2	.15 800 3	.25 600 4		
NoBid 5				
				Depends on 1 2 3

Figure A-11

Tree Data—Tabular Form

Tree name: Positronics Tree #2

STRUCTURE	NAMES	OUTCOMES	PROBABILITIES
1D2 2 2 5	Bid	300 500 700 NoBid	
2C3 3 3	AnodeBid	400 600 800	.35 .50 .15
3C4 4 4	Cost	200 400 600	.25 .50 .25
4E	B\$(Bid-Cost)*(Bid<AnodeBid)	Depends on 1 2 3	
5E	0		

### Positronics (Chapter 3)

We have already done most of the work to prepare the Positronics tree with decisions for input to Supertree. The schematic tree has been created (Figure 3-4). Now we need to number the nodes. We will stay with our practice of having node numbers increase from left to right in the tree (Figure A-7).

To modify our existing tree (Figure A-1) in Supertree, we first need to renumber the existing nodes to make room for the new node 1; Anode's bid was originally node number 1. We could enter all the data for the tree. However, if we have saved the tree entered in the previous section, we can use the Open option of the File menu to retrieve the data. We can then use the Change Tree Name option and the Renumber Node option from the Structure menu, as shown in Figure A-8.

We can now enter the decision node as node 1. Use the Input or Change Node Data option from the Structure menu. Supertree will first ask you for the number of the node (enter 1) and the type of the node (enter *Decision*). Then enter the data as in Figure A-9. The main differences from the dialog box for chance nodes is the lack of a column for probabilities and the lack of a field for dependent probabilities. We have given the decision node the name Bid and can use this variable in the endpoint model. Note that the number of branches has been changed to 4 and that the bottom branch goes to a new successor node, 5.

Figure A-12

10/50/90 Bars for Positronics' Alternatives

**Plot Distribution**

Present order of nodes: 1 2 3  
 New order of nodes: 1 2 3  
 Node at which to plot the probability distribution: 1

Type of Plot:  
 Cumulative  
 Histogram  
 10/50/90 Bars

Distributions to Plot:  
 Single  
 Multiple

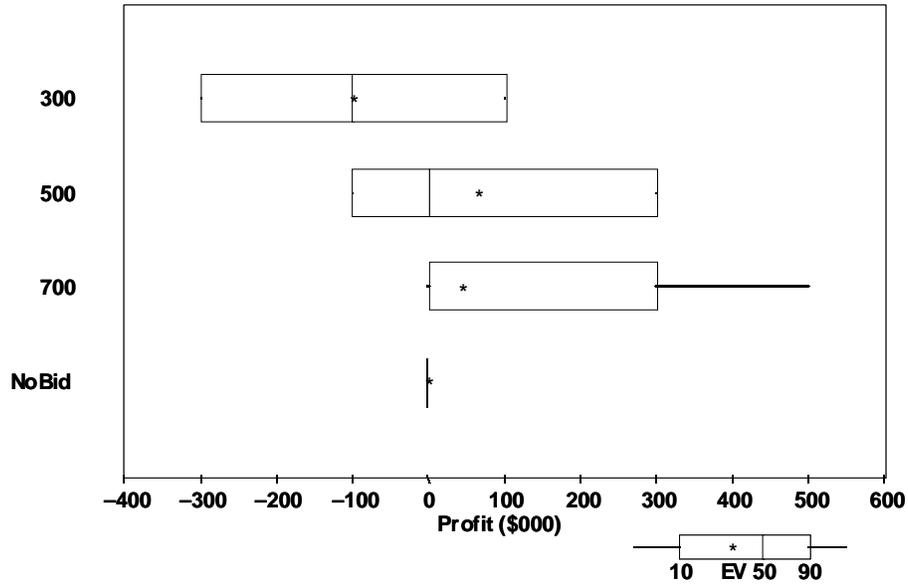
Label for axis: Profit (\$000)

OK Cancel

**Plot Distribution**

Smallest and largest values encountered are: -300 500  
 Lower and upper limits for display: -400 600  
 Number of intervals for axis: 10  
 Number of decimal places shown: 0

OK Cancel



The Input or Change Node Data option has been used to modify node 4 to have the value

$$(\text{Bid} - \text{Cost}) * (\text{Bid} < \text{AnodeBid}) \quad (\text{A-3})$$

and to depend on nodes 1, 2, and 3. A new endpoint node with *Value* as the name of program and value 0 was also created.

The Show Schematic Tree option of the Structure menu shows all this data as a schematic tree (Figure A-10), and the Show Tree Structure option of the Structure menu shows the input data in tabular form (Figure A-11).

Because the structure and endpoint model have been changed, we must Evaluate the tree again.

*Analyzing the Tree:* Selecting multiple rather than single plots under the Plot Distribution option of the Analyze menu, we obtain the probability distribution for all the alternative bid decisions (Figure 3-6). The staircase appearance is a result of the discrete approximation used in constructing the tree. If more branches had been used, the curves would be smoother and the plot easier to read.

An alternative representation of the probability distributions can be obtained by using the 10/50/90 bars feature of Plot Probability Distribution, as shown in Figure A-12. The bars show the 10, 50, and 90 percentiles of the distribution for each alternative for Bid and the line goes from the minimum to the maximum of the distributions; an asterisk (\*) marks the expected value. Some decision makers relate best to this simplified format.

The default decision criterion in Supertree is to maximize the expected value of the values given at the endpoints. Hence, we can use the Rollback option of the Analyze menu to find the expected value of the tree to be \$65,000. This expected value is the value of the preferred alternative—in this case, the \$500,000 alternative.

We can also use the Display option of the Analyze menu to see the whole of this small tree (Figure A-13). Note the > to indicate the chosen alternative is to bid \$500,000.

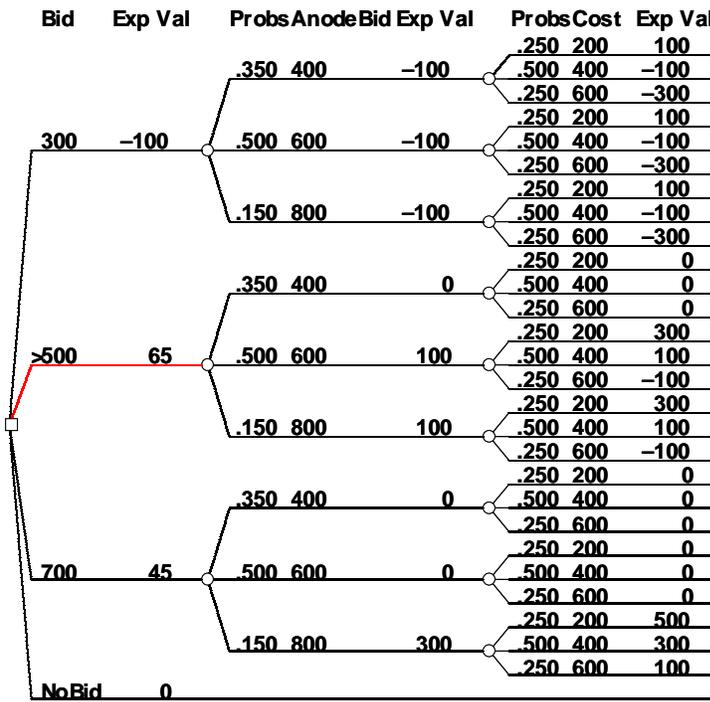
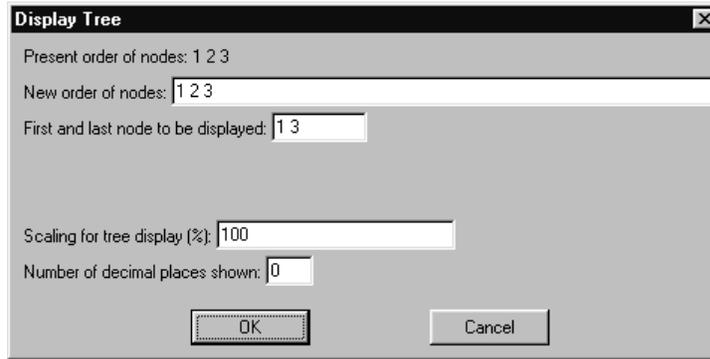
For large trees, it is impractical to display the entire tree to find out which scenarios lead to which values. Often, however, it is interesting to find a scenario that leads to a given value—either because the value is suspect or because we need a representative scenario to explain the results. The Trace Value in Tree option of the Analyze menu performs this task for you (Figure A-14). Of course, the task is trivial in a tree as simple as this.

The Sensitivity to Probability option of the Analyze menu performs probabilistic sensitivity analysis (also known as stochastic sensitivity analysis) as shown in Figure 3-8. As indicated in Figure A-15, the horizontal axis is the probability assigned to the first (top) branch of node 3; the rest of the probability is assigned to the bottom branch, and the middle branch is given zero probability. This two-branch approximation is used for ease of interpretation. If the probability at node 3 depended on another node, that dependency would have been overridden in this option.

Value of Perfect Information conceptually involves evaluation of the large tree shown in Figure 3-10. However, Supertree provides a simpler

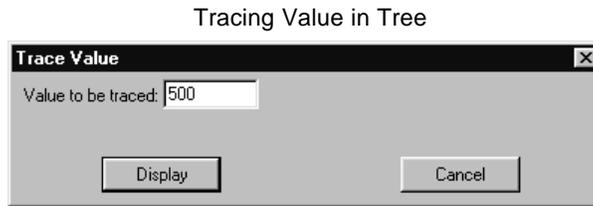
Figure A-13

Decision Tree for Positronics



approach by evaluating the subtree shown in Figure 3-12. Use the Rollback Tree option, give the new order of nodes as 2 1 3 and find that the expected value of the subtree is \$95,000. The new order of nodes specified in the Rollback Tree option puts node 2 (Anode Bid) before node 1 (Positronics Bid). The Rollback Tree option with node order 3 1 2 can be used to show that the value of the venture *with* (not *of*) perfect information on Positronics' cost is \$85,000 (Figure 3-13). Finally, the Rollback Tree option with node order 2 3 1 can be used to show that the value of the venture *with* perfect information on both AnodeBid

Figure A-14



**Value traced: 500**  
**The closest value is: 500**  
**Bid=700; Anode Bid=800; Cost=200**

and Positron's Cost is \$116,250.

The subtree displayed in Figure 3-12 can be obtained by the Display Tree option with the order of nodes 2 1 3 and 2 3 the first and last nodes to be displayed (Figure A-16).

#### Positronics (Chapter 4)

It is easy to input dependent probabilities in Supertree. If the tree from the previous section is open, clear the tree by using the New option of the File menu; if you have just opened Supertree, there is nothing to be cleared. We are clearing the old data out because we will put the nodes in a different order, as shown in Figure 4-2. Supertree could deal with the nodes in the order we originally entered them, but for the beginner, it is less confusing to reenter the tree.

Use the Input or Change Node Data option from the Structure menu and enter Bid as node 1, Cost as node 2, and AnodeBid as node 3. Make the probabilities for AnodeBid depend on Cost, node 2. Click on the Enter button in the Probability column and, in the large dialog box that appears, enter the data shown on the Show Schematic Tree option output in Figure A-17.

*Analyzing the Tree:* Since we have reentered the tree, we need to Evaluate it again before analyzing it. (This would not be necessary if we had only changed the probabilities.) After evaluating, go to the Plot Distribution option of the Analyze menu and plot the cumulative distribution (Figure 4-3).

The distributions for the two cases (independent and dependent probabilities) can be plotted on the same graph by using the Store Distribution and Recall Distribution options of the File menu. Store Distribution is used to store on disk the distributions associated with any particular tree, either for use with external programs or for use with the Recall Distribution option. The Recall Distribution option can be used to plot stored distributions on the same graph.

Figure A-18 illustrates a feature common to Store Distribution, Plot Distribution, Display Tree, and List Distribution Values. The distribution at

Figure A-15

Sensitivity to Probability of Anode's Bid Being \$200,000

**Sensitivity to Probability**

Present order of nodes: 1 2 3

New order of nodes: 1 2 3

Sensitivity to probability for node: 3

Label for axis: Profit (\$000)

OK Cancel

**Sensitivity to Probability**

Smallest and largest values encountered are: -300 195

Lower and upper limits for vertical axis: -300 200

Number of intervals for axis: 10

Number of decimal places shown: 0

If the first node is a decision, the sensitivity will be shown for all branches.  
 The vertical axis is the expected value.  
 The horizontal axis is the probability of the first branch of node 3;  
 the last branch of node 3 has the remainder of the probability.

OK Cancel

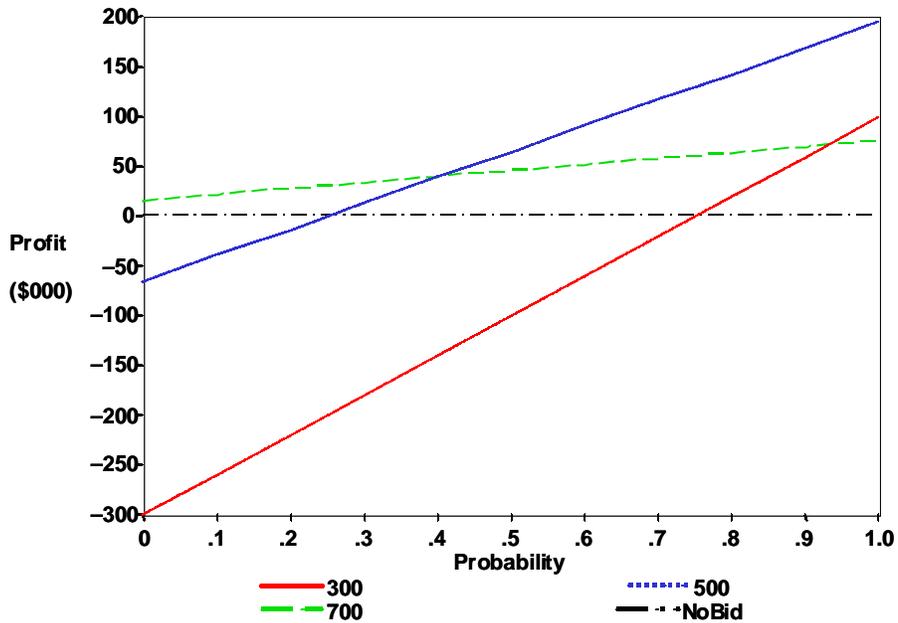
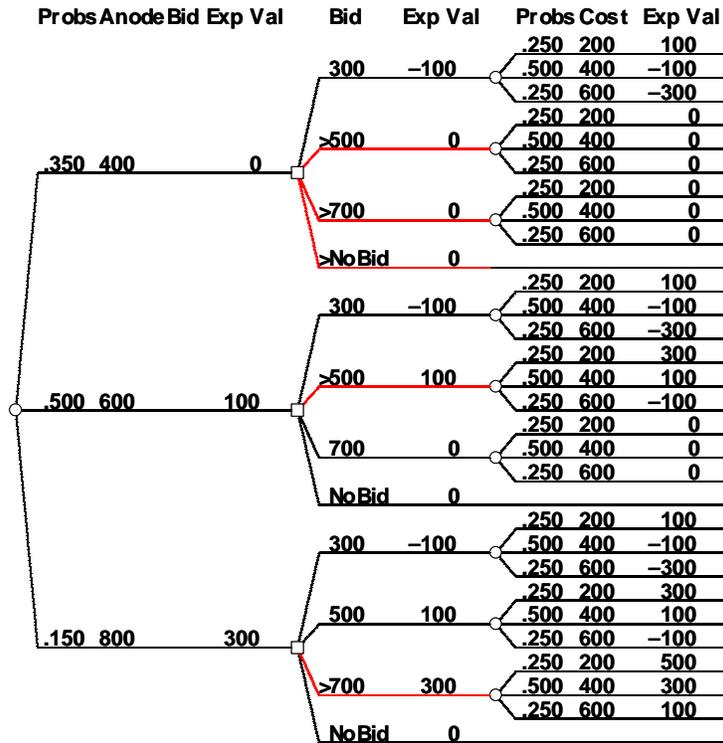
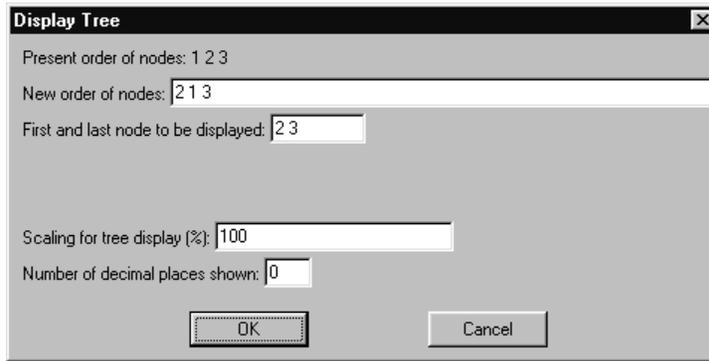


Figure A-16

Tree with Perfect Information on Anode's Bid



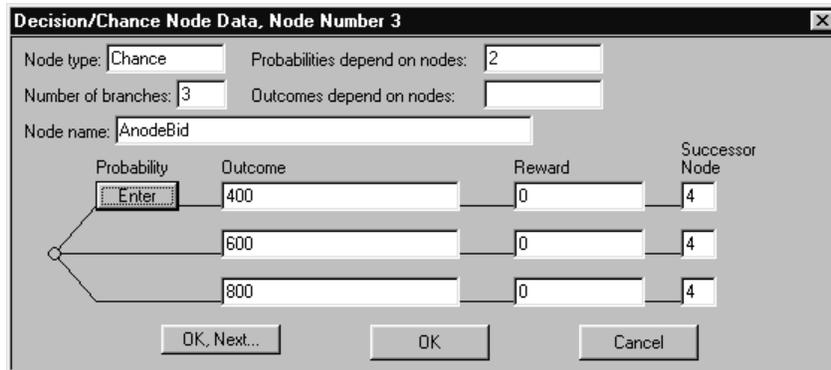
node 2 has been chosen as the node at which the distribution is desired. Because this node is not the first node, a new entry field appears asking for the branches to be chosen for the previous nodes. In Figure A-18, the distribution corresponding to Bid=500 has been chosen, and the distribution corresponding to that alternative is saved to disk.

The data can be recalled using the Recall Distribution option. Figure A-19 shows two dialog boxes used by Recall Distribution; between these two dialog boxes, the standard Windows dialog for opening files has been used to choose two files. On closing the second dialog box, the probability distributions contained in these two files will be plotted.

Having dependent outcomes is another way of representing probabilistic dependence for continuous variables. Entering dependent outcomes in Supertree is easy. Supertree even allows both dependent outcomes and dependent probabilities for a node (though it would take an unusual problem to need them both). Using the Input or Change Node Data option for node 3 (this option is used to change nodes as well as add them), enter a blank for "Probabilities depend on nodes" and a 2 for "Outcomes depend on nodes"; then reenter the original probabilities. Click on the Enter button in the Outcome

Figure A-17

Entering Dependent Probabilities



Tree name: Positronics Tree #3

Node 1	Node 2	Node 3	Node 4	Node 5
Bid	Cost	AnodeBid		
300	.25 200	* 400	B\$(Bid-Cost)*(Bid < Anode Bid)	0
500	.50 400	* 600		
700	.25 600	* 800		
NoBid				Depends on 1 2 3

Cost	PROBABILITY, NODE 3
200	0.45 0.5 0.05
400	0.15 0.7 0.15
600	0 0.15 0.85

Figure A-18

Storing the Probability Distribution for Bid=500, Dependent Probabilities

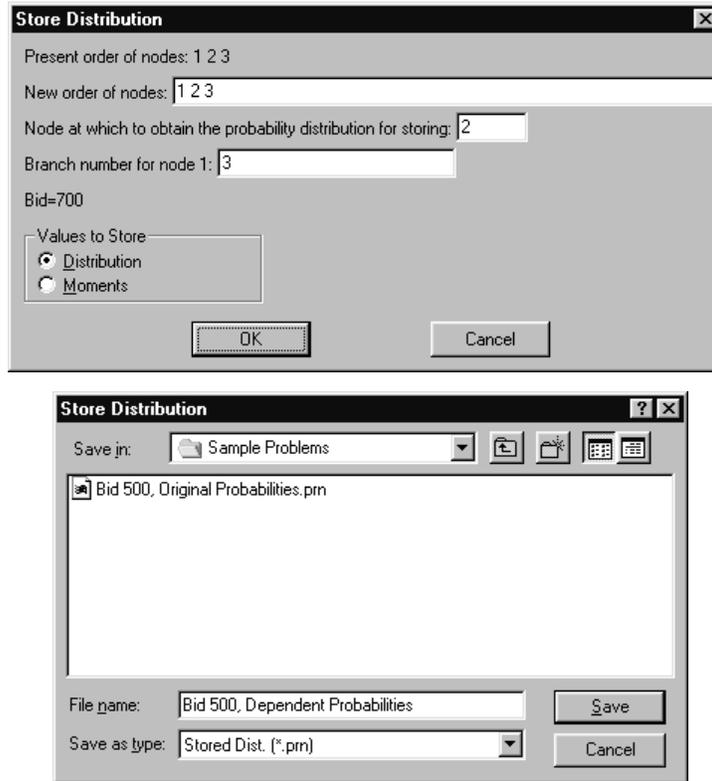


Figure A-19

Recalling the Probability Distributions for Bid=500, First and Last Dialog Boxes

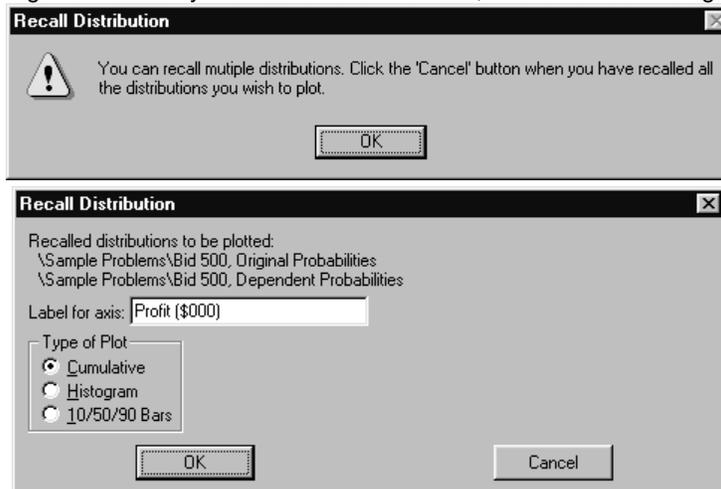
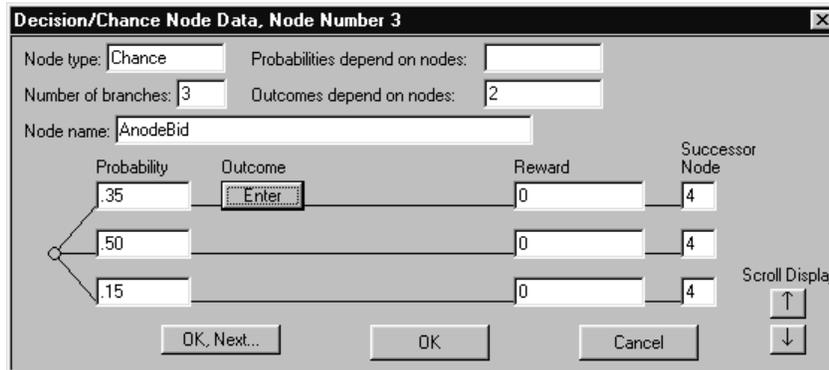


Figure A-20

Entering Dependent Outcomes



Tree name: Positronics Tree #3

Node 1 Bid	Node 2 Cost	Node 3 AnodeBid	Node 4	Node 5
300 2	25 200 3	.35 * 4	B\$(Bid-Cost)*(Bid<AnodeBid)	Depends on 1 2 3
500 2	.50 400 3	.50 * 4		
700 2	.25 600 3	.15 * 4		
NoBid 5				

Cost	OUTCOME, NODE 3
200	200 400 600
400	400 600 800
600	600 800 1000

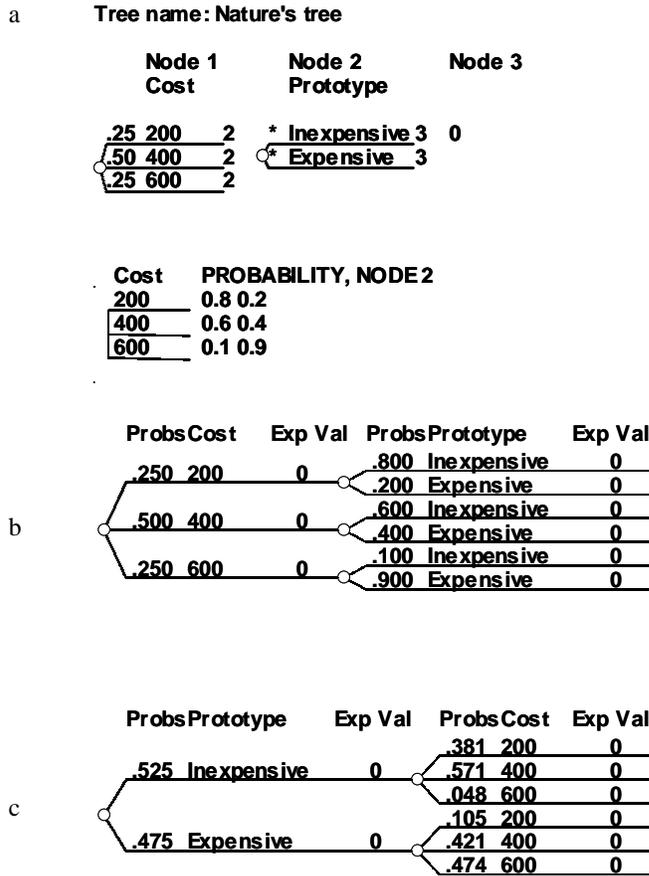
column and, in the large dialog box that appears, enter the data shown on the Show Schematic Tree option output in Figure A-20.

We could then try the Plot Distribution option of the Analyze menu. However, if we did try, Supertree would inform us that we have made changes that require running the Evaluate Tree option again. We have the option of using the old data, which might be desirable if we had made a change and then decided to change back to the original data. Supertree would have no way of knowing that there had been no net change. In this case, we want to use the Evaluate Tree option and then Plot the distribution (Figure A-22).

*Nature's Tree—Letting Supertree Do the Work:* Reversing trees by hand is a tedious and error-prone process. Supertree can perform the calculations automatically. The tree in Figure 4-12 can be entered into Supertree, as shown in Figure A-21a. The Show Schematic Tree information for this tree is shown. Since we are not really interested in values here, we have entered a Value endpoint node with value 0.

Figure A-21

Prototype Information



Before analyzing the tree, we still have to use the Evaluate Tree option. We can then use Display Tree to examine the tree in its original order (Figure A-21b), confirming that we have entered the data correctly.

We can use the Display Tree option to show the tree with the nodes reversed (2 1 rather than 1 2) (Figure A-21c). We now see the probability for the various Positronics costs, given, for instance, that the prototype turned out to be inexpensive.

*The Value of Imperfect Information:* One of the most important uses of Bayes' Rule and Nature's tree is in obtaining the value of imperfect information. If we obtain imperfect information, we know the outcome of the imperfect indicator before we make a decision—and before we learn the true state of nature. This order requires reversing Nature's tree.

Note the difficulty in dealing with the probabilities in the tree shown in

Figure A-22

Prototype Tree

Tree name: Positronics Tree, Prototype

Node 1 PrototypeCost	Node 2 Bid	Node 3 AnodeBid	Node 4 Cost	Node 5	Node 6
* Inexpensive 2	300 3	.35 400 4	.25 200 5	B\$(Bid-Cost)*(Bid<Anode Bid)	Depends on 2 3 4
* Expensive 2	500 3	.50 600 4	.50 400 5		
	700 3	.15 800 4	.25 600 5		
	NoBid 6				

Cost	PROBABILITY, NODE 1
200	0.8 0.2
400	0.6 0.4
600	0.1 0.9

Figure 4-15. If we need to change any of the input probabilities for Prototype Cost or Positronics' Cost, we would have to flip the tree (Figures 4-16 and 4-17) to obtain the new set of probabilities for the tree. However, there is a simpler way—we will let Supertree do the work for us.

We can do this by adding the node on Prototype Cost onto the front of the original tree (Figure 4-18) and by then comparing the new tree's value with that of the original tree (Figure 3-7). After renumbering and adding the new node, we obtain the Show Schematic tree display in Figure A-22. Note that Supertree allows you to input the probabilities in the Nature's tree order.

We then need to Evaluate the tree before using the Display Tree option to display a tree like that shown in Figure 4-18.

When reordering the tree, Supertree sometimes produces puzzling messages or results. These messages or results are normally concerned with decision-dependent probabilities, decision-dependent outcomes, or rewards.

*Decision-Dependent Probabilities:* Probabilities can depend on a decision node. For instance, the probabilities for Positronics' costs could depend on which branch of a cost control decision node we were on (Figure 4-19). Suppose we now decide to move the cost node in front of the cost control decision node in the decision tree. As discussed in Chapter 4, this is not allowed.

If we were to analyze a tree of this sort with the nodes in the improper order, Supertree would report an error, "Decision dependent probabilities prevent tree evaluation in this order."

*Decision-Dependent Outcomes:* For chance nodes whose outcomes depend on a decision node, we would expect the same problem as with decision-

dependent probabilities. After all, dependent probabilities and dependent outcomes are both ways of characterizing dependent probability distributions. However, as discussed in Chapter 4, there is an interpretation of dependent outcomes that allows us to interchange the nodes, and Supertree assumes we intend this interpretation.

The interpretation is that we learn whether we are on the high branch, the middle branch, or the low branch (assuming there are three branches) before we make the decision. We do not know the value of the outcome, only whether we are on the top branch, the second branch, or the third branch.

Whenever a node with dependent outcomes occurs before its conditioning node, the outcomes are shown in the Display Tree option as asterisks. There is no way to show the outcome values in a tree display in this order because they depend on a node that comes afterwards. However, all calculations are done with the correct combinations of outcome values because Supertree keeps track of which outcomes are associated with which scenarios (tree paths) regardless of how the nodes are reordered for display purposes.

*Rewards:* Supertree gives us the option of figuring the rewards into the endpoints or of keeping rewards at the node and figuring them into the values at that point. This makes a difference in the results of the Display Tree option (and the Plot Distribution option, if you are plotting a distribution at a node other than the first node in the tree).

In moving a node with rewards, there are two ways to interpret the reordering. First, we could be rearranging the order of events that make up the tree, in which case the rewards should move with the node to the new order. Second, we could be performing a value of information calculation, in which case the rewards should stay where they are and be incurred when the event happens, rather than when you get information on it. (Recall that node reordering is a shortcut to obtain the value of information.)

An unexpected effect can arise when nodes are reordered in an asymmetric tree with rewards. The reordering can force Supertree to put the tree into a more symmetric form. With this symmetrization, figuring in rewards at the nodes can cause surprising changes to endpoint values. These changes occur because figuring in rewards at a node may mean adding the node (and its rewards) on a path in the symmetrized tree where it was not

---

Figure A-23

---

Setting Risk Tolerance

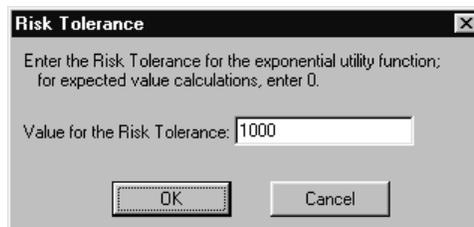


Figure A-24

Sensitivity to Risk Tolerance

**Sensitivity to Risk Attitude**

Present order of nodes: 1 2 3

New order of nodes: 1 2 3

Vary risk tolerance from infinity down to: 100

Label for axis: Profit (\$000)

OK Cancel

**Sensitivity to Risk Attitude**

Smallest and largest values encountered are: -188 39

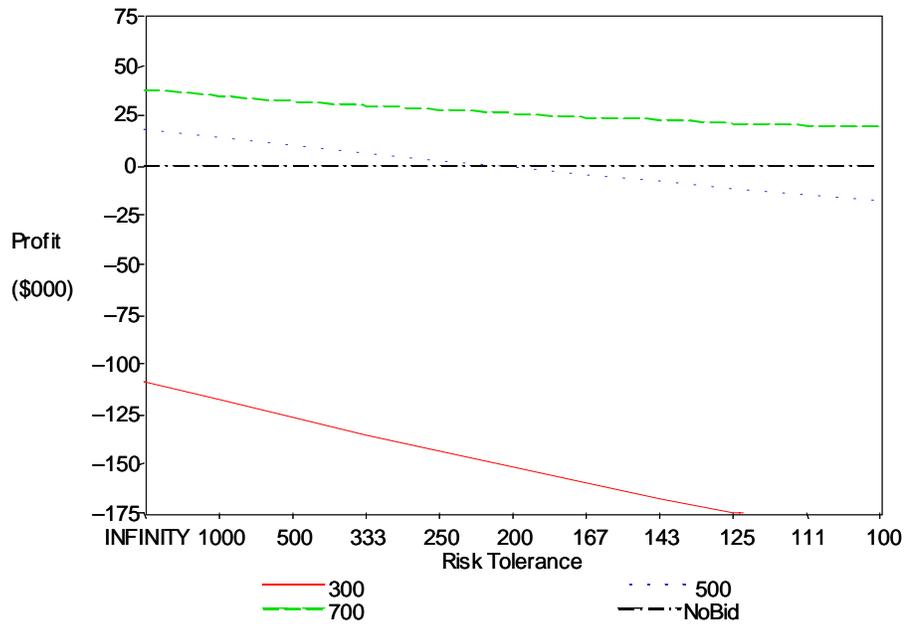
Lower and upper limits for vertical axis: -175 75

Number of intervals for axis: 10

Number of decimal places shown: 0

If the first node is a decision, the sensitivity will be shown for all branches.  
 The vertical axis is the certain equivalent.  
 The horizontal axis is the risk tolerance; the scale is linear in 1/risk tolerance.

OK Cancel



present in the original asymmetric tree. To keep the net value the same, Supertree must also subtract the reward from the endpoint value for that path, resulting in the unexpected endpoint values. The net change in the value of the scenarios (tree paths) is zero.

## Positronics (Chapter 5) \_\_\_\_\_

Supertree has the exponential utility function built in. Using the Set Risk Attitude option of the Analyze menu, we set the risk tolerance to \$1 million (Figure A-23). (A frequent error involves using different units for risk tolerance and for values.)

We can then use the Display Tree option to draw the tree in Figure 5-13. The other options of the Analyze menu also now show certain equivalents when appropriate, with decisions in the tree being made to maximize the certain equivalent.

Supertree has an automatic way of performing sensitivity analysis to risk attitude. The results from selecting the Sensitivity to Risk option from the Analyze menu are shown in Figures 5-17 and A-24. The horizontal axis is linear in  $1/\text{risk tolerance}$ , which is the risk-aversion coefficient. The leftmost values are for infinite risk tolerance, which is equivalent to the expected value. The certain equivalents are then plotted for each alternative for each value of the risk tolerance.

## Diagnostics (Chapter 6) \_\_\_\_\_

The Diagnostics example in Chapter 6 begins with a spreadsheet which performs a deterministic evaluation of the alternatives. This is similar to the way most real-world analyses evolve: begin by understanding the complexity of the problem, then add the complexity of uncertainty.

To understand the use of the Supertree and Sensitivity software, it is first necessary to understand how the spreadsheet was constructed.

The input section for Diagnostics' spreadsheet is shown in Figure 6-8 and A-25. The rows in the Alternative Table describe the components of each of the three alternatives. The Input table contains the values for the analysis, and the values used by the calculations are contained in cells C11:C62; the range names in cells D11:D62 are applied to these cells by selecting cells C11:D62 and using the Excel command Insert/Name/Create. The R&D Investment input is given in cells E65:O67 (zero values in cells I65:O67 are not displayed in Figure A-25); the range names in cells D65:D67 are applied to these rows by selecting cells D65:O67 and using the Excel command Insert/Name/Create. Finally, cells B9:H62 is selected and assigned the name RD\_InputTable by using the Excel command Insert/Name/Define; this range name will be used shortly.

The calculations section for Diagnostics' spreadsheet is shown in Figures 6-9 and A-26. Cell A3 contains the formula

Figure A-25

Input Section for Diagnostics' Spreadsheet

A	B	C	D	E	F	G	H	
1	Alternative Table	DiagRF		DiagStatic				
2	# Name	Device	Target Price	Device	Com p. Adv.	Graphics	Target Price	
3	1 Milk Existing Products	Current	\$20,000	Current	Features	OEM	\$10,000	
4	2 DiagRF Plus	Upgrade	\$25,000	Current	Features	OEM	\$15,000	
5	3 DiagStatic New	Current	\$20,000	New	Link+Features	Integral	\$10,000	
6								
8	<b>INPUT</b>							
9	Description	In Use	Range Name	Low	Base	Hgh	Units	
10	Alternative	3	Alternative				1, 2, 3	
11								
12	<b>Market</b>							
13	Total market, 2000	3500	Mkt_00		3500		units/year	
14	Total Market, 2010	4500	Mkt_10	4000	4500	5000	units/year	
15	RF Fraction of Market, 2000	17%	Mkt_RF_fr_00		17%		percent	
16	RF Fraction of Market, 2010	25%	Mkt_RF_fr_10	20%	25%	35%	percent	
17	<b>DiagStatic</b>							
18	DiagStatic, Market Share, 2000	10%	MS_00_DSt		10%		percent	
19	DiagStatic, Market Share growth rate	-20%	MS_gr_DSt	-25%	-20%	-15%	percent	
20	DiagStatic, Year Discontinued	2005	Yr_DSt_stop		2005		year	
21	If DiagStatic New is introduced before this year, DiagStatic is discontinued at that time							
22	DiagStatic, Price, 2000	\$9,500	ASP_00_DSt		\$9,500		\$/unit	
23	DiagStatic, Price CAGR	0%	ASP_gr_DSt	-5%	-1%	1%	percent	
24	DiagStatic COGS, 2000	\$4,500	COGS_00_DSt		\$4,500		\$/unit	
25	DiagStatic, COGS CAGR	2%	COGS_gr_DSt	0%	2%	3%	percent	
26	<b>DiagStatic New</b>							
27	DiagStatic New, Technical Success	Yes	tech_succ_DStn	No	Yes	Yes	yes/no	
28	DiagStatic New, Start Year	2003	Startyr_DStn		2003		year	
29	DiagStatic New, Years to Peak	3	Yrs_to_pk_DStn		3		years	
30	DiagStatic New, Years at Peak	8	Yrs_at_pk_DStn		8		years	
31	DiagStatic New, Years from Peak to 0	7	Yrs_to_0_DStn		7		years	
32	DiagStatic New, Market Share at Peak	20%	MS_pk_DStn	10%	20%	40%	percent	
33	DiagStatic New, Price, start year	\$14,000	ASP_sy_DStn	\$12,000	\$14,000	\$15,000	\$/unit	
34	DiagStatic New, Price CAGR	0%	ASP_g_DStn	-3%	0%	1%	percent	
35	DiagStatic New, COGS, start year	\$4,800	COGS_sy_DStn	\$4,600	\$4,800	\$5,200	\$/unit	
36	DiagStatic New, COGS CAGR	2%	COGS_g_DStn	0%	2%	3%	percent	
37	<b>DiagRF</b>							
38	DiagRF, Market Share, 2000	40%	MS_00_DRF		40%		year	
39	DiagRF, Market Share growth rate	-10%	MS_gr_DRF	-20%	-10%	-5%	percent	
40	DiagRF, Year Discontinued	2008	Yr_DRF_stop		2008		year	
41	If DiagRF Plus is introduced before this year, DiagRF is discontinued at that time							
42	DiagRF, Price, 2000	\$17,000	ASP_00_DRF		\$17,000		\$/unit	
43	DiagRF, Price CAGR	0%	ASP_gr_DRF	-4%	0%	1%	percent	
44	DiagRF, COGS, 2000	\$4,500	COGS_00_DRF		\$4,500		\$/unit	
45	DiagRF, COGS CAGR	2%	COGS_g_DRF	0%	2%	3%	percent	
46	<b>DiagRF Plus</b>							
47	DiagRF Plus, Start Year	2001	Startyr_DRFp		2001		year	
48	DiagRF Plus, Years to Peak	2	Yrs_to_pk_DRFp		2		years	
49	DiagRF Plus, Years at Peak	6	Yrs_at_pk_DRFp		6		years	
50	DiagRF Plus, Years from Peak to 0	5	Yrs_to_0_DRFp		5		years	
51	DiagRF Plus, Market share at Peak	40%	MS_pk_DRFp	25%	40%	45%	percent	
52	DiagRF Plus, Price, start year	\$19,000	ASP_sy_DRFp	\$17,000	\$19,000	\$23,000	\$/unit	
53	DiagRF Plus, Price CAGR	0%	ASP_gr_DRFp	-3%	0%	1%	percent	
54	DiagRF Plus, COGS, start year	\$4,800	COGS_sy_DRFp	\$4,600	4,800	\$5,300	\$/unit	
55	DiagRF Plus, COGS CAGR	2%	COGS_g_DRFp	0%	2%	3%	percent	
56	<b>GLOBAL VARIABLES</b>							
57	Base Year	2000	BaseYear		2000		year	
58	Discount Rate	10%	DiscountRate		10%		percent	
59	Tax Rate	38%	TaxRate		38%		percent	
60	Sales, General, Administrative	10%	SGA		10%		% of unit sales	
61	Working Capital, 1999	\$3,000,000	Wcap_99		\$3,000,000		\$	
62	Working Capital	29%	Wcap		29%		% of revenue	
63								
64	R&D Investment (\$000)			2000	2001	2002	2003	
65	DiagRF Plus		RD_DRFp	500	1,500			
66	DiagStatic New, pre-success		RD_pre_DStn	1,800	1,800			
67	DiagStatic New, post-success		RD_post_DStn		400	1,900	1,100	

Figure A-26

Calculations Section for Diagnostics' Spreadsheet

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Alternative			DiagRF				DiagStatic								
#	Name		Device	Target Price		Device	Comp. Adv.	Graphics	Target Price						
3	DiagStatic New		Current	\$20,000		New	Link+Features	Integral	\$10,000						
			1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Year
6	Market Units Sold														
7	Static		2,905	2,950	2,996	3,042	3,088	3,135	3,182	3,230	3,278	3,326	3,375	c_Mkt_Static	
8	RF		595	639	685	732	782	833	887	943	1,001	1,062	1,125	c_Mkt_RF	
10	Diagnostics' Units Sold														
11	DiagStatic		291	236	192	156	0	0	0	0	0	0	0	0	c_units_static
12	DiagStatic New		0	0	0	0	206	418	636	646	656	665	675	c_units_static_new	
13	DiagRF		238	230	222	214	205	197	189	180	172	0	0	0	c_units_rf
14	DiagRF Plus		0	0	0	0	0	0	0	0	0	0	0	0	c_units_rf_plus
16	Revenue (\$000)														
17	DiagStatic		2,760	2,242	1,821	1,480	0	0	0	0	0	0	0	0	c_rev_static
18	DiagStatic New		0	0	0	0	2,882	5,852	8,911	9,044	9,178	9,314	9,450	c_rev_static_new	
19	DiagRF		4,046	3,910	3,771	3,630	3,488	3,346	3,206	3,067	2,931	0	0	0	c_rev_rf
20	DiagRF Plus		0	0	0	0	0	0	0	0	0	0	0	0	c_rev_rf_plus
22	Cost of Goods Sold (\$000)														
23	DiagStatic		1,307	1,083	898	744	0	0	0	0	0	0	0	0	c_cogs_static
24	DiagStatic New		0	0	0	0	1,008	2,088	3,242	3,356	3,474	3,596	3,722	c_cogs_static_new	
25	DiagRF		1,071	1,056	1,038	1,020	999	978	956	933	909	0	0	0	c_cogs_rf
26	DiagRF Plus		0	0	0	0	0	0	0	0	0	0	0	0	c_cogs_rf_new
28	Financial Results (\$000)														
29	Revenue		6,806	6,152	5,592	5,109	6,370	9,199	12,117	12,112	12,110	9,314	9,450		
30	Costs		2,378	2,139	1,936	1,763	2,007	3,066	4,198	4,289	4,384	3,596	3,722		
31	Gross Margin		4,428	4,013	3,656	3,346	4,363	6,133	7,919	7,822	7,726	5,718	5,728		
33	SG&A		681	615	559	511	637	920	1,212	1,211	1,211	931	945		
34	R&D Expense		1,800	2,200	1,900	1,100	0	0	0	0	0	0	0		
36	EBIT		1,947	1,198	1,197	1,735	3,726	5,213	6,707	6,611	6,515	4,786	4,783		
37	Tax		740	455	455	659	1,416	1,981	2,549	2,512	2,476	1,819	1,818		
38	Earnings		1,207	743	742	1,076	2,310	3,232	4,159	4,099	4,039	2,967	2,966		
40	Working Capital	3,000	1,974	1,784	1,622	1,482	1,847	2,668	3,514	3,512	3,512	2,701	2,741		
41	Change in Working Capital		-1,026	-190	-162	-140	366	820	846	-2	-1	-811	40		
42	Cash Flow		2,233	932	904	1,216	1,944	2,412	3,312	4,101	4,040	3,778	2,926		
44	Cumulative Cash Flow		2,233	3,166	4,070	5,286	7,230	9,642	12,954	17,055	21,095	24,873	27,799		
45	PV Cash Flow		2,233	847	747	913	1,328	1,498	1,870	2,104	1,885	1,602	1,128		
46	Cumulative PV Cash Flow		2,233	3,081	3,828	4,742	6,070	7,567	9,437	11,541	13,426	15,028	16,156		
48	NPV (\$ million)														
49	Cash Flow 2000-2010			16											
50	Terminal Value			10											
51	Total			27	NPV										

A3:=INDEX(Input!A4:A6, Alternative)

(A3: is not part of the formula) and this formula is copied over to other cells in the row to show the components of the alternative chosen in the cell Alternative. Formulas for the cells in E7:E51 are shown below; the formulas in cells E7:E46 are copied across into the cells F7:046. Range names for some of the rows are given in column P.

$$E7:=Mkt\_00*((Mkt\_10/Mkt\_00)^(0.1*(Year-BaseYear)))*(1-(Mkt\_RF\_fr\_00+(Year-BaseYear)*((Mkt\_RF\_fr\_10-Mkt\_RF\_fr\_00)/10)))$$

$$E8:=Mkt\_00*((Mkt\_10/Mkt\_00)^(0.1*(Year-BaseYear)))*((Mkt\_RF\_fr\_00+(Year-BaseYear)*((Mkt\_RF\_fr\_10-Mkt\_RF\_fr\_00)/10)))$$

In the previous two equations, the 10 year time horizon has been written explicitly into the equations (.1 and 10) as an example of bad practice. If the expert had preferred to give values in 2008 rather than 2010, the facilitator would have had to search out all instances of the use of this factor of 10.

E11:=c\_Mkt\_Static\*MS\_00\_DSt\*(1+MS\_gr\_DSt)^(Year-BaseYear)\*  
 (Year<=Yr\_DSt\_stop)\*(c\_units\_static\_new=0)  
 E12:=c\_Mkt\_Static\*MS\_pk\_DStn\*MAX(0,MIN(1,(Year-Startyr\_DStn)/  
 Yrs\_to\_pk\_DStn))\*MAX(0,MIN(1,1-(1+Year-Startyr\_DStn-Yrs\_to\_pk\_DStn-  
 Yrs\_at\_pk\_DStn)/Yrs\_to\_0\_DStn))\*(3=Alternative)\*("yes"=tech\_succ\_DStn)  
 E13:=c\_Mkt\_RF\*MS\_00\_DRF\*(1+MS\_gr\_DRF)^(Year-BaseYear)\*  
 (Year<=Yr\_DRF\_stop)\*(c\_units\_rf\_plus=0)  
 E14:=c\_Mkt\_RF\*MS\_pk\_DRFp\*MAX(0,MIN(1,(Year-Startyr\_DRFp)/  
 Yrs\_to\_pk\_DRFp))\*MAX(0,MIN(1,1-(1+Year-Startyr\_DRFp-Yrs\_to\_pk\_DRFp-  
 Yrs\_at\_pk\_DRFp)/Yrs\_to\_0\_DRFp))\*(2=Alternative)

The terms involving MAX and MIN in cells E12 and E14 implement the market share model shown in Figure 6-6.

E17:=ASP\_00\_DSt\*(1+ASP\_gr\_DSt)^(Year-BaseYear)\*c\_units\_static/1000  
 E18:=ASP\_sy\_DStn\*(1+ASP\_gr\_DStn)^(Year-Startyr\_DStn)\*  
 c\_units\_static\_new/1000  
 E19:=ASP\_00\_DRF\*(1+ASP\_gr\_DRF)^(Year-BaseYear)\*c\_units\_rf/1000  
 E20:=ASP\_sy\_DRFp\*(1+ASP\_gr\_DRFp)^(Year-Startyr\_DRFp)\*c\_units\_rf\_plus/  
 1000

E23:=COGS\_00\_DSt\*(1+COGS\_gr\_DSt)^(Year-BaseYear)\*c\_units\_static/1000  
 E24:=COGS\_sy\_DStn\*(1+COGS\_gr\_DStn)^(Year-Startyr\_DStn)\*  
 c\_units\_static\_new/1000  
 E25:=COGS\_00\_DRF\*(1+COGS\_gr\_DRF)^(Year-BaseYear)\*c\_units\_rf/1000  
 E26:=COGS\_sy\_DRFp\*(1+COGS\_gr\_DRFp)^(Year-Startyr\_DRFp)\*  
 c\_units\_rf\_plus/1000

E29:=SUM(E17:E20)  
 E30:=SUM(E23:E26)  
 E31:=E29-E30

E33:=SGA\*SUM(E17:E20)  
 E34:=RD\_DRFp\*(Alternative=2)+(Alternative=3)\*(RD\_pre\_DStn+RD\_post\_DStn)\*  
 ("yes"=tech\_succ\_DStn)

E36:=E31-E33-E34  
 E37:=E36\*TaxRate  
 E38:=E36-E37

E40:=Wcap\*E29  
 E41:=E40-D40

E43:=E38-E41  
 E44:=E43+D44  
 E45:=E43/(1+DiscountRate)^(Year-BaseYear)  
 E46:=E45+D46  
  
 E49:=O46/1000  
 E50:=0.001\*(O38/DiscountRate)/((1+DiscountRate)^11)  
 E51:=E49+E50

Finally, the entry in cell D40 is =Wcap\_99/1000.

**Sensitivity Analysis:** Choose Sensitivity from Start/Supertree 95. From the Structure menu, choose Import Variable Data as in Figure A-27. This step is possible only with an Excel spreadsheet; for other programs, the data must be entered manually. After the first of the screens asking for the range name of the area containing the data, you will be asked to locate the spreadsheet (not shown in Figure A-27) and for the remaining information shown in Figure A-27.

Figure A-27

Importing Variable Data from Diagnostics' Spreadsheet

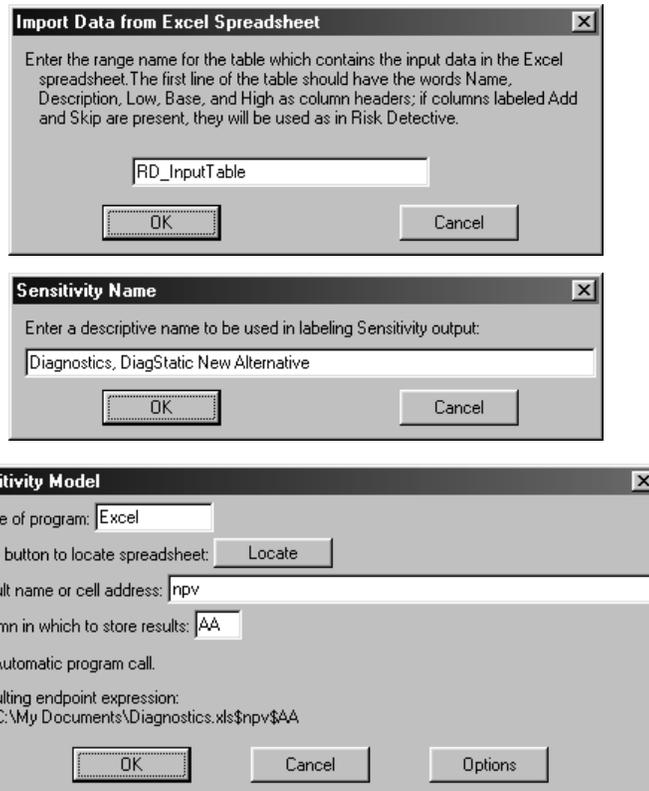


Figure A-28

Input of Single Variable Sensitivity Data

At this point, choose Import or Change Single Variable Data from the Structure menu and add the data shown in Figure A-28. This is a useful trick. Although there is no variation in this variable, it will set the alternative to be used in the sensitivity.

The dialog box shown in Figure A-28 is used to input or modify sensitivity data. The one entry that needs explanation is *Variation type*, which can be *Value* (the Low and High result values are substituted for the Base value), *Additive* (the Low and High result values are added to the Base value), or *Multiplicative* (the Base value is multiplied by the Low and High results).

The data that has been input can be shown by choosing Show Sensitivity Data from the Structure menu (Figure A-29). This data was imported from the spreadsheet or input as shown in Figures A-27 and A-28. The status of *new* in the final column indicates that all the variables have just been entered; the status will change to *old* once Sensitivity uses the spreadsheet to evaluate the sensitivity to that variable. At the bottom of the data shown in Figure A-29 are several default options for the handling of the Excel spreadsheet. These options can be modified by choosing Enter or Change Model from the Structure menu and clicking the Options button.

As with Supertree, you must choose Evaluate Sensitivity from the Evaluate menu. This causes Sensitivity to instruct Excel to run all the cases.

The display shown in Figure 6-10 can be obtained by choosing Plot Results from the Analyze menu, as shown in Figure A-30.

The joint sensitivities shown in Figure 6-11 are input by choosing Input or Change Joint Variable Data from the Structure menu, as shown in Figure A-31 for the ASP variables. The single variable ASP variations can then be deleted by choosing Delete Variables from the Structure menu (Figure A-32).

Because new variables were added, it is necessary to choose Evaluate Sensitivity before obtaining the first plot in Figure 6-12. Choose Save from the File menu, and then change the input data for Alternative from 3 to 2 and to 1 and evaluate again to obtain the second and third plots in Figure 6-12.

Figure A-29

Sensitivity Data

Sensitivity name: Diagnostics, DiagStatic New Alternative  
 Model Name: E:\C:\My Documents\Diagnostics.xls\$npv\$AA

VARIABLE	DESCRIPTION	BASE	TYPE	LOW	HIGH	STATUS
Mkt_10	Total Market, 2010	4500	VAL	4000	5000	NEW
Mkt_RF_fr_10	RF Fraction of Market, 2010	0.25	VAL	0.2	0.35	NEW
MS_gr_DSt	DiagStatic, Market Share growth rate	-0.2	VAL	-0.25	-0.15	NEW
ASP_gr_DSt	DiagStatic, Price CAGR	-0.01	VAL	-0.05	0.01	NEW
COGS_gr_DSt	DiagStatic, COGS CAGR	0.02	VAL	0	0.03	NEW
tech_succ_DStn	DiagStatic New, Technical Success	Yes	VAL	No	Yes	NEW
MS_pk_DStn	DiagStatic New, Market Share at Peak	0.2	VAL	0.1	0.4	NEW
ASP_sy_DStn	DiagStatic New, Price, start year	14000	VAL	12000	15000	NEW
ASP_gr_DStn	DiagStatic New, Price CAGR	0	VAL	-0.03	0.01	NEW
COGS_sy_DStn	DiagStatic New, COGS, start year	4800	VAL	4600	5200	NEW
COGS_gr_DStn	DiagStatic New, COGS CAGR	0.02	VAL	0	0.03	NEW
MS_gr_DRF	DiagRF, Market Share growth rate	-0.1	VAL	-0.2	-0.05	NEW
ASP_gr_DRF	DiagRF, Price CAGR	0	VAL	-0.04	0.01	NEW
COGS_gr_DRF	DiagRF, COGS CAGR	0.02	VAL	0	0.03	NEW
MS_pk_DRFp	DiagRF Plus, Market share at Peak	0.4	VAL	0.25	0.45	NEW
ASP_sy_DRFp	DiagRF Plus, Price, start year	19000	VAL	17000	23000	NEW
ASP_gr_DRFp	DiagRF Plus, Price CAGR	0	VAL	-0.03	0.01	NEW
COGS_sy_DRFp	DiagRF Plus, COGS, start year	4800	VAL	4600	5300	NEW
COGS_gr_DRFp	DiagRF Plus, COGS CAGR	0.02	VAL	0	0.03	NEW
Alternative	Strategy Alternative	3	VAL	3	3	NEW

Excel options:  
 Open linked spreadsheets.  
 Iterate with 100 maximum iterations and 0.001 maximum change.

Figure A-30

Plotting Sensitivity Results

**Plot Results** ✖

The low and high value for the sensitivity are 11 44

Enter the low and high values for the plot:

Number of intervals for axis:

Use double spacing in the plot.

Show variable description rather than name.

Show variable values on the plot.

Show % swing explained on the plot.  Cumulative  Absolute

Label for axis:

Number of decimal places to be shown:

There are 20 variables. Enter the numbers of the first and last variables for the plot:

Figure A-31

Input of Joint Sensitivity Variable

Variable Name	Base Value	Variation Type	Low Modifier	High Modifier
ASP_gr_DSt	-0.01	Value	-0.05	0.01
ASP_gr_DStn	0	Value	-0.03	0.01
ASP_gr_DRF	0	Value	-0.04	0.01
ASP_gr_DRFp	0	Value	-0.03	0.01

**Probabilistic Analysis:** Choose Supertree from Start/Supertree 95. It is possible to import directly data from Sensitivity to Supertree by choosing Import Sensitivity Data from the Structure menu. Figure A-33 shows a possible selection of variables to include in the tree from the saved sensitivity for DiagStatic New. For many problems, this simple procedure is sufficient to construct the tree. However, the Diagnostics problem is a bit too complicated to use this simple procedure.

The tree shown in Figure 6-13 is quite asymmetric, and poses a challenge for the novice user of any tree program. Methods for analyzing difficult (i.e., asymmetric) trees are presented below. The actual method chosen depends on the nature of the problem, the skill of the facilitator, and the capabilities of the audience that will see the tree.

Figure A-32

Deleting Sensitivity Variables

Figure A-33

Possible Import of Sensitivity Data into Supertree (not used in the analysis)

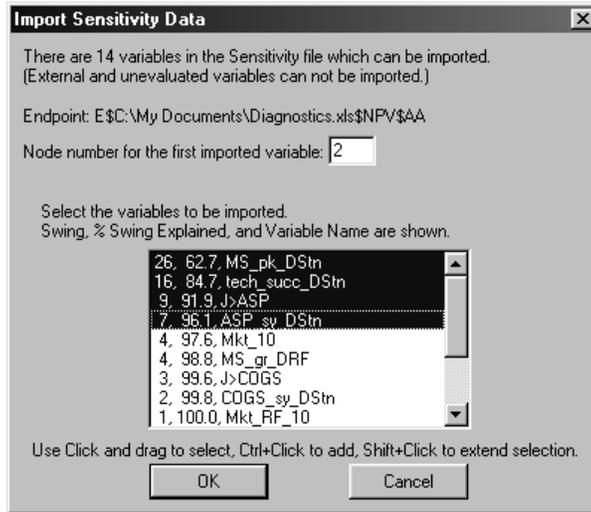


Figure A-34

Symmetric (Method 1) Tree for Diagnostics (not used in the analysis)

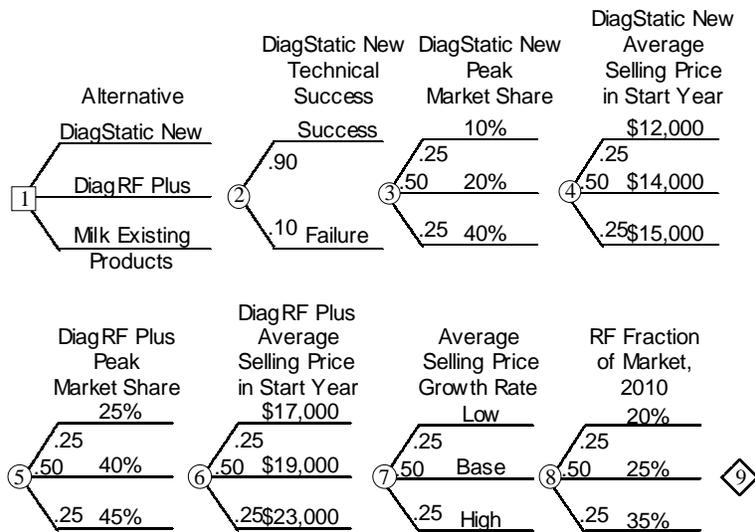
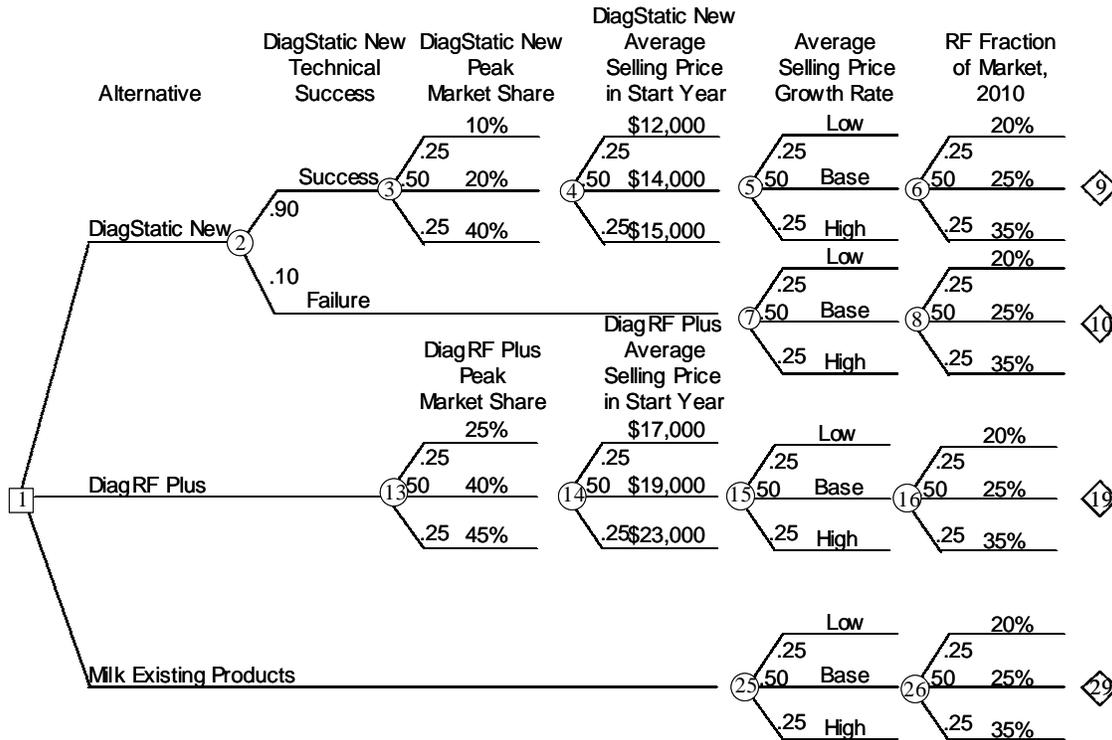


Figure A-35

As Given (Method 2) Tree for Diagnostics (not used in the analysis)



**1. Symmetrize the tree if possible.** There are only 180 paths through the Diagnostics tree in Figure 6-13. However, the simplest way to represent it for the computer is to create a completely symmetric tree. On the positive side, this is a quick and simple process. On the negative side, the number of branches in the tree can become enormous, and the time required for the spreadsheet calculations can become prohibitive.

To symmetrize the Diagnostics tree in the simplest fashion, reproduce all 7 chance nodes on each of the 3 decision branches. This tree has 4374 endpoints. Although this tree is beyond the capability of the student version of Supertree, the spreadsheet is simple, and the tree took less than a minute to evaluate on the author's laptop computer. The structure of this completely symmetric tree is shown in Figure A-34, where the tree has been broken into two lines to fit on the page.

This tree is *not* used in the analysis in this document.

**2. Construct the tree as given.** Usually there is a natural way to draw the tree. Although this may not be the most efficient way to enter the tree into the computer, it is easy to communicate the input and output with everyone involved.

The problem with tree construction occurs at asymmetric nodes—nodes for which the successors are not all the same. At the end of each branch of an asymmetric node is a subtree associated with that branch. If there are nodes that appear in more than one subtree, they must occur as separate nodes in each subtree.

The tree given in Figure 6-13 could be entered into the computer using the node numbering given in Figure A-35. The asymmetric nodes are the first node (Alternative) and the second node (DiagStatic New Technical Success). There are four subtrees, beginning at nodes 3, 7, 13, and 25. Two nodes (Average Selling Price Growth Rate and RF Fraction of Market, 2010) need to be added as separate nodes in each of these subtrees.

This tree is *not* used in the analysis in this document.

**3. Move symmetric nodes as far left as possible without interchanging chance and decision nodes.** Because the order of chance nodes is arbitrary, the facilitator can rearrange the tree to minimize the effects of asymmetry. The general rule is to move the symmetric nodes as far left as possible to remove them from the subtrees and thus avoid duplication. Interchanging chance and decision nodes changes the value of the tree (as in value of information calculations), and is left to the fourth method.

This method can be applied to the Diagnostics tree, with results shown in Figure A-36. In this case, the change is not great. There are now only three instances of the Average Selling Price Growth Rate node and of the RF Fraction of Market, 2010, node—instead of the four in Figure A-35.

This *is* the tree used in the analysis in this document.

**4. Move symmetric nodes as far left as possible.** Sometimes a very neat representation (from the computer's point of view) can be obtained by moving symmetric nodes as far left as possible, even if this interchanges the order of chance and decision nodes. The negative aspect of this method is that the analysis of tree results always involves a reordering of the tree to get the decisions back into the position that they belong. This can be hard to remember and even harder to explain.

Diagnostics' tree can be reordered into the form shown in Figure A-37. The two nodes, Average selling Price Growth Rate and RF Fraction of Market, 2010, are no longer duplicated. When tree analysis is performed, the facilitator must remember to use a *New order of nodes* of 3 1 2... to put the decision (node 3) at the beginning of the tree.

This tree is *not* used in the analysis in this document.

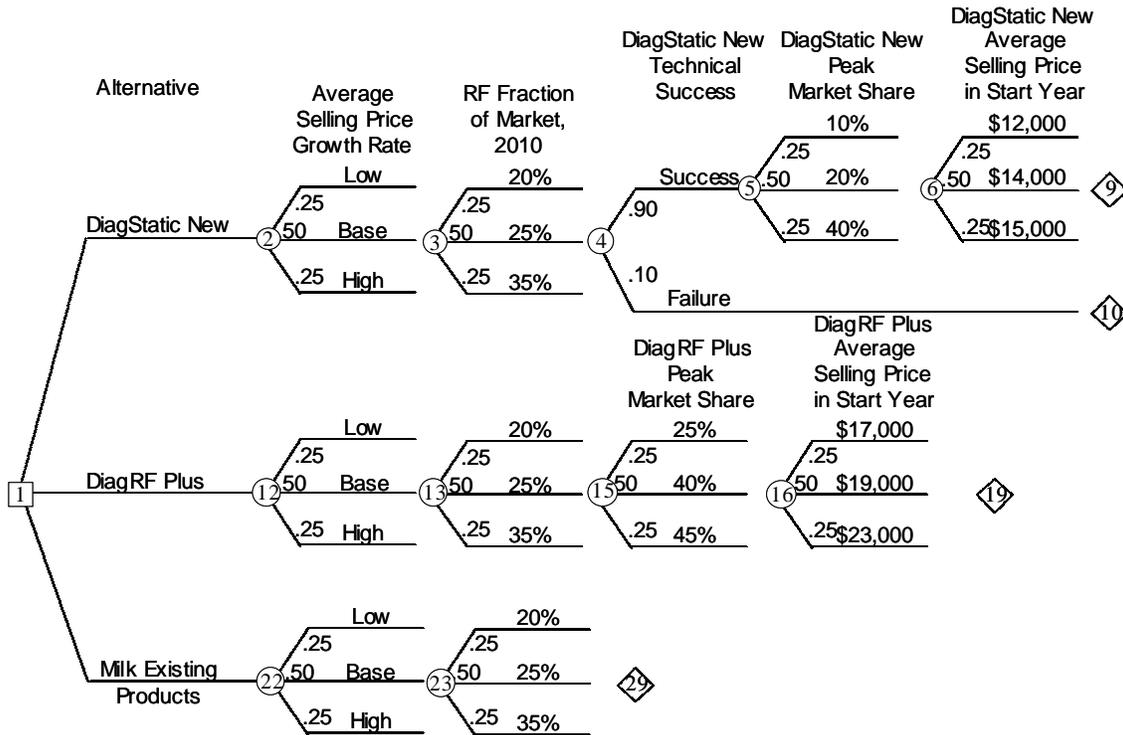
**Analyzing the tree with Supertree.** For the remainder of this document, we will use the tree shown in Figure A-36. The Supertree input for this tree is shown in Figure A-38.

Node 2 uses a Supertree feature to vary the four ASP growth rates simultaneously, with semicolons as separators between names and between outcomes. Nodes 12 and 22 are similarly defined

Node 9, the endpoint, needs the input from (depends on) nodes 1, 2, 3, 4, 5, and 6, but not the other nodes. The other endpoints, nodes 10, 19, and 29 have their dependency determined by the subtree they terminate.

Figure A-36

Reduced (Method 3) Diagnostics Tree



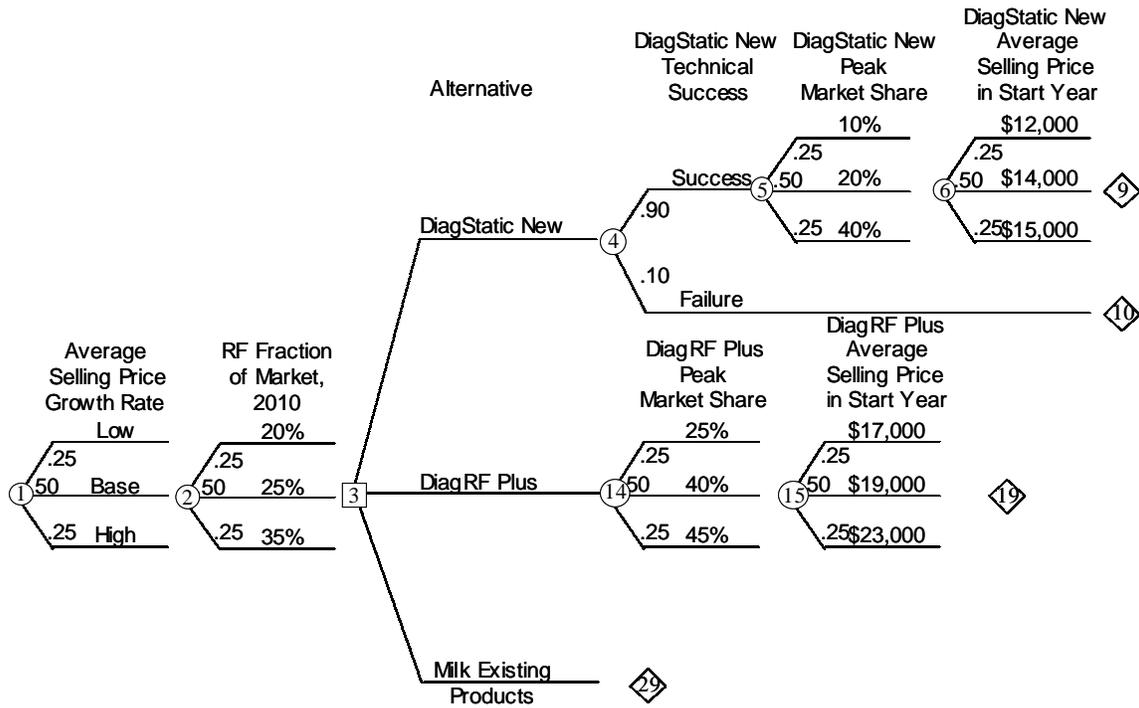
What is going on with the probabilities for nodes 2, 12, and 22 and for nodes 3, 13, and 23? If the tree were always going to be evaluated in the given order, there would be no need to create dependencies between these nodes—just enter the same probabilities (.25, .50, .25 in this case) for the nodes.

However, suppose we wanted to calculate the value of information on *Mkt\_RF\_fr\_10* by moving node 3 in front of node 1 (*New order of nodes 2 1...*)? Knowing that we are on, say, the top branch of node 3 means that we are also on the top branch of nodes 13 and 23 because there is only one uncertainty appearing in three places in the tree. The probabilistic dependency shown in Figure A-38 ties the three nodes together.

However, the facilitator should be careful about putting too many dependent probabilities in the tree. Dependent probabilities can create very large, memory-consuming data arrays in the computer. One approach is to put the probabilistic dependence into the structure only when it is needed for creating a new order of nodes involving the repeated node—and changing these probabilities can be done without evaluating the tree again.

Figure A-37

Reduced (Method 4) Diagnostics Tree (not used in analysis)



The output for the analysis in Chapter 6 uses techniques that have been demonstrated before in this document. Figures 6-14 and 6-15 are the output of the Plot Distribution option of the Analyze menu. Figure 6-16 can be obtained by using the technique shown in Figures A-18 and A-19 to store the four distributions to disk and then to recall them. Figure A-39 shows the dialog box for selecting the distribution for the DiagStatic New alternative, given Technical success—the nodes are reordered so that these are the first two nodes in the tree, and then the distribution is obtained at the third node.

Value of Perfect Information and Perfect Control (Figure 6-21) can be created by reordering the nodes and comparing the value with information with the value without information. Note that putting node 2 in front of node 1 yields the correct value of information for the ASP growth rates because of the dependency of the probabilities for nodes 2, 12, and 22.

The sensitivity to probability charts (Figures 6-22 through 6-28) are obtained using the Sensitivity to Probability option in the Analyze menu. Some care must be taken with the repeated nodes because the sensitivity to probability option replaces the existing probabilities for the nodes. For instance, you will obtain the correct graph for Figure 6-28 if you perform a

Figure A-38

## Reduced (Method 3) Diagnostics Tree in Supertree

STRUCTURE	NAMES	OUTCOMES	PROBABILITIES
1D2 12 22	Alternative	3 2 1	
2C3 3 3	ASP_gr_DSt;ASP_gr_DStn;A&SP_gr_DRF;ASP_gr_DRFp	-.05;-.03;-.04;-.03 -.&01;0;0;0 .01;.01;.01;.&01	.25 .50 .25
3C4 4 4	Mkt_RF_fr_10	.2 .25 .35	.25 .50 .25
4C5 10	tech_succ_DStn	Yes No	.9 .1
5C6 6 6	MS_pk_DStn	.1 .2 .4	.25 .50 .25
6C9 9 9	ASP_sy_DStn	12000 14000 15000	.25 .50 .25
9E	E\$:my documents\diagno&stics.xls\$npv\$AA	Depends on 1 2 3 4 5 6	
10E	E\$:my documents\diagno&stics.xls\$NPV\$AA	Depends on 1 2 3 4	
12C13 13 13	ASP_gr_DSt;ASP_gr_DStn;A&SP_gr_DRF;ASP_gr_DRFp	-.05;-.03;-.04;-.03 -.&01;0;0;0 .01;.01;.01;.&01	Depends on 2
13C15 15 15	Mkt_RF_fr_10	.2 .25 .35	Depends on 3
15C16 16 16	MS_pk_DRFp	.25 .40 .45	.25 .50 .25
16C19 19 19	ASP_sy_DRFp	17000 19000 23000	.25 .50 .25
19E	E\$:my documents\diagno&stics.xls\$NPV\$AA	Depends on 1 12 13 15 & 16	
22C23 23 23	ASP_gr_DSt;ASP_gr_DStn;A&SP_gr_DRF;ASP_gr_DRFp	-.05;-.03;-.04;-.03 -.&01;0;0;0 .01;.01;.01;.&01	Depends on 2
23C29 29 29	Mkt_RF_fr_10	.2 .25 .35	Depends on 3
29E	E\$:my documents\diagno&stics.xls\$NPV\$AA	Depends on 1 22 23	

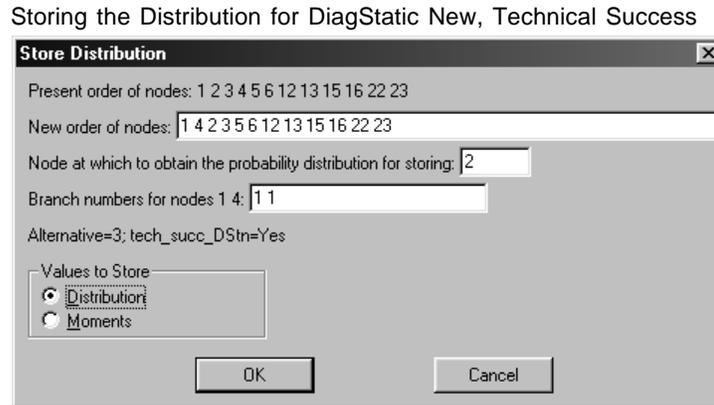
ASP_gr_DSt;ASP_gr_DStn;ASP_gr_DRF;ASP_gr_DRFp	PROBABILITY, NODE 12
-.05;-.03;-.04;-.03	1 0 0
-.01;0;0;0	0 1 0
.01;.01;.01;.01	0 0 1

Mkt_RF_fr_10	PROBABILITY, NODE 13
0.2	1 0 0
0.25	0 1 0
0.35	0 0 1

ASP_gr_DSt;ASP_gr_DStn;ASP_gr_DRF;ASP_gr_DRFp	PROBABILITY, NODE 22
-.05;-.03;-.04;-.03	1 0 0
-.01;0;0;0	0 1 0
.01;.01;.01;.01	0 0 1

Mkt_RF_fr_10	PROBABILITY, NODE 23
0.2	1 0 0
0.25	0 1 0
0.35	0 0 1

Figure A-39



sensitivity to the probability of node 3, but not if you perform the sensitivity to node 13 or node 23—in the latter two cases, the sensitivity overwrites the dependency linking the nodes.

The sensitivity to risk attitude in Figure 6-30 is obtained from the Sensitivity to Risk Attitude in the Analyze menu.

Finally, a policy matrix such as shown in Figure 6-31 can be obtained by displaying the tree up to the second decision point.

## Portfolios (Chapter 7)

Several methods of combining probabilistic results for a portfolio of businesses were shown in Figures 7-16 through 7-18. In all these methods, a probabilistic analysis was done for each business, and then the probabilistic results were combined.

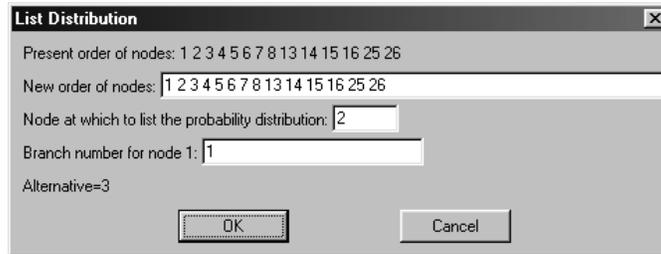
In Figure 7-16, the probability distribution (conditional on strategy and economic/environmental state) for each business was simplified into a two or three-branch tree. In Figure 7-17, the simplified probability distributions for the businesses were combined into a simplified Combined Business Uncertainty. In Figure 7-18, moments and cumulants were used.

Supertree can provide the data required for these calculations. The List Distribution Values in the Analyze menu provides a table of cumulative probabilities, a table of moments, and a three branch tree that preserves the first five moments of the probability distribution. The three branch tree could be used for input into Figure 7-16. The moments could provide input for Figure 7-18.

Figure A-40 shows this output for the Diagnostics business, one business in Medequip's portfolio. The data was requested at node 2, so that we could specify the alternative (node 1, branch 1). The bottom display (Store Distribution in the File menu) in Figure A-40 shows how the data can be saved to a tab-delimited ASCII file (name to be supplied in the following dialog box) for automated inclusion into a portfolio database.

Figure A-40

Obtaining Values for Use in Portfolios



Percentile	Value	Percentile	Value	Percentile	Value
0.010	9.212205042	0.350	19.33216774	0.750	29.35758788
0.020	10.04846475	0.400	20.33042923	0.800	32.3996861
0.050	10.89211506	0.450	21.94148704	0.850	36.24024298
0.100	12.0386219	0.500	23.58718914	0.900	44.10030504
0.150	14.57519136	0.550	25.6533455	0.950	48.33203976
0.200	16.03603992	0.600	26.50644039	0.980	49.95458561
0.250	17.70950807	0.650	27.67263825	0.990	53.16548598
0.300	18.8507464	0.700	28.78891707		

Expected value (mean): 25.18370929  
 Variance: 113.7297105

	Moment	Central Moment	Cumulant
First	25.18370929	0	25.18370929
Second	747.9489243	113.7297105	113.7297105
Third	25509.26191	944.8617006	944.8617006
Fourth	968989.599	38797.69288	-5.648273228
Fifth	39838411.62	665923.0623	-408665.4145

Three branch node that matches first five moments:

Probability	Value
0.3525398741	13.76561683
0.5169977303	27.31932097
0.1304623956	47.57503883

