

8. TUTORIAL FOR DECISION TREE ANALYSIS

CASE: ICI AMERICAS R&D PROJECT SELECTION, P. 213

Decision tree analysis is useful to managers choosing among various courses of action when the choice (or sequence of choices) will ultimately lead to some uncertain consequences. The TreeAge software allows you to take into account the potential *payoffs*, *risks*, and *ambiguities* associated with decisions when the decision process can be broken down into a sequence of actions and events. *Payoffs* are the monetary or other consequences of a decision; *risks* are the potential adverse consequences that may result from the decision because the decision maker lacks control over the consequences of the decision (i.e., he or she doesn't know the outcomes with certainty), and *ambiguities* are imprecise information about payoffs and the degree of risk.

A decision tree analysis typically consists of four steps:

- Structuring the problem as a tree in which the end nodes of the branches are the payoffs associated with a particular path (scenario) along the tree.
- Assigning subjective probabilities to events represented on the tree.
- Assigning payoffs for consequences (dollar or utility value associated with a particular scenario).
- Selecting course(s) of action based on analyses (e.g., rolling back of the tree, sensitivity analyses, Monte Carlo simulations). We describe each step using the QRS Company, example, p.192, in the text.

TreeAge is a comprehensive software package that includes a detailed online help file and an electronic manual. Here we describe only the features that you will need for the ICI case.

Note: To view or print a copy of the complete manual, you will need the original CD on which the Marketing Engineering software was distributed.

If you do not have Adobe Acrobat® reader installed on your system, you can install it by downloading the appropriate files from www.adobe.com, or you can install the version supplied with the Marketing Engineering CD in the directory... \adobe.

*After Acrobat™ is successfully installed, start the Acrobat program. From the **File** menu, select **Open** and open the file *manual.pdf* from the *x:\treeage\manuals* directory, where *x* is the letter representing your CD-ROM drive. Under the **File** menu, select **Print** to print any part of the manual.*

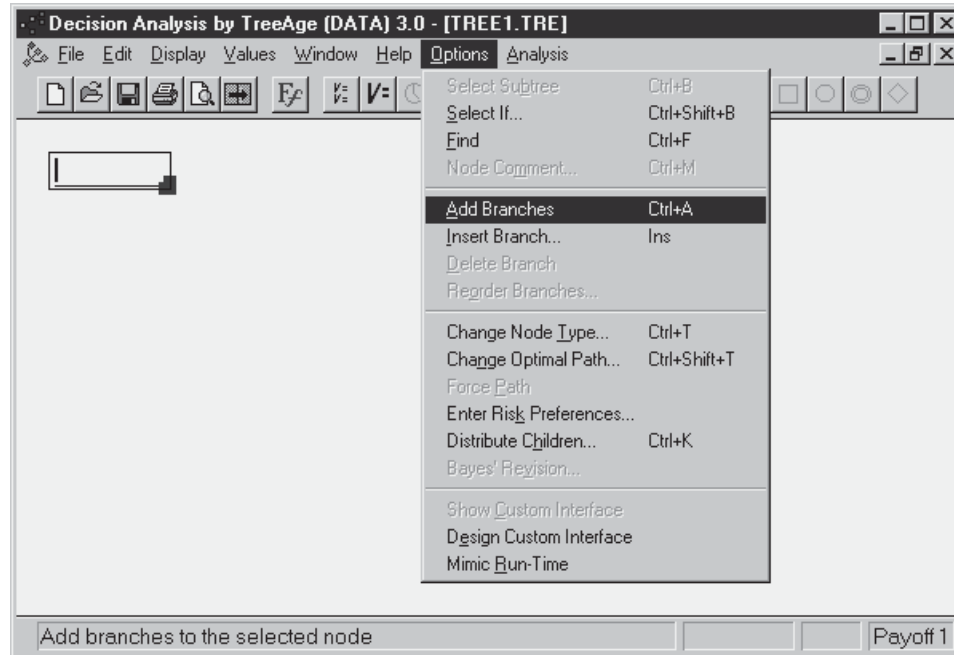
STEP 1—STRUCTURING THE PROBLEM AS A DECISION TREE

To start the program go to **Model** and choose **Decision Tree Analysis**, you will see an empty root node from which you can construct a tree. To load a pre-existing tree, go to the **File** menu and select **Open**. (Choose the QRS.TRE file in the .../MktgEng/data directory to familiarize yourself with the software. If you load QRS.TRE, you can go directly to **Step 2**.)

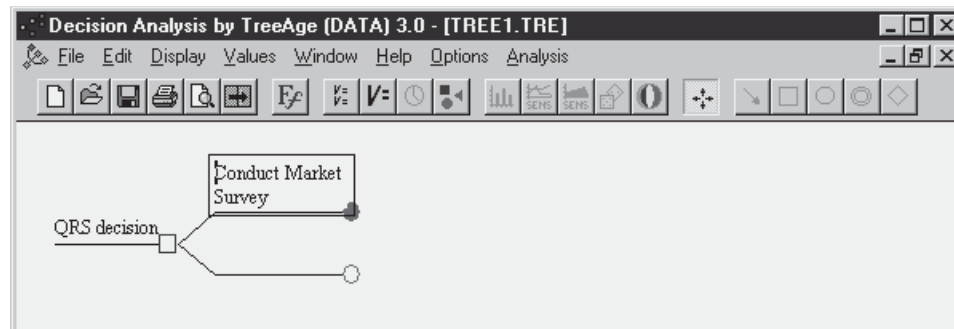
* Tutorial 8, May 2005

On the **Options** menu, select **Add Branch** or **Insert Branch** to add branches to any node on the tree. To delete a branch, click **Delete Branch**.

Another method for adding branches to a node is to double-click on the node. When the cursor is over the node's symbol, it will change to a branch cursor to indicate that double-clicking will add branches.



To indicate what a branch stands for, enter descriptive text in the box above it. Place the cursor above the line and click to get the box.



***Note:** Many decision trees have some subtree replication. You can cut and paste a subtree to other locations on the tree. Place the cursor at the root node of the subtree you want to copy and click. Go to the **Options** menu and click **Select Subtree**. Then go to the **Edit** menu and choose **Copy Subtree**. Next place the cursor on the node where you want to insert the subtree and click. Now go to the **Edit** menu and click **Paste**. You can cut and paste subtrees even after you assign names and probabilities to the branches and payoffs to the terminal nodes. (See also the **Clone** command under online **Help**.)*


The **Edit** menu contains four tree clipboards named *Tree clipboard1* to *Tree clipboard 4*. Thus, you can retain several subtrees at once, each in its own clipboard, to be pasted as needed.

STEP 2—ASSIGNING (CONDITIONAL) PROBABILITIES TO BRANCHES OF THE TREE

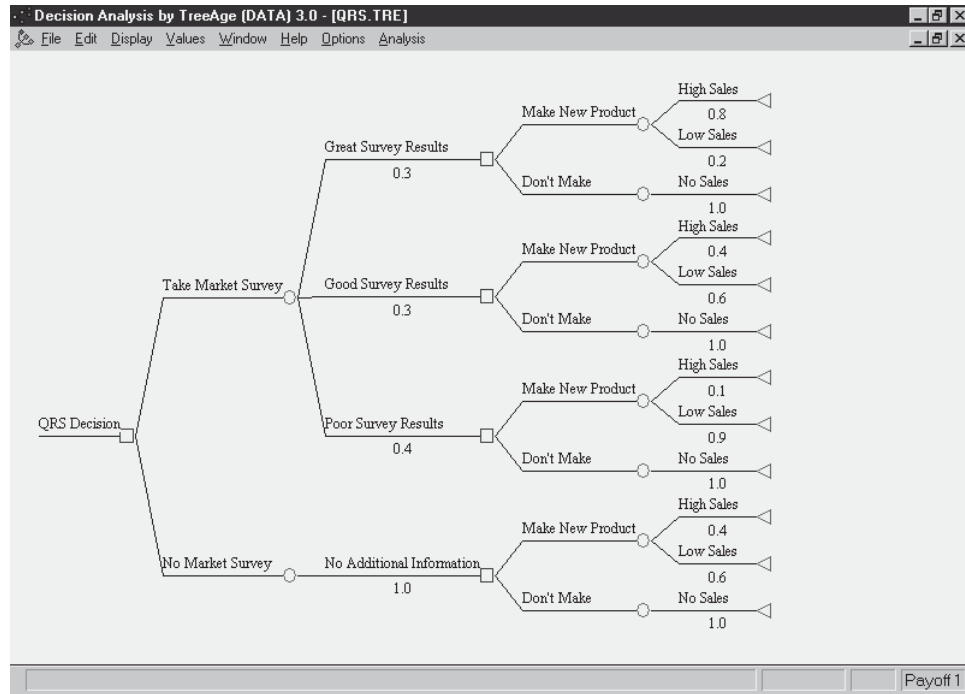
You can insert the probability of an outcome on the branch of the tree in the text box below the line. To get the text box, place the cursor below the line representing a branch and click.

NOTE: You can enter probabilities only on the branches of a tree that originate from a chance node. A decision tree contains several types of nodes:

1. A chance node (shown as a green circle) represents an uncertain or risky event. Branches emanating from a chance node represent all possible (non-overlapping) outcomes of the event.
2. A decision node (shown as a blue square) represents a decision the manager faces. Branches emanating from a decision node specify all available (non-overlapping) decision choices.
3. A terminal node (shown as a red triangle) represents a final outcome: the end of a path, often referred to as a scenario.

To change a node type, click the node, go to the **Options** menu and click **Change Node Type** and select the node type from the available choices. Alternatively, you can click the  icon on the toolbar and select the node type you want.

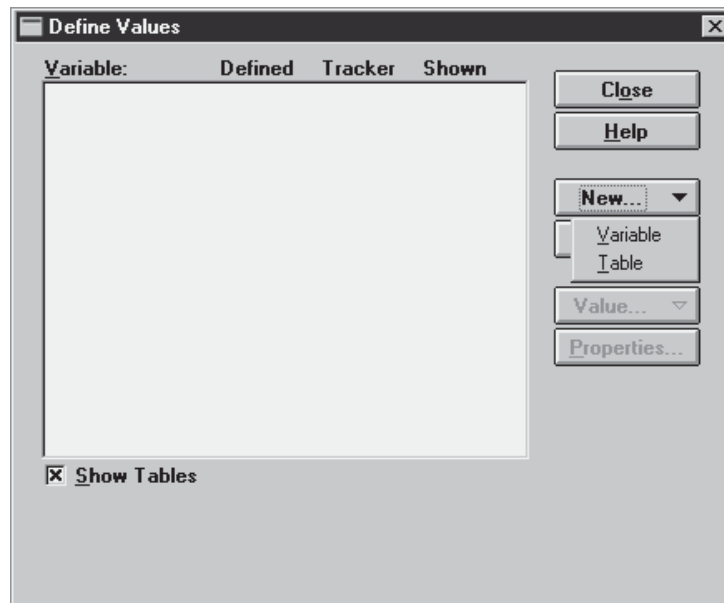
As an exercise, construct the tree shown below:



In the rest of the text under **Step 2**, we describe advanced features. You can skip to **Step 3** until you become familiar with the software.

In many cases, you will be uncertain about the accuracy of your probability estimates. Defining the probabilities as variables will enable you to perform sensitivity analyses to help you assess the significance of the uncertainty. To do this, you must define the variable, specify the value(s) it can take, and indicate the location(s) on the decision tree where these values will apply:

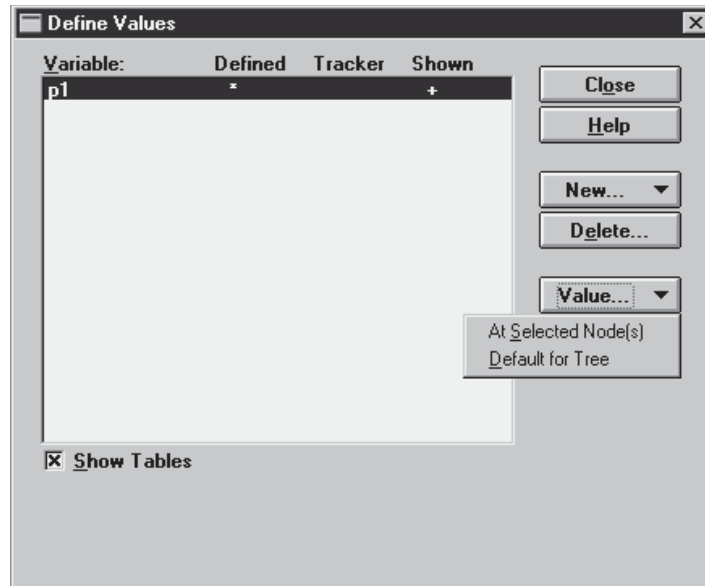
1. **Define a variable:** Go to the **Values** menu and choose **Define Values**. Click **New** and select **Variable** from the drop-down menu.



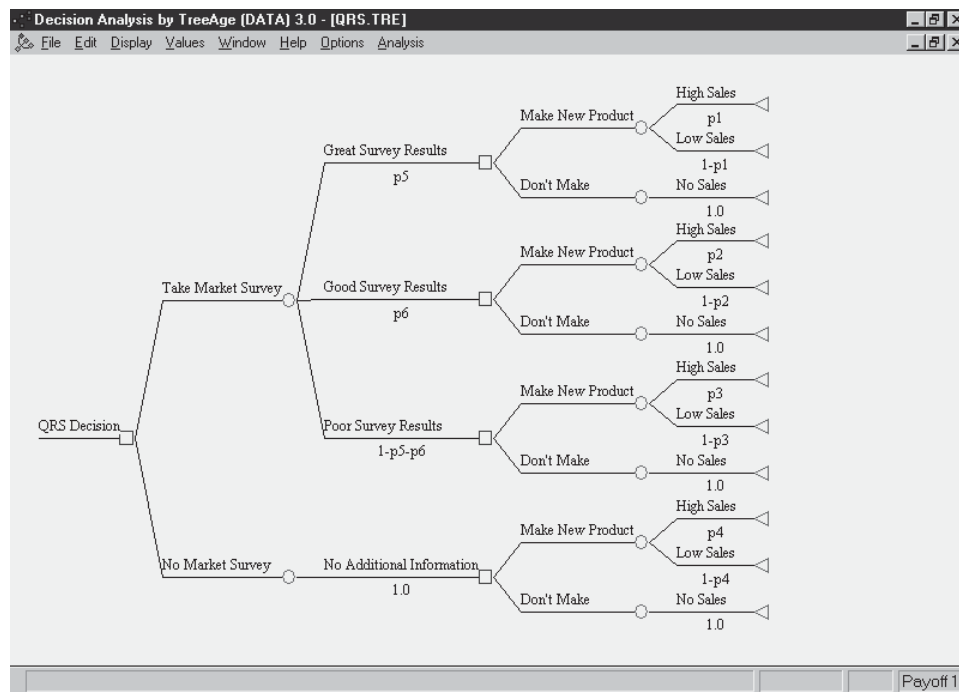
In the **Text Properties** section of the **Properties** dialog box, give your variable a name. If you like, you can also provide a short description or a longer comment, which can be useful for customizing the display,

Follow the above procedure to define each variable in your model.

2. *Specify the default value and, optionally, the range of values a variable takes.* Use the **Value Properties** section to specify a default value (baseline value) for a variable and a range of numeric values to be associated with it. For example, p1 could have the default value of 0.8 and values ranging from 0.6 to 0.9. You can accept or override the suggested range when specifying the parameters of the sensitivity analyses. It is not necessary to provide a range here, although you may find it convenient.
3. *Indicate the locations on the tree where the values apply.* Click on **Value**, and you will be presented with two options. Either you can define a value at a particular node or as a default for the whole tree. If you define a variable at a particular node, the program applies that value of the variable throughout the subtree rooted at the selected node. If you define a variable as the default for the tree, it applies to the entire tree, and its definition resides at the root node. Node-specific definitions are appropriate for probabilities whose values are likely to differ at various points on the tree, for example, the probabilities of high and low sales would depend on whether market research results were favorable. Default definitions are appropriate for probabilities whose values remain constant throughout the tree, for example, the rate of inflation.



4. *Associate the variable with probabilities on the tree:* Insert the variable name in the text box below the branches of the tree for which the variable will represent the probability value. In the example below, p1 represents the probability of “High Sales” under the “Make New Product” and “Great Survey Results” scenario.




Note: The probabilities along the branches emanating from each chance node must sum to 1.0. Thus, if two branches emanate from a chance node, you can assign one the variable $p1$ and the other $(1 - p1)$.

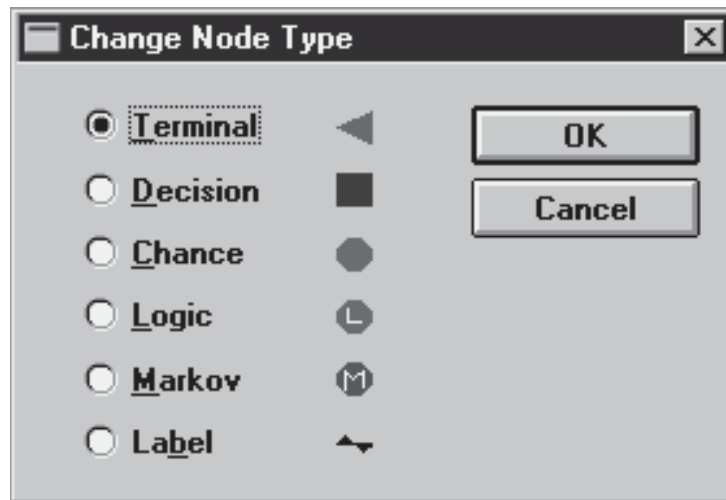
It is very important to make the variable assignments at the correct nodes. For this, you need to understand how the program uses variables in making calculations.

When the program encounters a variable in a probability field during calculations, it searches for the value assignment beginning with the node immediately to the right of the probability field and moves from there leftward to the root node. For a given variable, the program accepts the first definition (value assignment) that it locates as it makes this traversal. Thus, the program will disregard any definitions closer to the terminal node than the node immediately to the right of the probability field in question.

As a general rule, you should avoid using the same variable to define the probability of more than one event. Thus, if you have two subtrees representing the same uncertainty (high versus low sales), but the probability values are different, you should use different variables.

STEP 3—ASSIGNING PAYOFFS (PREFERENCES) FOR SCENARIOS

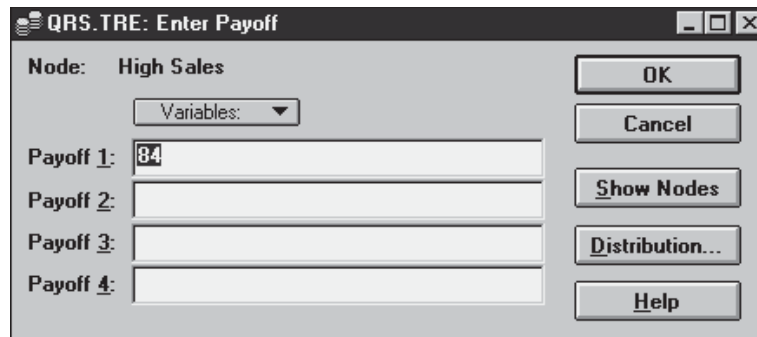
If you are sure about the dollar value (payoff) associated with a scenario, first select the terminal node (place the cursor on the node and click) and then go to the **Options** menu and select **Change Node Type**. You can also click on the  icon to change the node type. You will see the following dialog box:



Select the terminal node option (red triangle) and click **OK**.

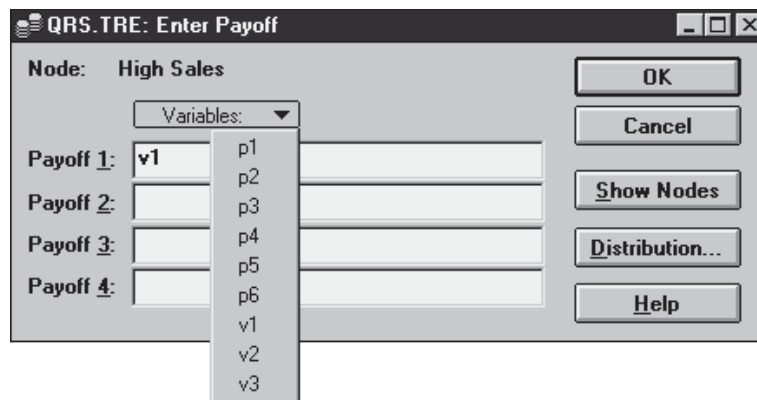
You will be prompted to enter a numerical value for **Payoff 1**. You can then enter the sure payoffs. You can associate up to four different payoffs with each scenario (e.g., dollar value, costs, utility value, or payoff realized by a partner firm). In the following example, we selected the terminal node under High Sales, which is under the Great Survey Results scenario, and entered the value eighty-four.

Enter a payoff for each terminal node.



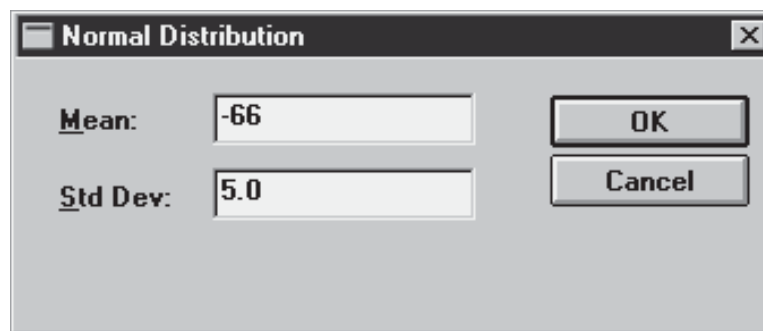
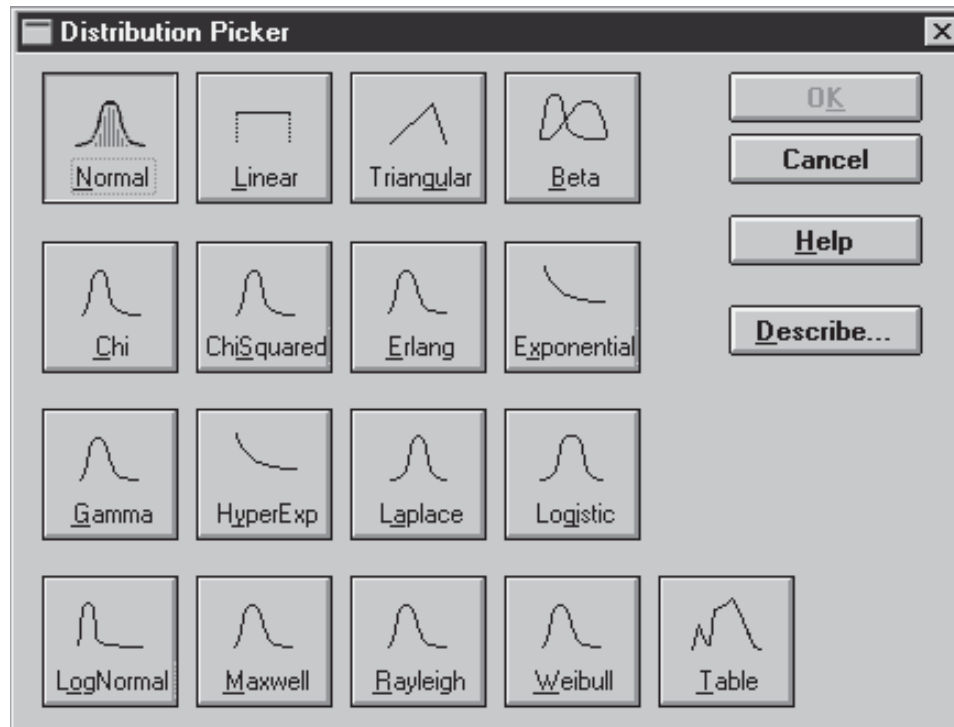
In the rest of the text under **Step 3**, we describe advanced features. You can skip to **Step 4** until you become familiar with the software.

For conducting sensitivity analyses, you can define variables to denote payoffs. The procedure for defining variables for payoffs is the same as the one we described for assigning variables for probabilities. In the following example, we will use the variable $v1$ to represent payoffs realized under High Sales and with No Market Survey. You can also use algebraic expressions of defined variables (e.g., $v1 + v2 - v3$) to represent more complex payoffs.



For variables used in calculating payoffs for a scenario, the program will search each node in the scenario, beginning with the terminal node and traversing leftward to the root node, looking for numeric definitions for each relevant variable. For a given variable, the program will accept the first definition (value assignment) that it locates on this traversal. Thus, if the same construct will have different values at two different nodes on the tree, it is best to define two separate variables that apply at those nodes. For example, if unit costs of production are higher at higher volumes, then the cost figures in scenarios with high sales should have larger numbers than cost figures in scenarios that call for lower sales.

Click the **Distribution** button to specify the frequency with which values of the variable would be selected in Monte Carlo analyses. In the example below, we first selected the **Normal** distribution from the palette of distributions and then specified a mean of -66 and a standard deviation of 5.0 for variable $v1$.

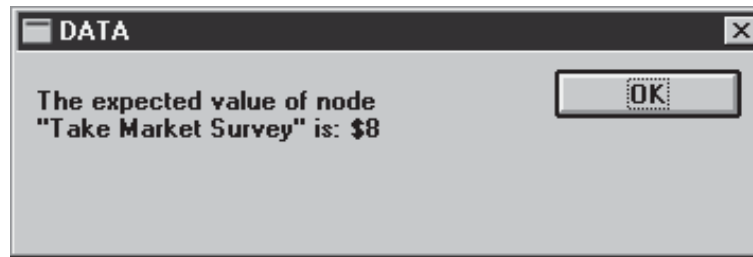



STEP 4—CONDUCTING ANALYSES TO SELECT DECISION OPTION(S)

You can conduct many types of analyses with the TreeAge software. We will describe those you are most likely to use for the ICI exercise. To learn about other types of analyses, play around with the other commands on the **Analysis** menu, which are described in the online help files.

Calculate the expected value of a node: Click on a node, go to the **Analysis** menu and select **Expected Value**. A dialog box will show the expected value; in this example, the expected value of the Take Market Survey node is \$8.

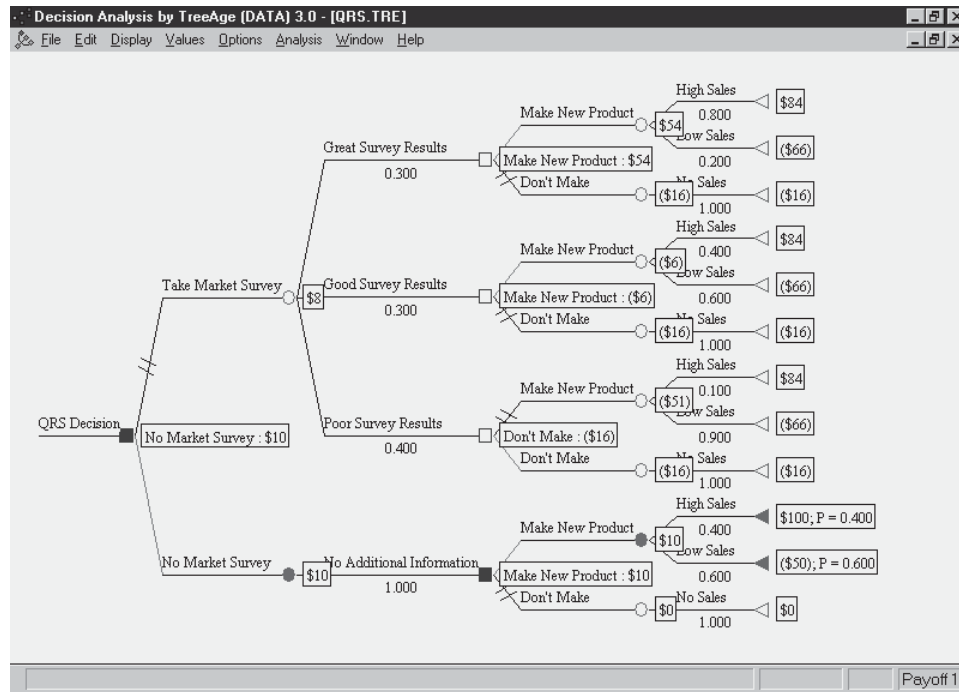
Note: In calculating the expected value, the program uses the baseline values of variables or the mean values of distributions associated with the variables.



Rolling back the tree: Instead of calculating the expected value of each node in the tree individually, you can calculate and display the expected values and probabilities of all nodes simultaneously. To do this, go to the **Analysis** menu and click **Roll Back**. Alternatively, you can click on the  icon on the tool bar.

Once you roll back the tree, you will see three additional pieces of information on the tree:

- The expected payoffs (in dollars or other appropriate units) shown in a rectangular box at each chance and decision node.
- The payoff and the overall probability for each terminal node.
- The path along the tree that leads to the highest expected payoff (the branches that are not along this path are marked with the symbol \). In this example, the “optimal” decision is to make the new product without conducting a market survey.

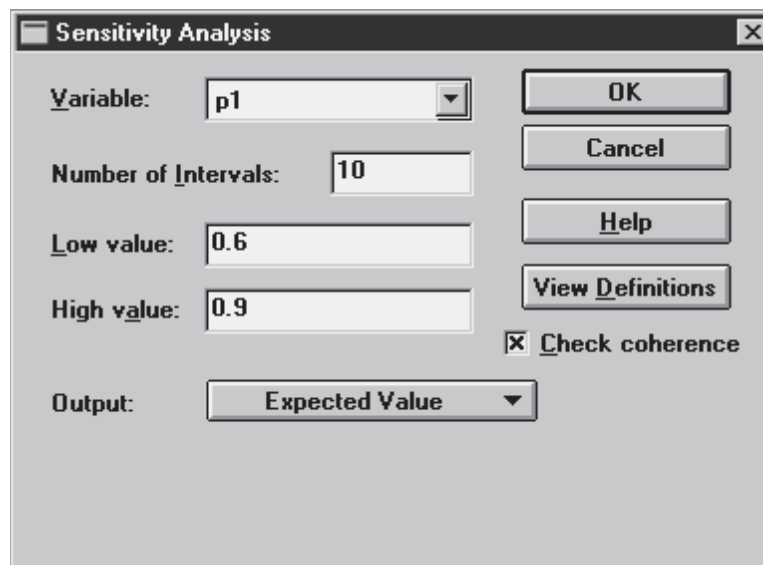


Sensitivity analyses: The TreeAge software offers several options for conducting sensitivity analyses to determine which factors have great impact on the decisions. The most common way to do this is to select a node and then go to the **Analysis** menu and select **Sensitivity Analysis**. You will then have four choices:

- Analyzing the effects of a change in one variable (One-way).
- Analyzing the effects of changes in any two variables simultaneously (Two-way).
- Analyzing the effects of changes in any three variables simultaneously (Three-way).
- Tornado diagram, which is a set of one-way sensitivity analyses on any subgroup of variables in your decision tree. We describe the one-way graphs and Tornado diagrams.

One-Way Sensitivity Analysis: If you choose **One-way**, you will see the following screen.

Note: It is important to first specify the node at which this analysis will apply. Typically, you would select the root node to see the impact of the sensitivity analysis on the overall decision.

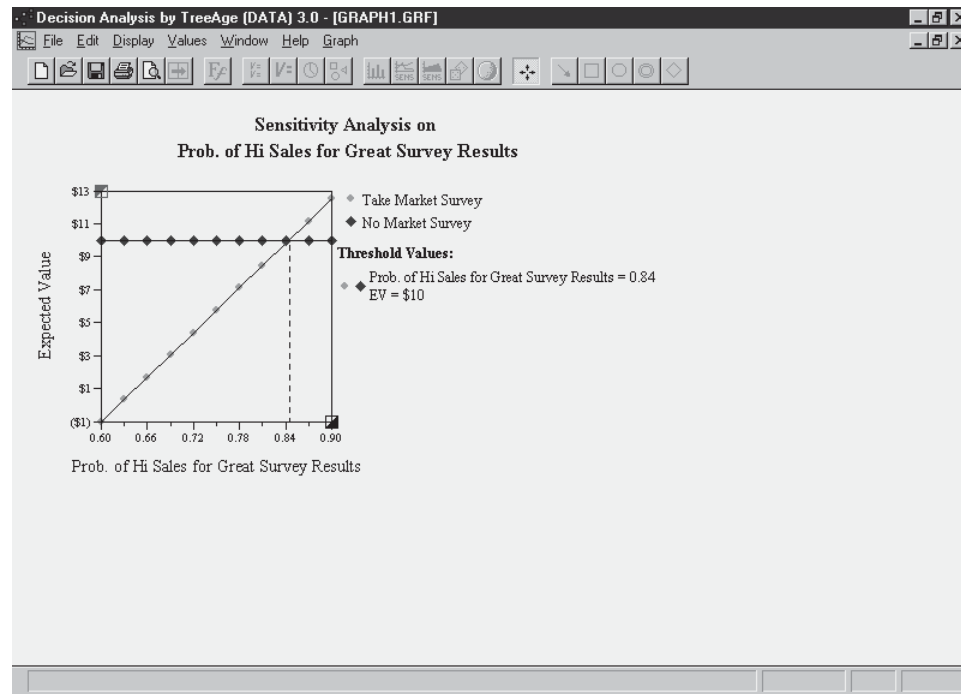


The image shows a dialog box titled "Sensitivity Analysis" with a close button (X) in the top right corner. The dialog contains the following fields and controls:

- Variable:** A dropdown menu with "p1" selected.
- Number of Intervals:** A text input field containing "10".
- Low value:** A text input field containing "0.6".
- High value:** A text input field containing "0.9".
- Output:** A dropdown menu with "Expected Value" selected.
- Buttons:** "OK", "Cancel", "Help", and "View Definitions" are arranged vertically on the right side.
- Check coherence:** A checked checkbox with the label "Check coherence".

After you specify the variable of interest and its range of variation, click **OK**. You will then see a chart showing how the expected value of each decision option changes as the value of the selected variable changes.

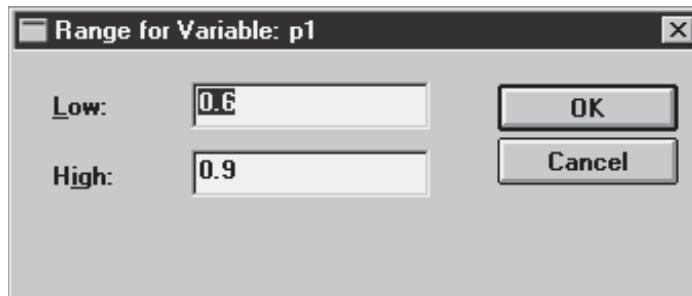
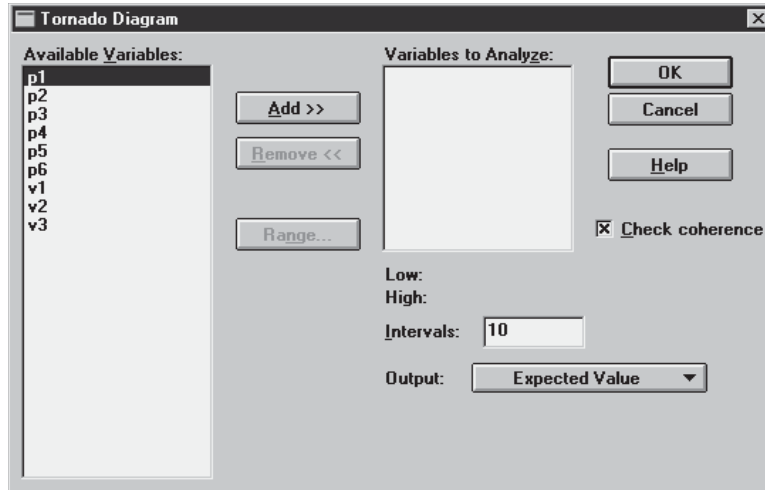
In the following example, the analysis indicates that if p1 (probability of High Sales given Great Survey Results) is equal to a little over 0.84, then it may pay to conduct a test market survey.



On the **File** menu, click **Close** to get back to the decision tree display.

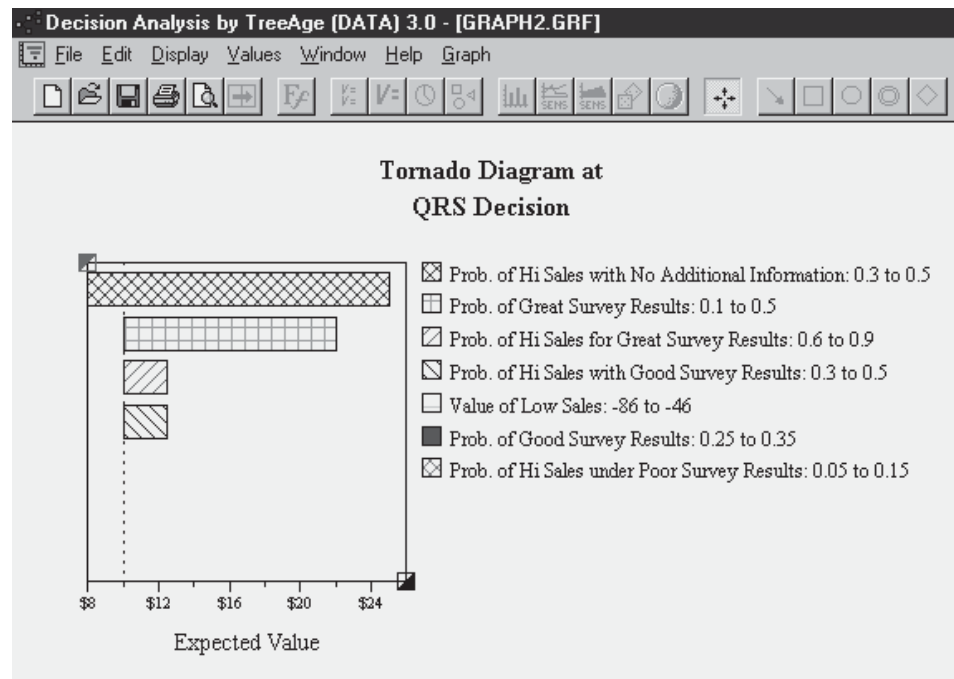
Tornado Diagram: An alternative way to conduct sensitivity analyses is the Tornado diagram, which is a set of mini-sensitivity analyses set forth in a single graph. It can include all or a subset of the variables defined in your tree. You specify which variables are to be included in the analysis and assign a range of values to each of them. In the resulting graph, each variable analyzed is represented by a horizontal bar. Each bar represents the range of possible outcomes generated by varying the related variable. A wide bar indicates that the associated variable has a large potential effect on the expected value of the decision. This is called a tornado diagram because the bars are arranged in order with the widest bar at the top and narrowest bar at the bottom, resulting in a funnel-like appearance. A vertical dotted line is drawn on the graph to indicate the expected value at the selected node (often the root node).

To construct a tornado diagram, select the chance node or decision node at which you want to construct the diagram. Next from the **Analysis** menu, select **Tornado Diagram** and then select **Variables to Analyze**. Click each variable to be included (from **Available Variables**) and then click **Add>>**. You will be prompted to specify the range of variation for each variable.



Once you enter the appropriate information, the program will display the results of the sensitivity analysis as bar graphs indicating the expected payoff as the values of the variable(s) change.

Note: The vertical dotted line at the selected node is the “fulcrum” that allows you to view the impact of each variable relative to the original (baseline) expected value. Thus, although the range of p1 is from 0.6 to 0.9, it affects the expected value of the decision only for values from 0.84 to 0.9 - the range in which the expected value of the decision becomes higher than 10, the baseline.



Monte Carlo analysis: In Monte Carlo analysis, the model runs a number of simulated trials. The result of each trial is a single scenario selected according to the probabilities specified in the model. On most decision trees, no specified outcome corresponds to the expected value. The results from the simulation are a distribution of payoffs rather than a single expected value. Over many simulation trials, the average result will fall very close to the expected value, but you will also obtain information about the variance around the expected value. You can find more details about the Monte Carlo analysis in the online help and in the detailed manual for the program that you can print out as we described at the beginning of this tutorial.

LIMITATIONS OF THE EDUCATIONAL VERSION OF THE SOFTWARE

The educational (demonstration) version of TreeAge is identical to the full version in most respects, except:

- You cannot save any documents. Once you complete an exercise, you cannot store the tree for future use (although you can print out a copy from which you can reconstruct the tree). So, do not exit the program until you are sure you have completed all analyses.
- The maximum size tree you can create manually is 50 nodes.
- The maximum size tree you can open is 125 nodes. We have included several example files (with extension *.tre) that you can open to learn more about how decision trees are used in various application areas.