User's Guide

PrecisionTree

Decision Analysis Add-In
For Microsoft® Excel

Version 5.7
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Welcome

Welcome to PrecisionTree, the decision analysis software that's an add-in to Microsoft Excel. Now you can do something you've never been able to do before - define a decision tree or influence diagram directly in your spreadsheet. PrecisionTree allows you to run a complete decision analysis without leaving the program where your data is – your spreadsheet!

Why You Need Decision Analysis and PrecisionTree

You might wonder if the decisions you make are suitable for decision analysis. If you are looking for a way to structure your decisions to make them more organized and easier to explain to others, you definitely should consider using formal decision analysis.

When faced with a complex decision, decision makers must be able to organize the problem efficiently. They have to consider all possible options by analyzing all available information. In addition, they need to present this information to others in a clear, concise format. PrecisionTree allows decision makers to do all this, and more!

But what exactly does decision analysis allow you to do? As the decision maker, you can clarify options and rewards, describe uncertainty quantitatively, weigh multiple objectives simultaneously and define risk preferences, all in an Excel spreadsheet.

Modeling Features

As an "add-in" to Microsoft Excel, PrecisionTree "links" directly to Excel to add Decision Analysis capabilities. The PrecisionTree system provides all the necessary tools for setting up and analyzing decision trees and influence diagrams. And PrecisionTree works in a style you are familiar with — Excel-style menus and toolbars.

With PrecisionTree, there's no limit to the size tree you can define. Design a tree which spans multiple worksheets in an Excel workbook! PrecisionTree reduces the tree to an easy-to-understand report right in your current workbook.

PrecisionTree Nodes

PrecisionTree allows you to define influence diagram and decision tree nodes in Excel spreadsheets. Node types offered by PrecisionTree include:

- Chance nodes
- Decision nodes
- End nodes
- Logic nodes
- Reference nodes

Values and probabilities for nodes are placed directly in spreadsheet cells, allowing you to easily enter and edit the definition of your decision models.

Model Types

PrecisionTree creates both decision trees and influence diagrams. Influence diagrams are excellent for showing the relationship between events and the general structure of a decision clearly and concisely, while decision trees outline the chronological and numerical details of the decision.

Values in Models

In PrecisionTree, all decision model values and probabilities are entered directly in spreadsheet cells, just like other Excel models. PrecisionTree can also link values in a decision model directly to locations you specify in a spreadsheet model. The results of that model are then used as the payoffs for each path through the decision tree.

All calculations of payoffs happen in "real-time" – that is, as you edit your tree, all payoffs and node values are automatically recalculated.

Decision Analysis

PrecisionTree's decision analyses give you straightforward reports including statistical summaries, risk profiles and policy suggestions. And, decision analysis can produce more qualitative results by helping you understand tradeoffs, conflicts of interest, and important objectives.

All analysis results are reported directly in Excel for easy customization, printing and saving. There's no need to learn a whole new set of formatting commands since all PrecisionTree reports can be modified like any other Excel worksheet or chart.

Sensitivity Analysis	Have you ever wondered which variables matter most in your decision? If so, you need PrecisionTree's sensitivity analysis options. Perform both one and two-way sensitivity analyses and generate tornado graphs, spider graphs, strategy region graphs, and more!
	For those who need more sophisticated sensitivity analyses, PrecisionTree links directly to TopRank, Palisade Corporation's sensitivity analysis add-in.
Reducing a Tree	Because decision trees can expand as more possible decision options are added, PrecisionTree offers a set of features designed to help you reduce trees to a more manageable size. All nodes can be collapsed, hiding all paths which follow the node from view. A single subtree can be referenced from multiple nodes in other trees, saving the re-entry of the same tree over and over.
Risk Analysis	@RISK, Palisade Corporation's risk analysis add-in, is a perfect companion to PrecisionTree. @RISK allows you to quantify the uncertainty in any spreadsheet model using distribution functions. Then, at the click of a button, @RISK performs a Monte Carlo simulation of your model, analyzing every possible outcome and graphically illustrating the risks you face.
	Use @RISK to define uncertain (chance) events in your model as continuous distributions instead of estimating outcomes in a finite number of branches. Probability distributions can be applied to any uncertain value or probability in your decision trees and supporting spreadsheets. With this information, @RISK can run a complete Monte Carlo simulation of your decision tree, showing you the range of possible results that could occur.
Advanced Analysis Capabilities	PrecisionTree offers many advanced analysis options including:

- Utility functions

- Use of multiple worksheets to define trees

- Logic nodes

Table of Contents

Chapter 1: Getting Started

Introduction

This introduction describes the contents of the PrecisionTree package and shows how to install PrecisionTree and attach it to your copy of Microsoft Excel 2000 or higher.

Checking Your Package

Your PrecisionTree package should contain:

The PrecisionTree User's Guide (this book) with:

- Preface and Getting Started

- Overview of Decision Analysis

- Overview of PrecisionTree

- Modeling Techniques

- PrecisionTree Command Reference

- Technical Appendices

The PrecisionTree CD-ROM including:

- PrecisionTree System Files

- PrecisionTree Example Files

- PrecisionTree Tutorial

The PrecisionTree Licensing Agreement

If your package is not complete, please call your PrecisionTree dealer or supplier or contact Palisade Corporation directly at (607) 277-8000 or toll-free (800) 432-7475 (USA/Canada only).

Deciding What to Read

If you want to use PrecisionTree right away, you can go directly to the installation instructions at the end of this chapter. If you know about decision analysis but not about PrecisionTree, try working through the on-line tutorial after installing the PrecisionTree system. If you are not familiar with decision analysis, start with the Overview of Decision Analysis which follows this chapter. The overview discusses concepts and techniques of decision analysis and gives a good background for proceeding through the tutorial.

Both the Modeling Techniques chapter and the PrecisionTree Command Reference provide valuable information about your everyday use of PrecisionTree. The Modeling Techniques chapter shows you how to model typical decisions you may encounter. Included on the PrecisionTree CD-ROM are examples which illustrate the described modeling techniques. The PrecisionTree Command Reference explains all PrecisionTree toolbar and menu commands.

Use the Technical Appendices when you need more information on a topic or concept. For the latest information on your version of PrecisionTree, check your PrecisionTree disks for a README.WRI file. This file contains information about PrecisionTree that may be more current than the information contained in this manual.

PrecisionTree Professional and Industrial

PrecisionTree is available in both Professional and Industrial versions. In PrecisionTree Professional, the size of a single tree is limited to 1000 nodes.

Working with your Operating Environment

This User's Guide assumes that you have a general knowledge of the Windows operating system and Excel. In particular:

- You are familiar with your computer and using the mouse.

- You are familiar with terms such as icons, click, double-click, menu, window, command and object.

- You understand basic concepts such as directory structures and file naming.

If You Need Help

Technical support is provided free of charge for all registered users of PrecisionTree with a current maintenance plan, or is available on a per incident charge. To ensure that you are a registered user of PrecisionTree, **please register online at www.palisade.com/support/register.asp**.

If you contact us by telephone, please have your serial number and User's Guide ready. We can offer better technical support if you are in front of your computer and ready to work.

Before Calling   Before contacting technical support, please review the following checklist:

- *Have you referred to the on-line help?*

- *Have you checked this User's Guide and reviewed the on-line multimedia tutorial?*

- *Have you read the README file? It contains current information on PrecisionTree that may not be included in the manual.*

- *Can you duplicate the problem consistently? Can you duplicate the problem on a different computer or with a different model?*

- *Have you looked at our site on the World Wide Web? It can be found at **http://www.palisade.com**. Our Web site also contains the latest FAQ (a searchable database of tech support questions and answers) and PrecisionTree patches in our Technical Support section. We recommend visiting our Web site regularly for all the latest information on PrecisionTree and other Palisade software.*

Palisade Corporation welcomes your questions, comments or suggestions regarding PrecisionTree. Contact our technical support staff using any of the following methods:

- *Email us at support@palisade.com*
- *Telephone us at (607) 277-8000 any weekday from 9:00 AM to 5:00 PM, EST. Follow the prompt to reach Technical Support*
- *Fax us at (607) 277-8001.*
- *Mail us a letter to:*
  Technical Support
  Palisade Corporation
  798 Cascadilla St
  Ithaca, NY 14850
  USA

If you want to contact Palisade Europe:

- *Email us at support@palisade-europe.com*
- *Telephone us at +44 1895 425050 (UK).*
- *Fax us at +44 1895 425051 (UK).*
- *Mail us a letter to:*
  Palisade Europe
  31 The Green
  West Drayton
  Middlesex
  UB7 7PN
  United Kingdom

If you want to contact Palisade Asia-Pacific:

- *Email us at support@palisade.com.au*
- *Telephone us at + 61 2 9252 5922 (AU).*
- *Fax us at + 61 2 9252 2820 (AU).*
- *Mail us a letter to:*

  Palisade Asia-Pacific Pty Limited
  Suite 404, Level 4
  20 Loftus Street
  Sydney NSW 2000
  Australia

Regardless of how you contact us, please include the product name, exact version and serial number. The exact version can be found by selecting the Help About command on the PrecisionTree menu in Excel.

Student Versions

Telephone support is not available with the student version of PrecisionTree. If you need help, we recommend the following alternatives:

- *Consult with your professor or teaching assistant.*
- *Log-on to http://www.palisade.com for answers to frequently asked questions.*
- *Contact our technical support department via e-mail or fax.*

PrecisionTree System Requirements

System requirements for PrecisionTree 5.5 for Microsoft Excel or higher for Windows include:

- *Pentium PC or faster with a hard disk.*
- *Microsoft Excel Version 2000 or higher*
- *Microsoft Windows 2000 SP4 or higher.*

Installation Instructions

General Installation Instructions

The Setup program copies the PrecisionTree system files into a directory you specify on your hard disk. To run the Setup program in Windows 2000 or higher:

1) Insert the PrecisionTree CD-ROM in your CD-ROM drive

2) Click the Start button, click Settings and then click Control Panel

3) Double-click the Add/Remove Programs icon

4) On the Install/Uninstall tab, click the Install button

5) Follow the Setup instructions on the screen

If you encounter problems while installing *PrecisionTree*, verify that there is adequate space on the drive to which you're trying to install. After you've freed up adequate space, try rerunning the installation.

Removing PrecisionTree from Your Computer

If you wish to remove PrecisionTree from your computer, use the Control Panel's Add/Remove Programs utility and select the entry for PrecisionTree.

The DecisionTools Suite

PrecisionTree for Excel is a member of the DecisionTools Suite, a set of products for risk and decision analysis described in **Appendix E: Using PrecisionTree With Other DecisionTools**. The default installation procedure of PrecisionTree puts PrecisionTree in a subdirectory of a main "Program Files\Palisade" directory. This is quite similar to how Excel is often installed into a subdirectory of a "Microsoft Office" directory.

One subdirectory of the Program Files\Palisade directory will be the PrecisionTree directory (by default called PRECISIONTREE5). This directory contains the program files plus example models and other files necessary for PrecisionTree to run. Another subdirectory of Program Files\Palisade is the SYSTEM directory which contains files which are needed by every program in the DecisionTools Suite, including common help files and program libraries.

Setting Up the PrecisionTree Icons or Shortcuts

The PrecisionTree setup program automatically creates an PrecisionTree command in the Programs menu of the Taskbar. However, if problems are encountered during Setup, or if you wish to do this manually another time, follow these directions.

1) *Click the Start button, and then point to Settings.*

2) *Click Taskbar, and then click the Start Menu Programs tab.*

3) *Click Add, and then click Browse.*

4) *Locate the file PTREE.EXE and double click it.*

5) *Click Next, and then double-click the menu on which you want the program to appear.*

6) *Type the name "PrecisionTree", and then click Finish.*

Macro Security Warning Message on Startup

Microsoft Office provides several security settings (under **Tools>Macro>Security**) to keep unwanted or malicious macros from being run in Office applications. A warning message appears each time you attempt to load a file with macros, unless you use the lowest security setting. To keep this message from appearing every time you run a Palisade add-in, Palisade digitally signs their add-in files. Thus, once you have specified **Palisade Corporation** as a trusted source, you can open any Palisade add-in without warning messages. To do this:

- Click **Always trust macros from this source** when a Security Warning dialog (such as the one below) is displayed when starting PrecisionTree.

Software Activation

Activation is a one time license verification process that is required in order for your PrecisionTree software to run as a fully licensed product. An **activation code** is on your printed/emailed invoice and may resemble a dash separated sequence like "19a0-c7c1-15ef-1be0-4d7f-cd". If you enter your Activation code during installation, then your software is activated the first time the software is run and no further user action is required. If you wish to activate your software after installation, select the PrecisionTree Help menu Software Activation command and enter your activation code in the displayed **Palisade License Activation** dialog box.
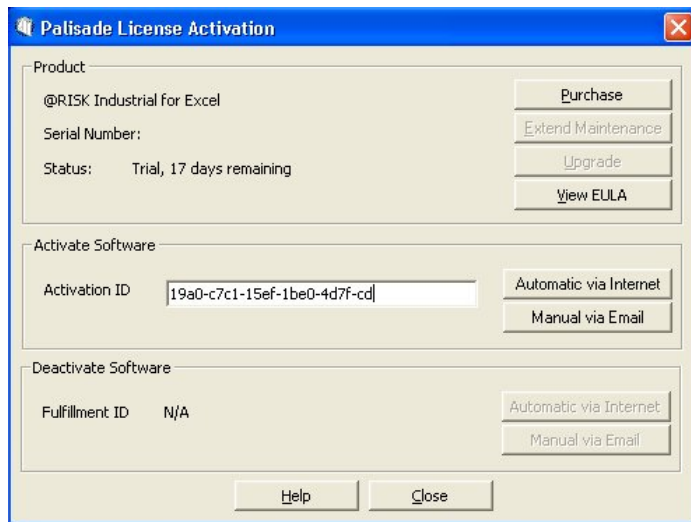
Frequently Asked Questions

1) What if my software is not activated?

If you do not enter an activation code during installation or you are installing a trial version, your software will run as a trial version with time and/or number of uses limitations and must be activated with an activation code in order to run as a fully licensed product.

2) How long can I use the product before I have to activate it?

Software that is not activated may be run for fifteen days. All of the product's features are present, but the License Activation dialog will appear each time the program is launched to remind you to activate and to indicate the time remaining. If the 15 day trial period expires, the software will require activation in order to run.

3) How do I check my activation status?

The License Activation dialog box is viewed through the PrecisionTree Help menu License Activation command. Activated software shows a status of **Activated** and trial version software shows a status of **Not Activated**. If the software is not activated, the remaining time that the software is allowed to run is displayed.

4) How do I activate my software?

If you do not have an activation code you may obtain one by clicking the Purchase button in the License Activation dialog. An online purchase will be immediately given an activation code and an optional link to download the installer should reinstallation become necessary. To purchase by phone call the local Palisade office given in the **Contacting Palisade** section of this chapter.

Activation may be done over the Internet or via email:

- **Activation if you have Internet Access**

In the Palisade License Activation dialog box, type or paste the activation code and press "Automatic via Internet". A success message should appear after a few seconds and the License Activation dialog box will reflect the software's activated status.

- **Activation if you do not have Internet Access**

Automated activation by email requires a few steps:

1. **Click "Manual via Email"** to display the request.xml file which you may save to disk or copy to the Windows clipboard. (It is recommended you note the location on your computer of the request.xml file.)

2. **Copy or attach the XML file** to an email and send it to *activation@palisade.com*. You should receive an automatic response to the return address in your email shortly.

3. **Save the response.xml attachment** in the response email to your hard drive.

4. **Click on the Process button** that is now in the Palisade License Activation dialog box and navigate to the response.xml file. Select the file and click OK.

A success message should appear and the License Activation dialog will reflect the software's activated status.

5) How do I transfer my software license to another machine?

Transfer of a license, or **rehosting**, may be performed through the Palisade License Activation dialog box as a two step procedure: *deactivation* on the first machine and *activation* on the second machine. A typical use of rehosting is to transfer your copy of PrecisionTree from your office PC to your laptop. To rehost a license from *Machine1* to *Machine2*, make sure both machines have the software installed and are connected to the Internet during the deactivation/activation rehosting.

1. On *Machine1*, click deactivate **Automatic via Internet** in the License Activation dialog. Wait for the success message.

2. On *Machine2*, click activate **Automatic via Internet.** Wait for the success message.

If the machines do not have Internet access then you may follow the similar instructions above for rehosting by the automated email process.

6) I have Internet Access but I am still unable to Activate/Deactivate automatically.

Your firewall must be set to allow TCP access to the licensing server. For single user (non network installations) this is http://service.palisade.com:8888 (TCP port 8888 on http://service.palisade.com).

Quick Start

On-line Tutorial

In the on-line tutorial, PrecisionTree experts guide you through sample models in movie format. This tutorial is a multi-media presentation on the main features of PrecisionTree.

The tutorial can be run by selecting the PrecisionTree **Help Menu Getting Started Tutorial command.**

Using PrecisionTree

Starting PrecisionTree

The PrecisionTree system is comprised of several files and libraries, all of which are necessary to run the program. The Excel add-in file PTREE.XLA starts PrecisionTree within Excel, opening necessary files and initializing libraries.

- To start PrecisionTree , click the PrecisionTree icon in the Windows Start Programs Palisade DecisionTools group.

- To open an example file, use the PrecisionTree Help menu Example Spreadsheets command. The default location for the examples is C:\PROGRAM FILES\PALISADE\PRECISIONTREE5\EXAMPLES\ENGLISH.

Exiting PrecisionTree

To exit PrecisionTree and Excel:

- Select Exit from the Excel File menu.

To unload PrecisionTree without ending your Excel session:

- Select the PrecisionTree Utilities menu Unload Precision Tree Add-In command.

Chapter 2: Overview of Decision Analysis

Introduction

PrecisionTree brings advanced modeling and decision analysis to Microsoft Excel worksheets. You might wonder if the decisions you make are suitable for decision analysis. If you are looking for a way to structure your decisions to make them more organized and easier to explain to others, you definitely should consider using formal decision analysis.

Modeling with PrecisionTree

Modeling is a catch-all phrase that usually means any type of activity where you are trying to create a representation of a real life situation — so you can analyze it. Your representation, or model, can be used to examine the situation, and hopefully understand what the future might bring. Since you've probably built an Excel spreadsheet, you've built a model! But don't worry, you don't have to be an expert in statistics or decision theory to create a decision model, and you certainly don't have to be an expert to use PrecisionTree. We can't teach you everything in a few pages, but we'll get you started. Once you begin using PrecisionTree you'll automatically begin picking up the type of expertise that can't be learned from a book.

Another purpose of this chapter is to explain how PrecisionTree works with Microsoft Excel to perform decision analysis. You don't have to know how PrecisionTree works to use it successfully, but you might find some explanations useful and interesting.

What is Decision Analysis?

Decision analysis provides a systematic method for describing problems. It is the process of modeling a problem situation, taking into account the decision maker's preferences and beliefs regarding uncertainty, in order to identify the decision that should be made.

A decision analysis gives you a straightforward report consisting of the preferred decision path and a risk profile of all possible results. Decision analysis can also produce more qualitative results by helping to understand tradeoffs, conflicts of interest, and important objectives.

Modeling a Decision

The first step in decision analysis is defining the problem you wish to solve. Do you want to maximize profit or minimize the impact on the environment? Probably, your goal is a combination of the two. Once you have clarified your goals, you are ready to design a model.

Decisions may be modeled in one of two forms, decision trees and influence diagrams. While decision trees are the traditional tool used in decision analysis, influence diagrams are a recent, and powerful, addition to the decision maker's arsenal. The rest of this chapter provides a thorough explanation of both techniques.

Influence Diagrams

Introduction

Influence diagrams present a decision in a simple, graphical form. Decisions, chance events and payoffs (values) are drawn as shapes (called nodes) and are connected by arrows (called arcs) which define their relationship to each other. In this way, a complex decision may be reduced to a few shapes and lines. Influence diagrams are excellent for showing the relationship between events and the general structure of a decision clearly and concisely.

- **Nodes.** In PrecisionTree, decision nodes are drawn as green squares, chance nodes as red circles and payoff nodes as blue diamonds.

- **Arcs.** Arcs point from a predecessor node to a successor node, indicating a dependence between the two nodes. An arc may contain different forms of influence: value, timing or structural (or a combination of the three).

Sports Wager Example

A simple decision to model is one where there is one decision and one chance event affecting the outcome. For example, you may have an opportunity to bet on a sports game. Your decision is whether to bet on Team A or Team B (or not at all). The chance event is the outcome of the game. The payoff node represents the monetary payoff (or loss) of the wager.

Influence Diagram for a Sports Wager
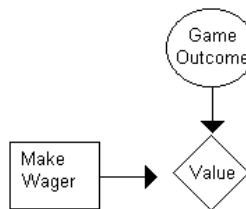
Since both the wager and the game outcome affect the payoff, an arc is drawn from each node into the payoff node. An arc drawn from the chance node to the decision node implies that you know the game outcome before making the wager, while an arc drawn from the decision node to the chance node implies that the game outcome can change depending on the decision you make. In the simplest case, neither of these situations would occur so the two nodes are not connected.

Guidelines for Using Arcs

Arcs describe relationships between nodes in an influence diagram. Three types of influence may be specified between nodes: value, timing and structure.

A **Value** influence specifies that the values for the successor node are influenced by the possible outcomes for the predecessor node.

A **Timing** influence specifies that the predecessor node always occurs prior to the successor node.

A **Structure** influence specifies that the structure of the outcomes of the successor node is affected by the outcome of the predecessor node.

Guidelines for Designing Influence Diagrams

In order to make your model as complete as possible, you should follow these additional guidelines when designing your diagram.

- **Your influence diagram should have only one payoff node.** There should only be one endpoint of the analysis, as described by the payoff node.

Influence Diagram with Two Payoff nodes
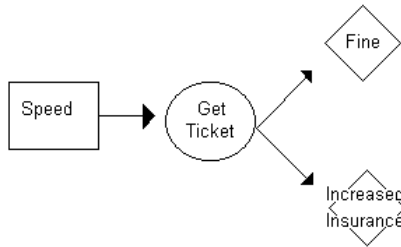
This example contains two payoff nodes. The cost of the speeding fine and the increase in the insurance premium can be combined into one payoff node.

- **Your influence diagram should not contain any cycles.** A cycle is a "loop" of arcs in which there is no clear endpoint. To recognize a cycle, trace back from the payoff node. If you come across the same node more than once in the same path, your diagram contains a cycle. (Note: to form a cycle, all arcs in the cycle must be of the same type)
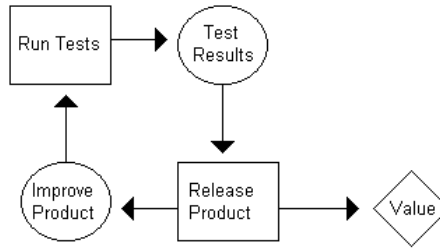
This example above contains a cycle. Which event occurs first? When does it end?

- **Your influence diagram should avoid barren nodes.** Barren nodes are chance or decision nodes that do not have successors, and thus do not influence the outcome of the model. You might want to use barren nodes to illustrate an event, but PrecisionTree ignores these nodes when analyzing the model.
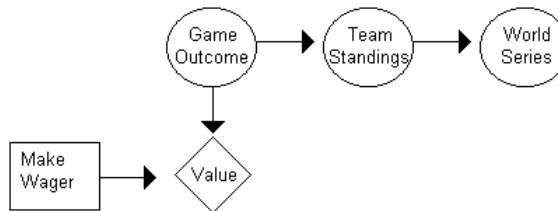
The diagram above contains two barren nodes. The World Series node is barren since it has no successors. The Team Standings node does have one successor, but since the successor is a barren node, the Team Standings node is also barren.

Influence Diagrams

Decision Trees

Introduction

Decision trees are a comprehensive tool for modeling all possible decision options. While influence diagrams produce a compact summary of a problem, decision trees can show the problem in greater detail. Decision trees describe events in chronological order but can be much larger than influence diagrams.

- **Nodes.** As with influence diagrams, decision trees also have nodes. In PrecisionTree, decision nodes are drawn as green squares and chance nodes as red circles. However, the payoff node is now called an end node and is represented with a blue triangle. Two additional nodes (logic and reference) are available for advanced model making.

- **Branches.** Decision trees do not have arcs. Instead, they use branches, which extend from each node. Branches are used as follows for the three main node types in a decision tree:

Types of nodes in a decision tree include:

■ A **Decision node** has a branch extending from it for every available option.

● A **Chance node** has a branch for each possible outcome.

◀ An **End node** has no branches succeeding it and returns the payoff and probability for the associated path.

Sports Wager Example - Revisited

The sports wager example discussed earlier can also be modeled with a decision tree. Since the chronology of the model is Make Wager → Game Outcome → Collect Payoff, the decision node begins the tree, followed by the chance node. The end nodes represent the payoffs.
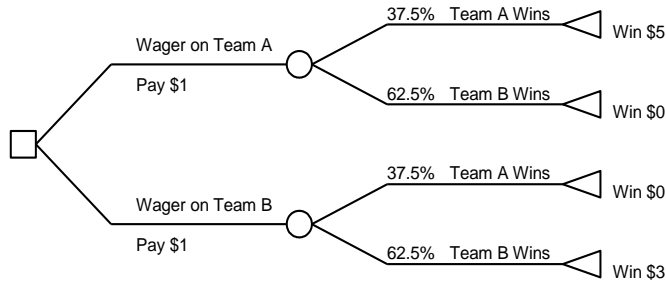
In the above model, the options, values and percentages are visible right on the diagram. But, you can also see a drawback of the decision tree: the tree is much larger than the corresponding influence diagram. Imagine how large a tree can be when there are hundreds of events!
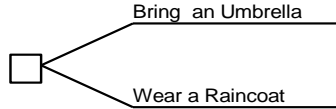
Guidelines for Designing Trees

In order to make your model as complete as possible, your tree should represent all possible events as accurately as possible. Follow these guidelines when designing your tree.

- **Define decision nodes so that only one option may be chosen at each node and every possible option is described**.

This example implies that you cannot wear a raincoat and carry an umbrella at the same time. But can't you do both? Unless there is a specific reason why you cannot bring an umbrella when you wear a raincoat, you should include more options in your decision model.

- **Define chance nodes so they are mutually exclusive and collectively exhaustive.** A node where only one outcome is possible (but multiple outcomes are described) is mutually exclusive and a node where all possibilities are described is collectively exhaustive.

The first node is not mutually exclusive, as it can snow on Monday *and* be sunny on Tuesday. The second node is not collectively exhaustive, as it could rain on Monday.

- **The tree should proceed chronologically from left to right**.
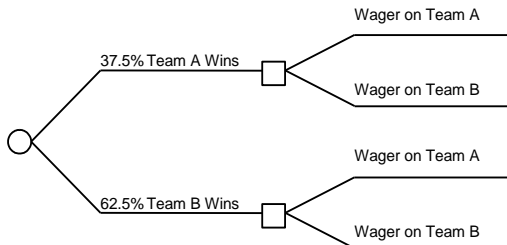
Putting the chance node first, as in this example, implies that the wager is made after the game is played. In general, you bet on a game before you know the outcome, so the decision node should come first.

Influence Diagrams vs. Decision Trees

A Comparison of the Techniques

As described here, PrecisionTree allows you to create models as either decision trees or influence diagrams. Each form of a decision model has both advantages and drawbacks, and by using each you can create the most comprehensive and understandable model of your decision problem.

Benefits of Influence Diagrams

Influence diagrams are a compact and efficient method of describing a decision model. As compared to a decision tree, which can have hundreds or thousands of nodes and branches, influence diagrams can show the decisions and events in your model using a small number of nodes, often on a single worksheet. This makes the diagram very accessible, helping others to understand the key aspects of the decision problem without getting bogged down in details of every possible branch as shown in a decision tree. You'll find influence diagrams especially useful for presenting your decision model to others and creating an overview of a complex decision problem. Influence diagrams also show the relationships between events in your decision model – that is, "what influences what?" In a decision tree, it is often difficult to see what outcomes influence the values and probabilities of other events. Influence diagrams also allow you to automatically perform Bayseian revision of chance node probabilities.

Drawbacks to Influence Diagrams

A drawback to influence diagrams is their abstraction. It is difficult to see what possible outcomes are associated with an event or decision as many outcomes can be embedded in a single influence diagram decision or chance node.

It is also not possible to infer a chronological sequence of events in your decision from the arcs in your influence diagram. This can make it difficult to determine whether the influence diagram and the decision tree it represents accurately depict the timing present in your decision problem.

Benefits of Decision Trees

Decision trees, as opposed to influence diagrams, show all possible decision options and chance events with a branching structure. They proceed chronologically, left to right, showing events and decisions as they occur in time. All options, outcomes and payoffs, along with the values and probabilities associated with them, are shown directly in your spreadsheet. There is very little ambiguity as to the possible outcomes and decisions the tree represents; just look at any node and you'll see all possible outcomes resulting from the node and the events and decisions that follow.

In PrecisionTree you can either analyze your decision model directly in your influence diagram or analyze the decision tree which PrecisionTree can create from the influence diagram. Values and probabilities for different possible events and decision options can be entered either in decision trees or influence diagrams.

Performing a Decision Analysis

Once you have designed a model and defined its parameters, you're ready to run an analysis. A decision analysis on a decision tree or influence diagram produces statistics, graphs and policy suggestions.

In addition to the results produced when a decision analysis is run, many statistics on a decision tree or influence diagram models are available "real-time" as values are entered or edited in a decision model.

Solving Decision Trees

The method for calculating the optimum path in a decision tree is called "folding back." A brief outline of this method is described below.

1) **Chance node reduction** — calculate the expected value of the rightmost chance nodes and reduce to a single event.

2) **Decision node reduction** — choose the optimum path of the rightmost decision nodes and reduce to a single event.

3) **Repeat** — return to step 1 if there are nodes that have not been analyzed.

Also see Appendix A: Technical Notes – Calculation Algorithm for Decision Trees for additional information.

Constructing Risk Profiles

The above methods describe how to determine the optimum path in a decision tree. But, you also need to know the consequences of following the suggested path. That's where risk profiles enter the picture.

What is a Risk Profile?
A risk profile is a distribution function describing the chance associated with every possible outcome of your decision model. The risk profile graphically demonstrates the uncertainty of your decision.

The following steps are performed to construct a risk profile from a decision tree:

1) **For a cumulative payoff tree (the default method in PrecisionTree), the tree is "collapsed" by multiplying probabilities on sequential chance branches.** The value of each path in the tree is calculated by summing the value for each branch in the path. Using this path value, the expected value is calculated for the remaining chance node.
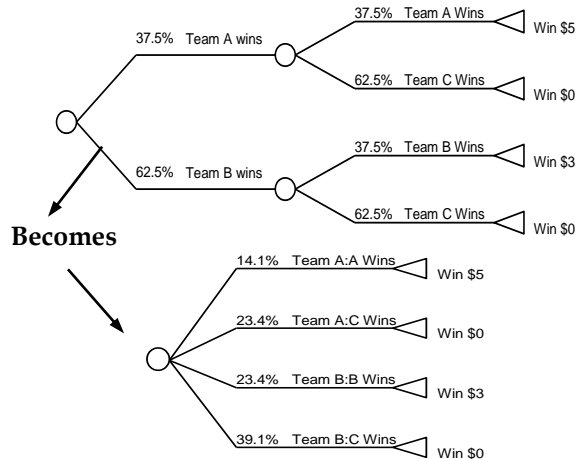
Both trees have an expected value of $1.40. (EV= $1.40)

2) Decision nodes are reduced by considering only the optimal branches.

Becomes
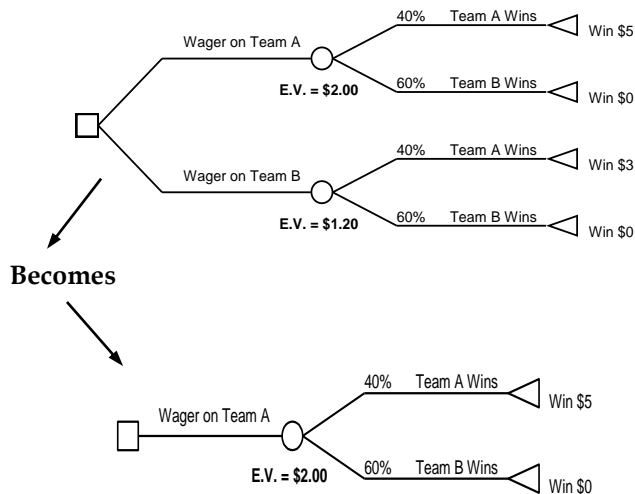
The decision to Wager on Team A is the optimum decision in this example.

3) **These steps are repeated until the tree is completely reduced to a single chance node with a set of values and corresponding probabilities [X, P].** If any two outcomes have the same X value, they are combined into once chance event and their probabilities are summed.
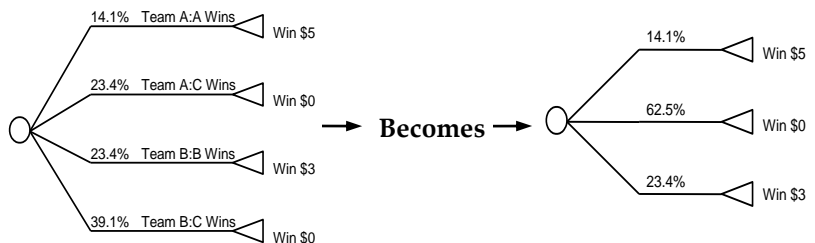
In the example above on the left, two branches have a value of $0. The branches are combined as shown in the example on the right.

4) **The final set of [X, P] pairs defines a discrete probability distribution which is used to construct the risk profile.**

The risk profile is graphed as a discrete density distribution in the Probability Chart, and a cumulative density distribution in the Cumulative Chart. The discrete density distribution shows the probability that the outcome equals a value X. The cumulative density distribution shows the probability that the outcome is less than or equal to X.
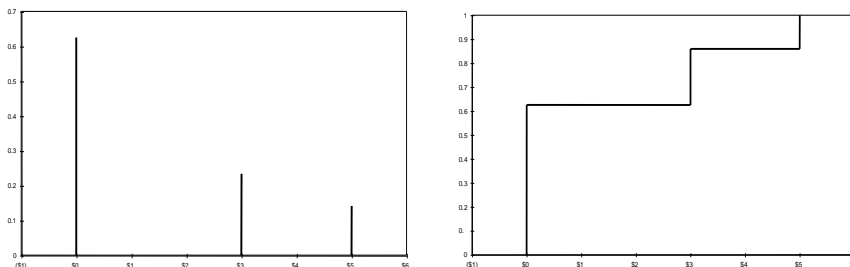
In the Probability Chart (left), the height of the line at $0 is 0.625, which is equal to the probability that the wager yields $0. On the Cumulative Chart (right), the probability that the wager produces a value less than or equal to $5 is 100%.

Also included in the Risk Profile is the Statistical Summary, which provides a statistical summary report of the decision analysis.

Policy Suggestion

A Policy Suggestion report lets you know which option was chosen at each node by displaying a reduced version of your tree, with the optimum path highlighted and the value and probability of each path displayed.
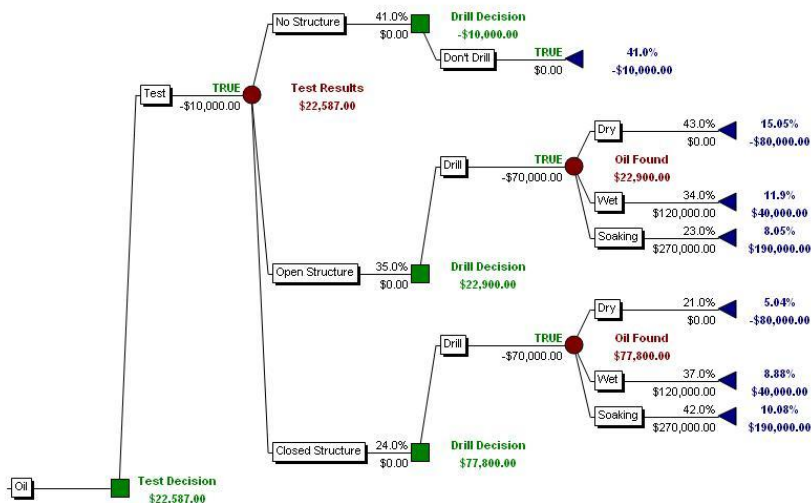
As you can see, only one option is highlighted at each decision node, since only one decision yields the optimum payoff. For chance nodes, however, all branches are highlighted since any of the chance events could occur.

A Policy Suggestion Decision Table is also available, which identifies the optimal choice to be made at each decision node encountered on the optimal path, along with information such as the arrival probability and benefit of correct choice.

Decision	Optimal Choice	Arrival Probability	Benefit of Correct Choice
'Test Decision' (C42)	Test	100.0000%	$2,587.00
'Drill Decision' (E12)	Don't Drill	41.0000%	$30,100.00
'Drill Decision' (E26)	Drill	35.0000%	$32,900.00
'Drill Decision' (E38)	Drill	24.0000%	$87,800.00

Solving Influence Diagrams

The analysis of an influence diagram generates the same results as analyzing the decision tree which is equivalent to the diagram. In essence, any influence diagram can be converted to a decision tree, and the expected value of the converted tree, along with its risk profile, will be the same as is shown when the influence diagram is analyzed.

Sensitivity Analysis

Have you ever wondered which variables matter most in your decision? If so, you need sensitivity analysis, which measures the impact of changing an uncertain variable to its extreme values while keeping all other variables constant. Sensitivity analysis can be used on both decision trees and influence diagrams.

What is Sensitivity Analysis?

Sensitivity analysis allows you to examine the effect of changing one or more of the variables in your model. This can be particularly useful for finding threshold values, where an optimal choice for a decision node changes. Sensitivity analysis does not give you an explicit answer to your problem, but can help you to better understand your model.

The results of a sensitivity analysis are usually presented graphically. The numerous diagrams and plots demonstrate the impact of variables on the decision.

There are many ways to run a sensitivity analysis on your decision model. None of these ways are better than the others, but each method gives you a different set of information for understanding your model. This chapter discusses some of the different types of sensitivity analyses and the graphs produced by them.

Definition of Terms

Before getting into the details of sensitivity analysis, you should understand some of the special terms used in this chapter:

- An **input** is a value or probability defined in your decision model

- The **base case** value of an input is the number you entered when you first designed the model (usually the most likely value)

- The **minimum** value of an input is the lowest possible value you think this variable can reasonably have

- The **maximum** value of an input is the highest possible value you think this input can reasonably have

- The number of **steps** is the number of equally spaced values across the minimum-maximum range that will tested during the sensitivity analysis

One-Way Sensitivity Analysis

One-way sensitivity analysis studies the effect of a single input on the expected value of a model. This value could be either the payoff related to an event (Deterministic Sensitivity Analysis) or the probability related to a chance occurrence (Probabilistic Sensitivity Analysis).

Defining a Sensitivity Input

Before running a one-way sensitivity analysis, you must decide which input you wish to study and define the upper and lower bounds of the input. It's up to you to choose reasonable minimum and maximum values for the input in question.
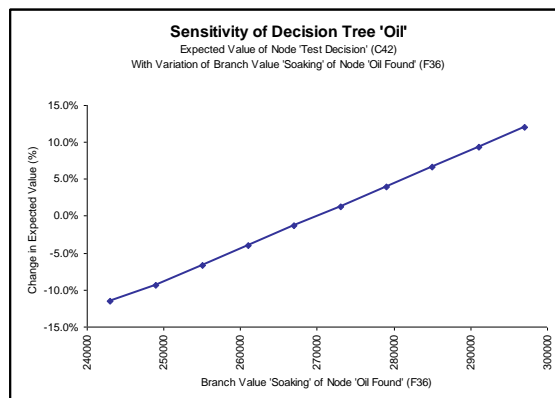
At the beginning of a sensitivity analysis, the base case values of all inputs are placed into the model and the expected value is calculated. This value can be referred to as the base case of the model, and is the value that all subsequent results are compared to.

During the calculation process, the base case value of the input is replaced with its minimum value and a new expected value is calculated. Then, a set of values ranging from the minimum value for the input up to its maximum are substituted in and the expected value is calculated for each. Finally, the input is returned to its original value in preparation for analysis of another input.

When running a sensitivity analysis, it is important to define reasonable limits for your inputs in order to avoid exaggerating the uncertainty of the inputs. In addition, remember to consider the uncertainty in your limits.
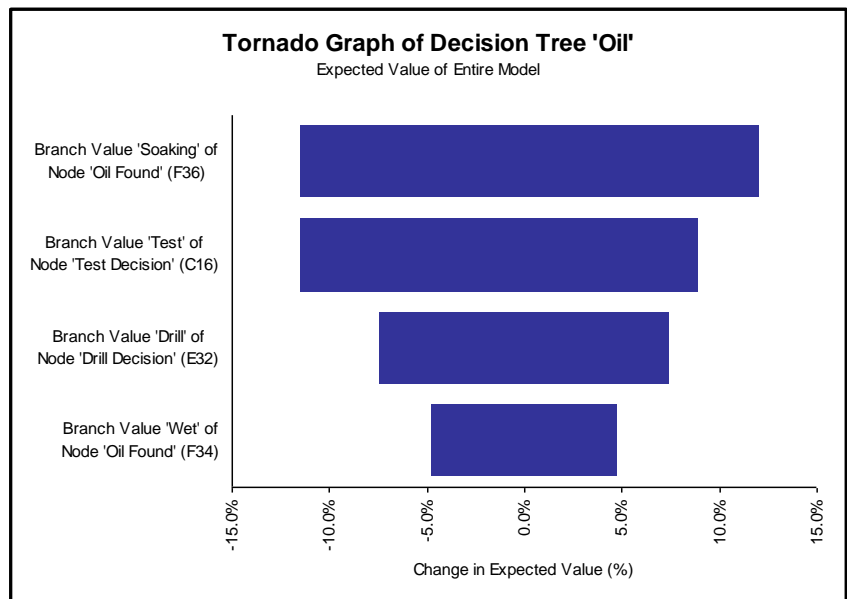
One-Way Sensitivity Graphs

The results of a one-way sensitivity analysis can be plotted on a simple diagram. The value of the selected input is plotted on the X-axis and the expected value of the model is plotted on the Y-axis.

Sensitivity of Decision Tree 'Oil'
Expected Value of Node 'Test Decision' (C42)
With Variation of Branch Value 'Soaking' of Node 'Oil Found' (F36)

Tornado Graphs

A tornado graph compares the results of multiple analyses. The X-axis is drawn in the units of the expected value, or can also be in terms of percent change. For each input (listed on the Y-axis), a bar is drawn between the extreme values of the expected value calculated from the lower and upper bound values. The input with the greatest range (the difference between the maximum and minimum value) is plotted on the top of the graph, and the inputs proceed down the Y-axis with decreasing range. The longest bar in the graph is associated with the input that has the largest impact on expected value.

Tornado Graph of Decision Tree 'Oil'
Expected Value of Entire Model

Branch Value 'Soaking' of Node 'Oil Found' (F36)	
Branch Value 'Test' of Node 'Test Decision' (C16)	
Branch Value 'Drill' of Node 'Drill Decision' (E32)	
Branch Value 'Wet' of Node 'Oil Found' (F34)	

-15.0%   -10.0%   -5.0%   0.0%   5.0%   10.0%   15.0%

Change in Expected Value (%)

The tornado graph brings attention to the inputs that require further attention (those plotted on the top of the graph). The tornado graph can summarize the impact of a large number of inputs in a neat, simple graph.

Spider Graphs

A spider graph also compares the results of multiple analyses. For each input, the percentage of the base case is plotted on the X-axis and the expected value of the model is plotted on the Y-axis. The slope of each line depicts the relative change in the outcome per unit change in the independent input and the shape of the curve shows whether a linear or non-linear relationship exists. In this graph, the total variation in the *Value1* has the largest total effect on expected value, but each unit of change in *Prob1* causes the greatest unit change in expected value. This is shown in a steeper line for *Prob1* as compared to *Value1*.
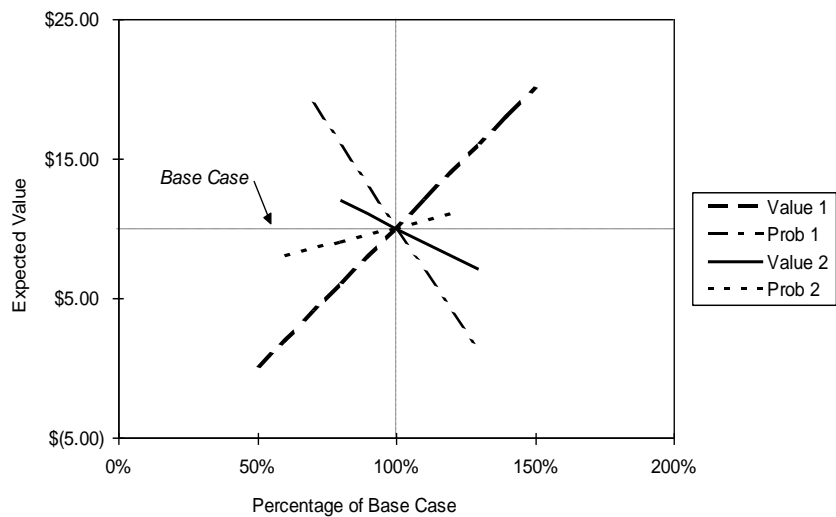
Spider graphs provide more information about each input than tornado graphs. For example, spider graphs show the reasonable limits of change for each independent input and the unit impact of these changes on the outcome. While tornado graphs may lead the decision maker to think that risk is proportional, the slopes in spider graphs reveal any unproportional changes in outcomes.

The number of inputs used in a spider graph should not exceed seven, but a limit of five is recommended to avoid clutter. If your sensitivity analysis contains a large number of inputs, it is a good idea to plot them on a tornado graph first to determine which inputs have the greatest impact. Then, use only these inputs on your spider graph.

Two-Way Sensitivity Analysis

Two-way sensitivity analysis studies the impact of two inputs on a decision model. Typically, the two most critical inputs are studied.

Defining the Sensitivity Inputs

During the calculation, all the possible combinations in value for the two inputs are generated and placed in the input cells. The resulting calculated value for the model is saved for each combination.

The results of a two-way sensitivity analysis can be plotted on a 3D graph. The value of the first input is plotted on the X-axis and the value of the second input is plotted on the Y-axis. The value of the decision model is plotted on the Z axis. The points calculated by the two-way sensitivity analysis are plotted and a surface is drawn to connect them.
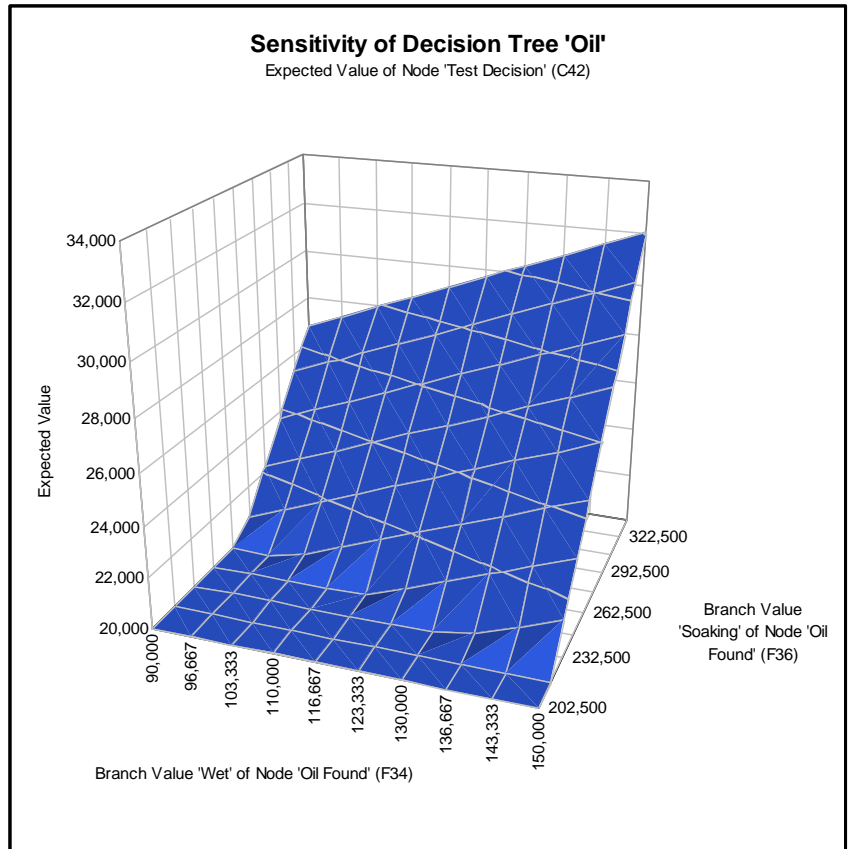
Sensitivity of Decision Tree 'Oil'
Expected Value of Node 'Test Decision' (C42)

Strategy Region Graphs

Strategy region graphs show regions where different decisions are optimal given changes in two selected inputs. The value of the first input is plotted on the X-axis and the value of the second input is plotted on the Y-axis. The strategy region graph is very similar to the two-way sensitivity graph, but the graph now shows the regions where each possible decision is optimal. For example, your decision to start your own business or invest your money "safely" may depend on expected sales and the cost of raw materials.

When a decision node is selected as the output of a two-way sensitivity analysis a strategy region graph can be created. The optimal decision at each of the input input combinations tested during the sensitivity analysis is plotted on the graph.
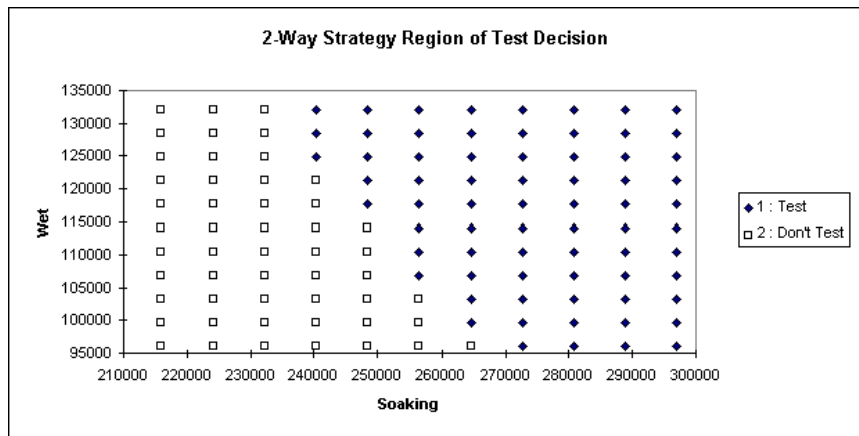
This diagram suggests whether to Test or Don't Test. By studying the possible combinations in value for the two input inputs you can determine which decision is optimal at different possible input values.

Chapter 3: Overview of PrecisionTree

Introduction

This chapter provides an introduction to PrecisionTree and the process of setting up a decision tree using PrecisionTree and Excel. The chapter includes the following sections:

- **A Quick Overview of PrecisionTree** - a quick look at a decision tree in PrecisionTree and the results of a decision analysis

- **Setting Up a Decision Tree** - a step-by-step guide to creating a decision tree

- **Setting Up an Influence Diagram** - a step-by-step guide to creating an influence diagram

- **Running a Decision Analysis** - an overview of running a decision analysis and sensitivity analysis

- **Advanced Features** - an overview of additional features of PrecisionTree that can be used in building your decision models

A Quick Overview of PrecisionTree

This section of the **Overview of PrecisionTree** provides a quick look at PrecisionTree and the results of a decision analysis. You'll see how a simple decision tree looks in an Excel spreadsheet and see the types of reports and graphs PrecisionTree creates.

PrecisionTree Toolbar and Menu

PrecisionTree extends the analytical capabilities of your Microsoft Excel spreadsheet to include decision analysis using decision trees and influence diagrams. To add decision analysis capabilities to your spreadsheet, PrecisionTree uses both a toolbar and menu commands.
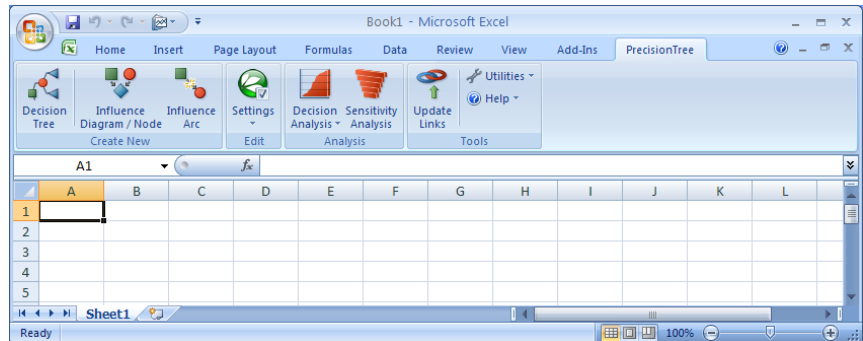
PrecisionTree creates a new menu "PrecisionTree" on the Excel menu bar in Excel 2003 and earlier. This menu contains commands for designing and analyzing decision trees and influence diagrams. The PrecisionTree toolbar contains icons which provide easy access to PrecisionTree menu commands. In Excel 2007, all commands are available via the PrecisionTree ribbon bar.

The toolbar and menu commands are used to make selections from your spreadsheet "add-in" style. Decision trees and influence diagrams are designed directly in a spreadsheet and all PrecisionTree results and graphs are generated as Excel charts or spreadsheets for further customization and presentation.

Defining Nodes

In PrecisionTree, nodes of an influence diagram or decision tree are defined directly in your spreadsheet. For a decision tree, the probabilities and values associated with the branches from a node can be entered directly in spreadsheet cells next to each branch. Each node returns a value representing the expected value or certainty equivalent of the decision model at the node. For an influence diagram, the probabilities and values associated with the possible outcomes for a node are entered in a Value table which is displayed when the node is selected. This table is a standard Excel spreadsheet with cells, rows and columns.

PrecisionTree provides an easy-to-use interface which enters nodes in your spreadsheet automatically. Once a tree is started, nodes are edited or added by clicking on node symbols in your worksheet. Left-clicking on a node displays its settings. Right-clicking on a node displays a PrecisionTree menu with additional commands that can be used. Influence diagram nodes are added by clicking the **Create New Influence Diagram Node** icon on the toolbar.

Decision Tree Defined with PrecisionTree
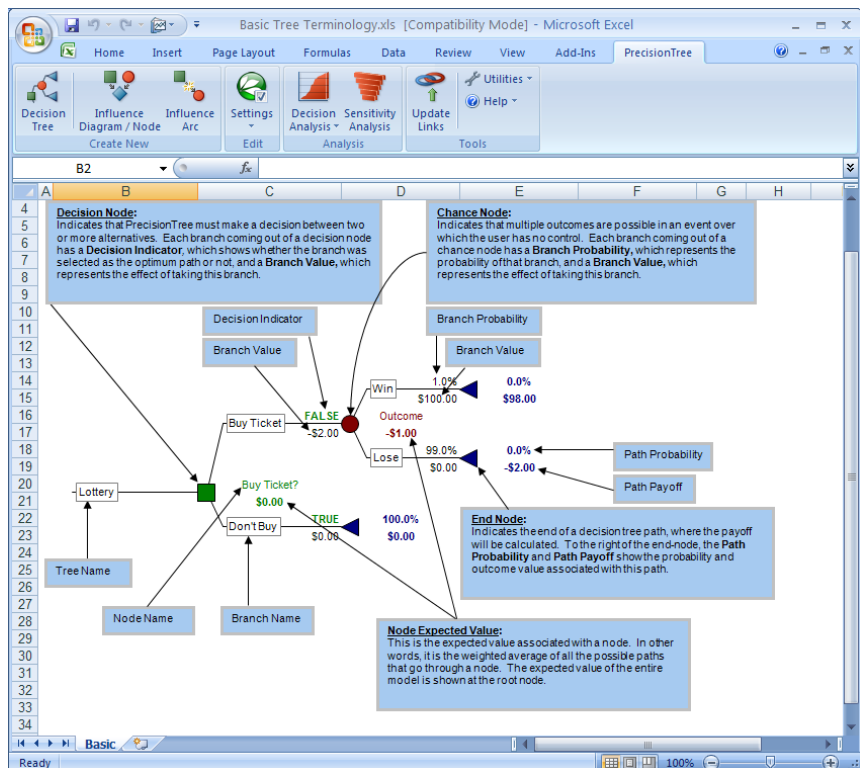
In a decision tree in PrecisionTree, decision nodes are represented by green squares, chance nodes by red circles and end nodes by blue triangles. The name of each node and the value of the tree at the node are shown next to each node symbol. Each branch has a label and two values, in cells above and below the branch. For a chance node, the two values are branch probability and branch value. For a decision node, the top cell for each branch has a TRUE or FALSE, indicating whether the branch was selected as the optimum path. The cell below the branch contains the branch value. For an end node, two values are shown: the probability that the path through the tree will occur, and the value if the path does occur.

Influence Diagram Defined in PrecisionTree
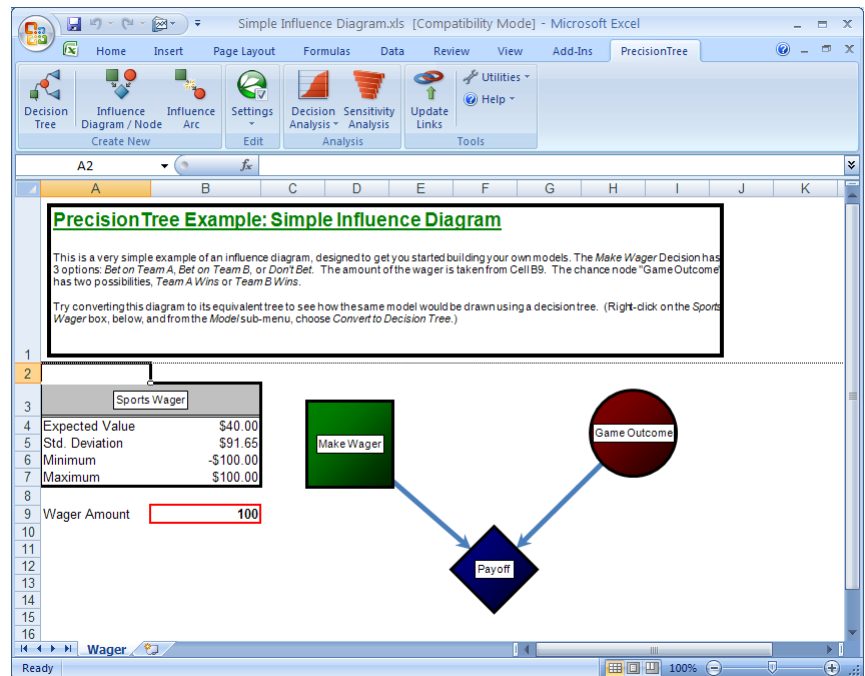
In an influence diagram in PrecisionTree, decision nodes are represented by green squares, chance nodes by red circles, calculation nodes by blue rounded rectangles and payoff nodes by blue diamonds. The name of each node is shown inside each node symbol. Clicking on the node symbol allows you to enter or edit the outcomes for a node and their values. Influence arcs are shown as arrows between nodes. Different forms of influence between nodes may be entered by clicking on an arc.

PrecisionTree displays a set of results for your decision model in your spreadsheet "real-time", with your results changing immediately as you enter or edit values in your model. The expected value for a decision tree is shown at the root of the tree, or in the top left of the worksheet for an influence diagram. Just as with other spreadsheet models, you can change a value in your model and immediately see the effect on your results. When you run a full decision analysis, these real-time results are supplemented with additional reports and graphs of your model.

Running a Decision Analysis

Once a decision model has been defined, using either a decision tree or influence diagram, you are ready to run a decision analysis. The decision analysis finds the optimum path through the decision tree or influence diagram and calculates the possible outcomes on this path.

To run an analysis, select the Risk Profile or Policy Suggestion command from the Decision Analysis submenu on the PrecisionTree menu, or click the Decision Analysis icon on the PrecisionTree toolbar. Then, select the tree or influence diagram (or start node for a sub-tree) that you wish to analyze. For more information on how a decision analysis is performed, please refer to the Overview of Decision Analysis.

Decision Analysis Results

PrecisionTree decision analysis results include a distribution of possible results for your model (called a risk profile). In addition, PrecisionTree determines the optimum path through the model to create a policy suggestion. These results are presented in Excel worksheets and charts.

Typical Risk Profile Graph
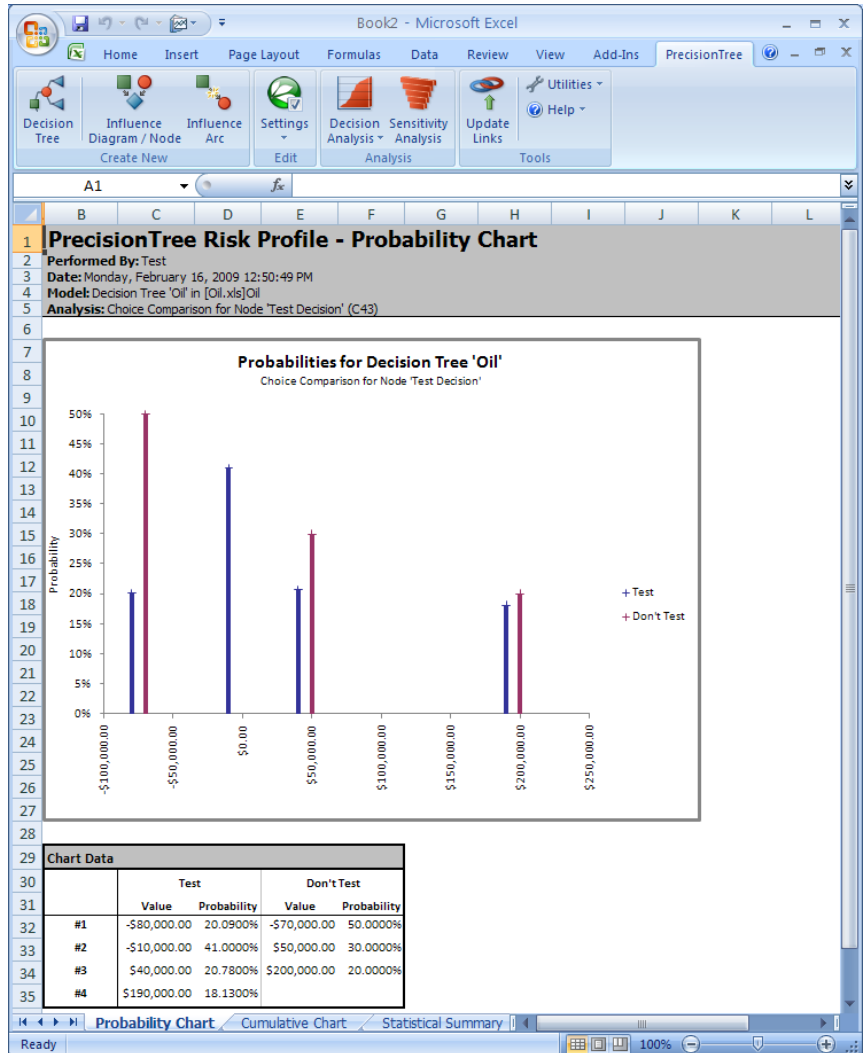
A Risk Profile is a distribution function describing the chance associated with every possible outcome of your decision model. The risk profile graphically demonstrates the uncertainty of your decision using a frequency or cumulative frequency graph (this information is also represented in a statistical report).
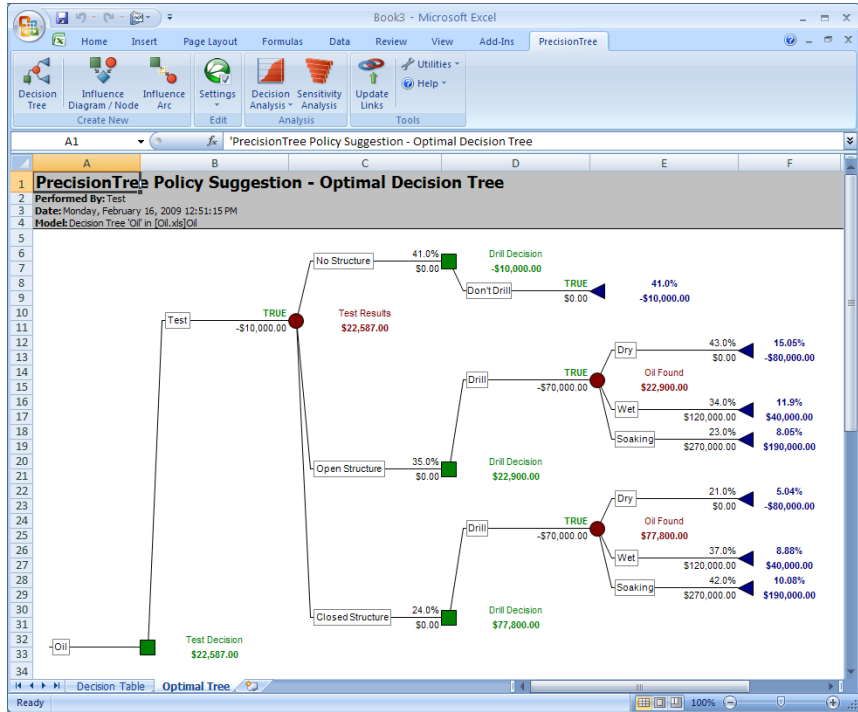
For a decision tree, PrecisionTree also offers a Policy Suggestion Report, letting you know which option was chosen at each node. The report, an enhanced version of your tree, is drawn directly in a spreadsheet with the optimum path highlighted and the expected value of each node displayed.

Also available in PrecisionTree is the Policy Suggestion Decision Table, which identifies the optimal choice to be made at each decision node encountered on the optimal path, along with information such as the arrival probability and benefit of correct choice.
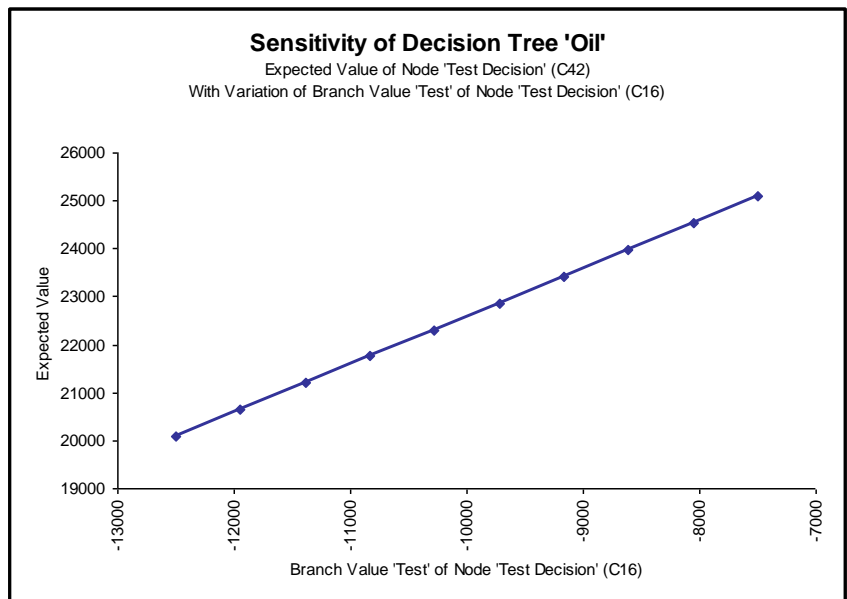
Running a Sensitivity Analysis

You may wonder how much a value in your model affects the outcome of your decision. For example, how much does the expected value of a model change if one of the payoffs increases? Sensitivity analysis tells you just how "sensitive" your model is to changes in certain inputs.

PrecisionTree runs both a one-way sensitivity analysis (which analyzes one input at a time) and a two-way sensitivity analysis (which studies how a combination of two inputs affects the outcome). To run an analysis, select the Sensitivity Analysis command from the PrecisionTree menu. PrecisionTree prompts you for the output and the cell(s) to vary. For more information on how a sensitivity analysis is performed, please refer to the Overview of Sensitivity Analysis.

Sensitivity Analysis Results

The results of a PrecisionTree sensitivity analysis are presented graphically in Excel charts. PrecisionTree creates tornado graphs, spider graphs, strategy region graphs and more. Each graph helps you determine how important an input is to the outcome of your decision.

*Typical
One-Way
Sensitivity
Graph*

Sensitivity of Decision Tree 'Oil'
Expected Value of Node 'Test Decision' (C42)
With Variation of Branch Value 'Test' of Node 'Test Decision' (C16)

Setting Up a Decision Tree

This section of the Overview of PrecisionTree provides a more in-depth look at the process of setting up a decision tree in Excel using PrecisionTree. You'll learn how to create a decision tree by defining nodes and branches.

To define a decision tree model, you'll use the commands on the PrecisionTree menu or toolbar. If you're not familiar with decision trees, please read the Overview of Decision Analysis first. This section assumes that you understand basic decision analysis concepts and techniques.

Defining the Decision

To design a decision tree, you must define the events involved in your decision. Unlike influence diagrams, events in a decision tree progress in chronological order.

For example, let's look at the classic oil-drilling example:
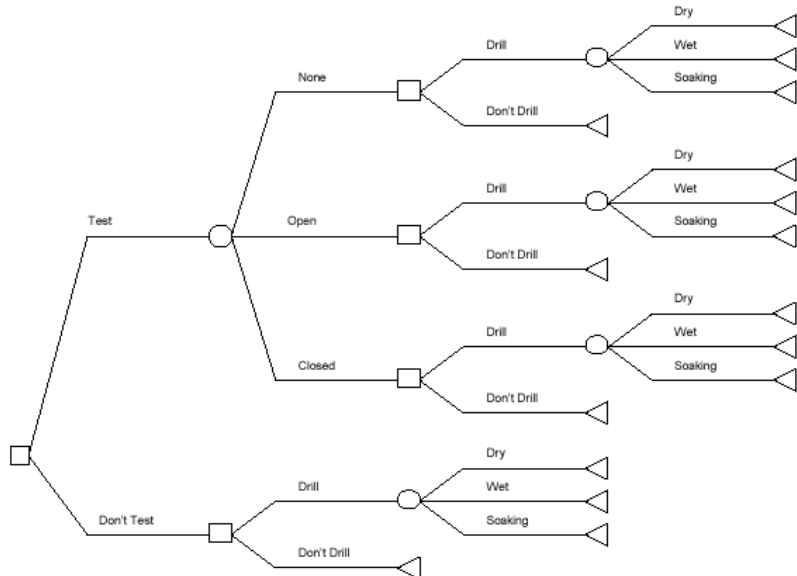
Our first decision is whether to run geological tests on the prospective site. Then, depending on the test results, the next decision is whether to drill for oil. The final chance event is the amount of oil found. The tree progresses from left to right – the decision to test is always made before the decision to drill.

Creating a New Tree

To create a decision tree using PrecisionTree, first select the **New menu Decision Tree command** on the PrecisionTree menu or click the **Create New Decision Tree** icon on the PrecisionTree toolbar. For the oil drilling example, you'll create a standard cumulative decision tree. PrecisionTree also allows you to create a linked tree, where branch values are linked to a model in your spreadsheet, and a formula tree, where the payoff for each path through the tree is determined by calculating a user-defined formula. In **Chapter 4: Modeling Techniques**, you'll see how to create the same oil drilling model as these other types of trees. The different types of trees each have a different method for calculating the payoffs from the decisions represented in the tree.

Naming Your Decision Tree

When the **Create New Decision Tree** icon is clicked, a single branch representing the "root" or start of your tree is created at a location in the worksheet you select. The **Model Settings** dialog is then displayed, showing the name of this new tree, along with the settings for the tree.
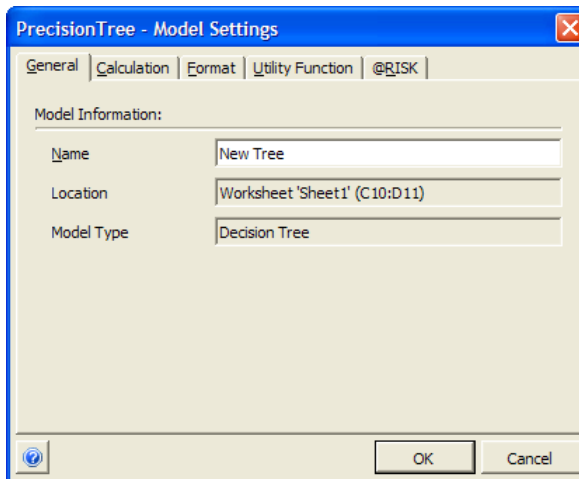

Let's call this tree "Oil Drilling". Change the name of the tree to Oil Drilling and click OK.

Creating a Decision Node

A decision node represents an event where the decision maker must choose one of a number of options. To create a new decision node, click the single end node (the blue triangle) that was made when you created the new tree. Clicking a node allows you to edit the node's definition, changing it from an end node to a decision node in this case.
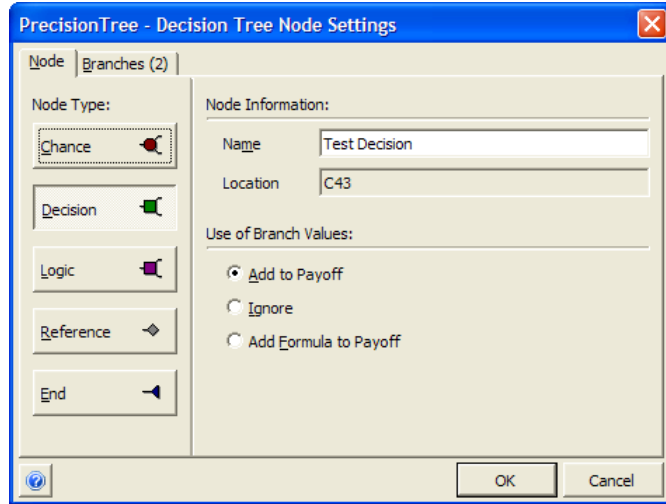
Clicking on the decision node icon in the Decision Tree Node Settings dialog box – with a green square – changes the end node to a decision node. For the oil drilling example, a decision node with two possible outcomes, *Test* and *Don't Test,* represents our initial decision.

In this example, the name of our decision node is *Test Decision*. There are two branches (or decision options) following the node. After entering the node's name and clicking OK, PrecisionTree will create a new decision node in the spreadsheet. This node has two branches that, by default, are labeled *Branch1* and *Branch2*.

Entering Branch Names and Values

For each branch from a decision node there is a label and a value. In PrecisionTree, the labels, values, and probabilities for all nodes and branches in a decision tree are entered directly in your Excel worksheet. For the *Test Decision* decision node the two branches are named *Test* and *Don't Test*. You type these labels directly in the spreadsheet, replacing the default *New Branch*, by clicking on the name of each branch. Alternatively, you can enter the names in the Branches tab of the Node Settings dialog.

A branch value is also needed for each branch from the decision node. Since testing costs $10,000, the value for the Test branch is -10000. If we don't test, our value is 0 since there are no costs associated with that

option. You type these values directly in the spreadsheet, in the cell below the branch name. This is where the default branch value of 0 is located. Alternatively, you can also enter the values for each branch in the Branches tab of the Node Settings dialog.

Since the decision has two outcomes, two branches extend to the right of the node to an end node. Each end node is represented with a blue triangle. These end nodes show the value and probability of the path through the tree which terminates at the end node.

Testing Decision
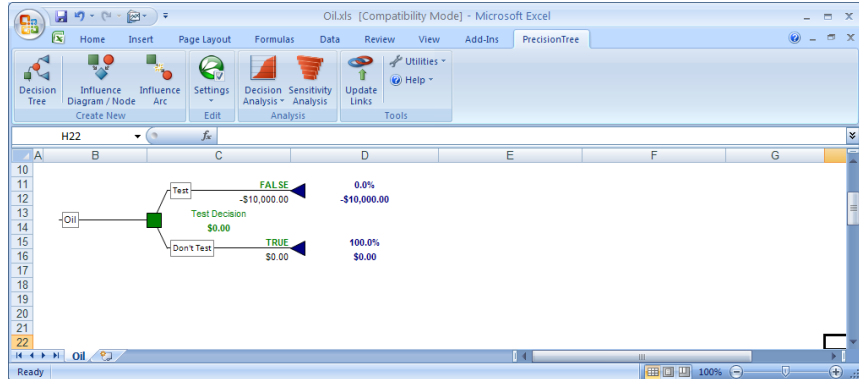
All nodes return the expected value or certainty equivalent of the node. This value is shown in the cell beneath the node name. The method used to calculate these values depends on the default settings for the model.

Each branch from a decision node has a TRUE or FALSE decision indicator. If a branch is selected as the optimum path, TRUE is shown. Unselected branches display FALSE.

Note: A branch for a decision node will display TRUE when it is the selected branch or decision option with the optimal path value. If more than one branch has the optimal path value (i.e., the paths from two branches have the same expected value or utility), the topmost branch will be followed and labeled TRUE.

Creating a Chance Node

A chance node represents an event with a set of possible outcomes over which the decision maker has no control. Once the decision to test has been made, a chance node is used to define the results of the test (a prediction of the amount of oil present). This node should extend to the right of the Test outcome, replacing the existing end node.

To replace an end node with a chance node, click on the end node to be replaced, displaying the DecisionTree Node Settings dialog box. Then, click the Chance node icon under Node Type. The chance node icon is a red circle.
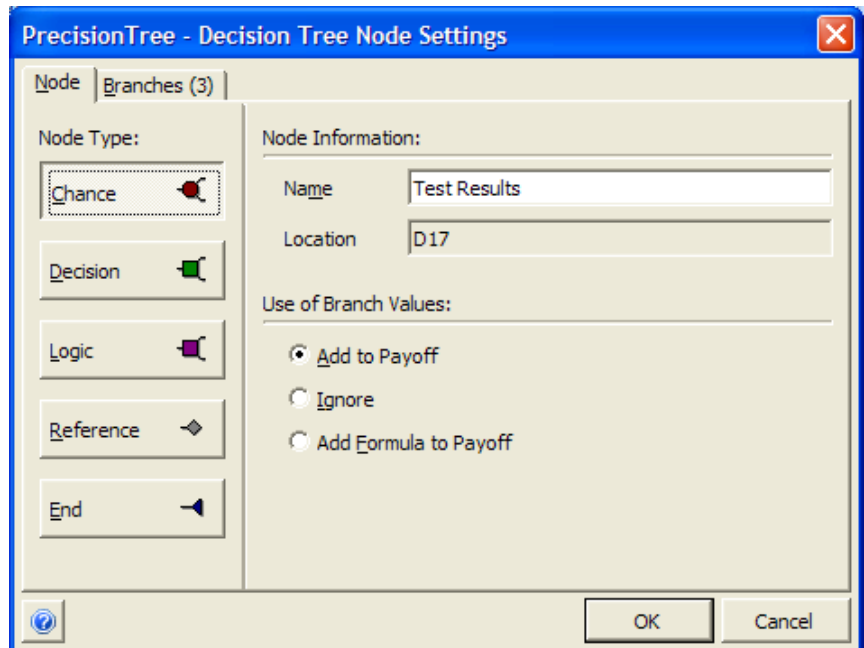
There are three branches (or possible outcomes) from the node. For each branch from a chance node there is a label, value and probability. For the Test chance node there are three possible results: *No Structure, Open Structure* or *Closed Structure*. Let's use the Branches tab in the Decision Tree Node Settings dialog box to enter these. Alternatively, you can also enter labels and probabilities for a chance node directly in your spreadsheet, as was done with the decision node. First, click the Add button to add a new branch. Then you need to set the probability of each outcome occurring to 41%, 35% and 24% respectively.

These values are entered directly in the Branches tab. In this case, the branch probabilities sum to 100%. You can choose whether PrecisionTree requires branch probabilities which total 100% or automatically normalizes branch probabilities, by using the Model Settings dialog Chance Probabilities option (on the Calculation tab).

Click OK and the new Chance node and its three branches are displayed in the spreadsheet.
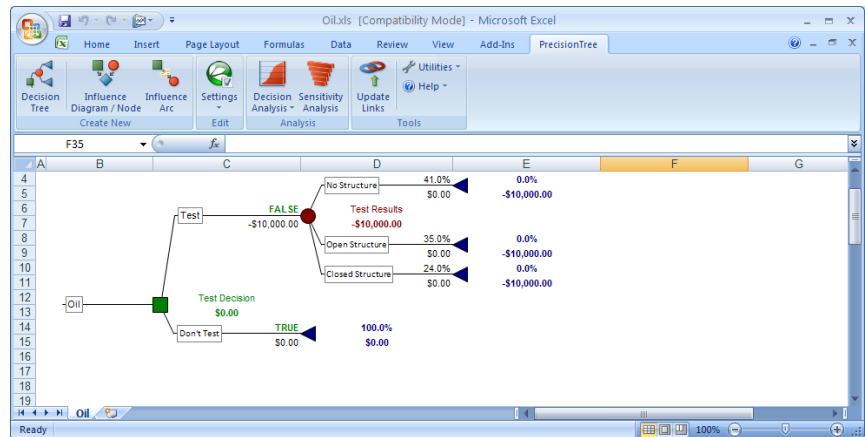
Notice the layout of the decision tree PrecisionTree has drawn for you. In the cell next to each node is the name of the node and its expected value. You can see the names, values and probabilities for each node's branches next to the branches themselves. You can edit these values and labels directly in your spreadsheet if you decide to change the definition of a branch.

Completing the Tree

The entire decision can be defined using the methods described above. For the oil drilling example, each outcome is followed by a decision to drill and the amount of oil found.

Complete Oil Drilling Decision Tree
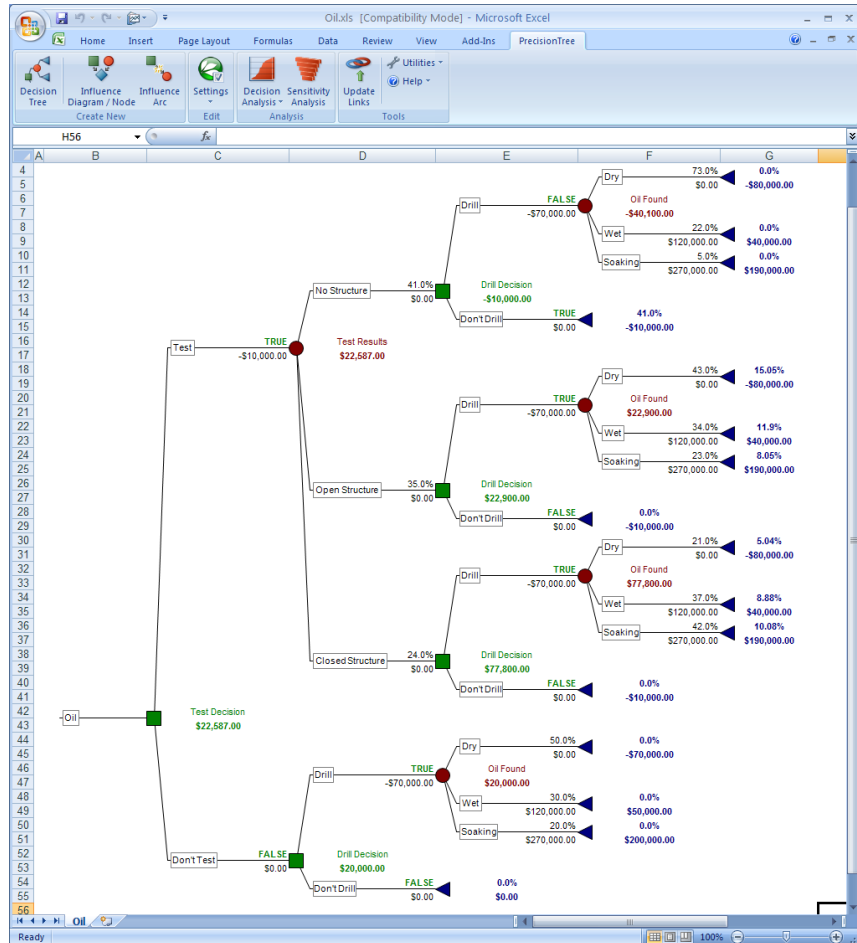
The screen above shows the completed oil drilling decision tree. At the end of each path in the decision tree are end nodes. The payoff and probability for each path through the tree are returned by the end nodes. In this example, the payoff returned depends on the cost of testing, the cost of drilling and the amount of oil found.

The example workbook OIL.XLS contains the oil drilling example described in this section.
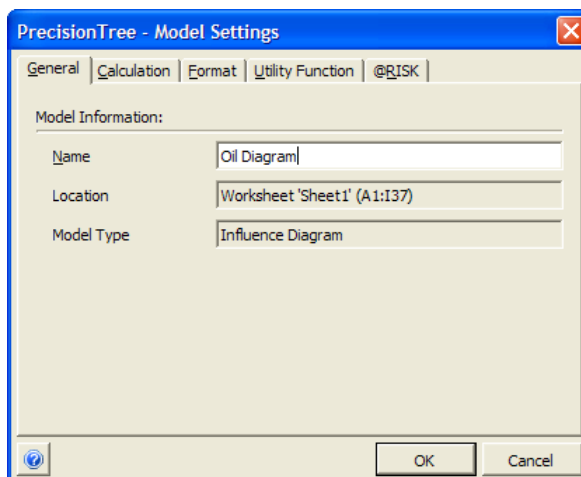
Setting Up an Influence Diagram

This section of the Overview of PrecisionTree provides a more in-depth look at the process of setting up an influence diagram in Excel using PrecisionTree. You'll learn how create an influence diagram by defining nodes and arcs. In addition, you'll specify values and probabilities for the possible outcomes represented by the nodes in an influence diagram in tables in a spreadsheet. The influence diagram created here will be for the oil drilling problem which was modeled using a decision tree earlier in this chapter. The completed model is included with PrecisionTree in the example file OIL – INFLUENCE DIAGRAM.XLS.

To define an influence diagram, you'll use the commands on the PrecisionTree menu or toolbar. This section assumes that you understand basic decision analysis concepts and techniques. If you're not familiar with influence diagrams, please read the Overview of Decision Analysis first.

Creating a New Influence Diagram

A new influence diagram is created when the **New menu Influence Diagram Node command** is selected, or the **Create New Influence Diagram Node** icon is clicked, and there is no influence diagram on the current worksheet. At this point, you select where you want a new node to appear in your worksheet. The default is that you select the cell where you would like the payoff node, or final outcome of the model, to go, but you can change the type of node by clicking on it. The name of the diagram – the default *New Diagram* - is shown in the top left of the current worksheet. The Model Settings dialog box is displayed, allowing you to name your model and enter its settings.

Influence Diagram Model Settings Dialog Box

The displayed settings control how PrecisionTree calculates results from your influence diagram, specifying which path through the diagram to follow, whether or not to apply a utility function to the model calculations, and other options. For now, we'll just change the name of the diagram from the default *New Diagram* to *Oil Drilling Model*.

Types of Influence Diagram Nodes

The available node types in an influence diagram are:

- **Chance nodes** (represented by red circles) representing events over which the decision maker has no control, with a set of possible uncertain outcomes.

- **Decision nodes** (represented by green squares) where a set of possible options are available to the decision maker.

- **Calculation nodes** (represented by rounded blue rectangles), that take results from predecessor nodes and combine them using calculations to generate new values. There are no options or uncertainty associated with calculation nodes.

- **Payoff node** (represented by a blue diamond), that calculates the final outcome of the model. Only one payoff node is allowed in each influence diagram.

The Influence Node Settings dialog box also allows you to access the Value table for a node. You enter the probabilities and values for the possible outcomes for the node in the Value table.

For our new influence diagram, we will leave the first node as a payoff node with the default name *Payoff*.

Entering a Chance Node

The next node for the oil drilling influence diagram is a chance node named *Amount of Oil*. This node, directly or indirectly, influences many of the other nodes in your model. To set up this node, click on the **Create New Influence Diagram Node icon**, and click on the cell where you want to place the node. In the **Influence Node Settings dialog box**, first change the name to *Amount of Oil*.
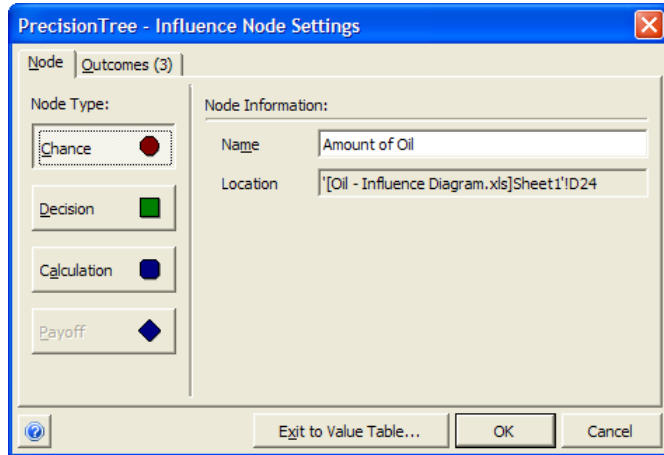
There are three possible outcomes for *Amount of Oil – Dry, Wet and Soaking*. These are specified in the Outcomes tab. By clicking the **Add** button, a third outcome can be added to the default *Outcome #1* and *Outcome #2*.
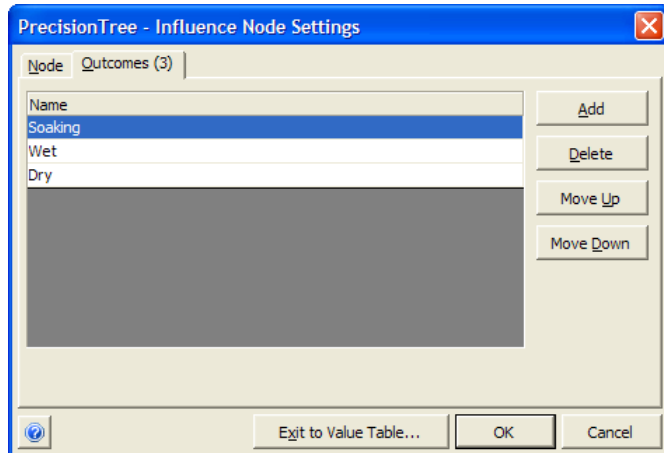

Then, enter the name of each outcome in the table and click OK.

Adding Other Influence Diagram Nodes

Now, we'll add the remaining nodes and their possible outcome names to our diagram. By clicking the Create New Influence Diagram Node icon and clicking in the cell where you want each node positioned, add:

- A decision node, *Drill Decision*, with two options, *Drill* and *Don't Drill*.

- A decision node, *Test Decision*, with two options, *Test* and *Don't Test*.

- A chance node, *Test Results* with, three possible outcomes, *No Structure, Open Structure* and *Closed Structure*.

Influence Diagram with Only Nodes
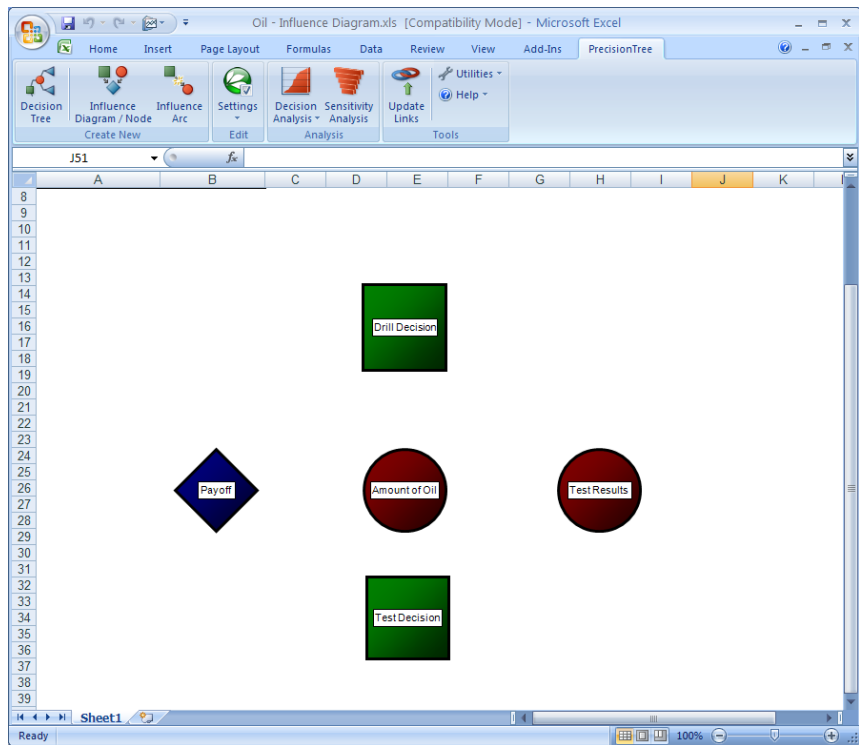
The Oil Drilling influence diagram, with all nodes entered, is shown above. The next step in creating this decision model is to connect the nodes with arcs that indicate the relationships among the elements of the model.

Entering Influence Arcs

An influence diagram has arcs between nodes to indicate relationships between decisions, chance events, calculation nodes and payoffs. Arcs, for example, can indicate that an outcome which occurs for one node influences the values and probabilities used for another node.

In our diagram here, the *Amount of Oil* chance node influences two other nodes – *Test Results* and the *Payoff* node. The values for *Payoff* and *Test Results* (and the probabilities for *Test Results*) are influenced by the outcome which occurs for the *Amount of Oil* – i.e., a value for *Payoff* and *Test Results* will be specified for each possible outcome for *Amount of Oil* - *Dry, Wet* and *Soaking*. This influence is shown in the diagram by drawing arcs from the *Amount of Oil* node to the *Payoff* and *Test Results* nodes. Arcs are drawn by clicking the **Create New Influence Diagram Arc icon** and drawing a line from the *Amount of Oil* node to each of the other two nodes.

Each time you draw an arc, the Influence Arc Settings dialog box is displayed, allowing you to enter the type of influence the arc describes.

Influence Arc Settings Dialog Box
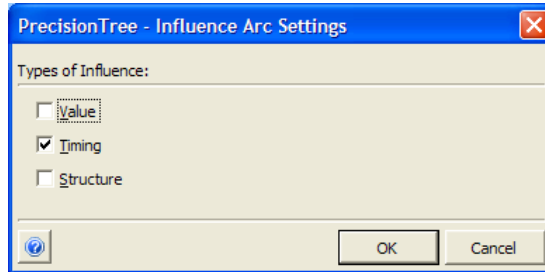
Types of Influence Between Nodes

Some influence arcs specify a value influence, as described here between *Amount of Oil* and *Payoff*. Other arcs only indicate timing - when one event must occur prior to another, or structure - when an outcome for one event affects the outcomes which occur for another event (or whether the event takes place at all!). An arc can specify multiple types of influence; for example, an arc from *Test Decision* to *Payoff* describes not only a value influence but also a timing influence, as the *Test Decision* is made prior to the *Payoff* calculation being performed.

Timing and structure influence are important when your influence diagram is converted to a decision tree. They specify which events precede others in the converted decision tree (timing influences) and which nodes are "skipped" and branches "pruned off" when certain outcomes occur. This allows you to make what is known as an "asymmetric" tree. The decision tree which represents the Oil Drilling problem is an asymmetric tree as some paths (such as *Don't Test - Don't*

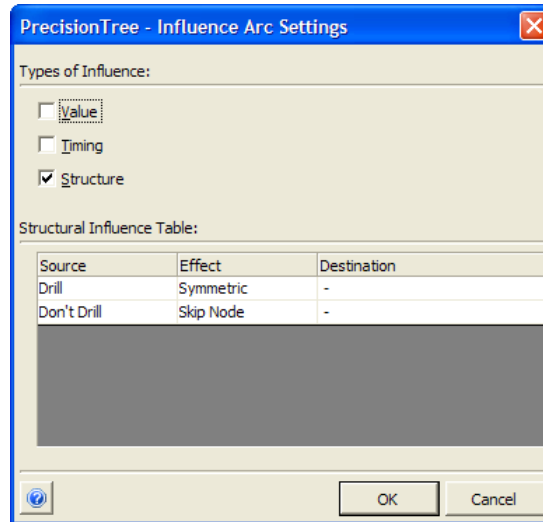*Drill*) have fewer nodes and branches than other paths (such as *Test – Open Structure - Drill - Soaking*).

To define all relationships for the Oil Drilling model, the following influence arcs with specified influence types are added to model:

1) An arc from *Amount of Oil* to *Test Results*; influence type is **value** only as the amount of oil influences the results of the test, but the amount of oil is not known until after the test results.

2) An arc from *Amount of Oil* to *Payoff*; influence type is **value and timing** as the amount of oil influences the payoff calculation.

3) An arc from *Test Decision* to *Payoff*; influence type is **value and timing** as the cost of testing influences the payoff calculation.

4) An arc from *Test Results* to *Drill Decision*; influence type is **timing** only, as the outcome for the *Test Results* is known prior to the drilling decision.

5) An arc from *Drill Decision* to *Amount of Oil*; influence type is **structure** only, as the amount of oil is not known prior to the drilling decision; however, if the decision is made not to drill, the *Amount of Oil* node is skipped; i.e., you'll never know the amount of oil without drilling.

6) An arc from *Test Decision* to *Test Results*; influence type is **timing and structure**, as the decision to test happens prior to the *Test Results* outcome being known; however, the decision to test has no effect on the outcome for *Test Results* except that the *Test Results* node is skipped if you don't test; i.e., you'll never know the *Test Results* without testing.

7) An arc from *Drill Decision* to *Payoff*; influence type is **value and timing** as the cost of drilling influences the payoff calculation and precedes that calculation chronologically.

When each arc is entered, the appropriate influence type is selected in the Influence Arc Settings dialog box. When a structure influence is desired, it is necessary to specify how the predecessor node will affect the structure of the outcomes from the successor node. When you select structure influence in the Influence Arc Settings dialog, you will be able to describe the type of structure in the Structural Influence Table.

Each of the outcomes from the predecessor node (in this case, *Drill Decision* outcomes) can have a structural influence on the outcomes from the successor node (*Amount of Oil*). By default, structure influence is symmetric; that is, each outcome for the successor node is possible at each outcome for the predecessor node. In the case of the arc from *Drill Decision* to *Amount of Oil*, however, the *Amount of Oil* node will be skipped when drilling is not performed. To specify this, **Skip Node** is set as the structure influence type for the *Don't Drill* outcome of *Drill Decision.*
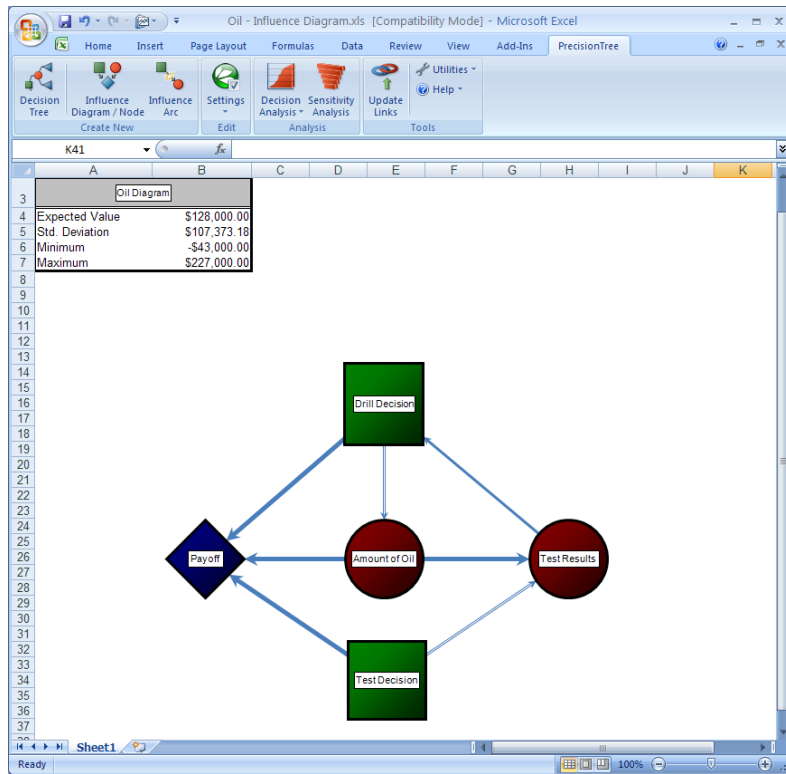
Once the appropriate influence types have been entered for each arc in the diagram, the structure of your model is complete. Now all that remains is to enter the values for the outcomes for each node.

Entering Influence Node Values

Right-clicking on a node and selecting the **Influence Value Table command** displays the Value table for an influence diagram node. A Value table is used to enter the values for the possible outcomes for the node (and, for a chance node, the probabilities of those outcomes). A value is entered for each possible combination of outcomes of the predecessor, or influencing, nodes.
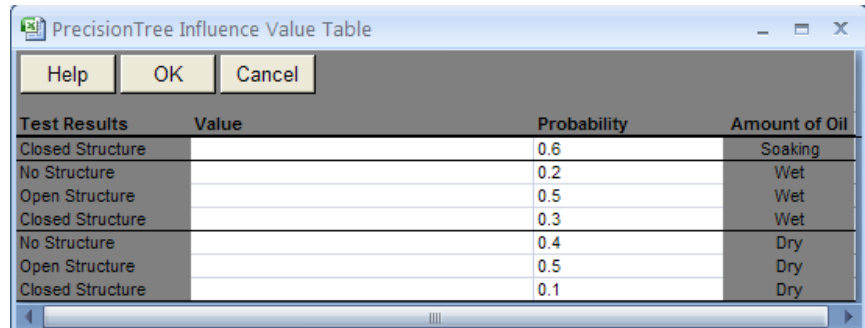
The Value table is a standard Excel spreadsheet with values of influencing nodes shown. In the Value table, values and probabilities are entered in the white columns. In the table above, the possible values for *Amount of Oil* and their probabilities of occurrence are shown.

The *Amount of Oil* chance node influences the probabilities of the *Test Results* chance node. There are three different possible outcomes for *Test Results – No Structure, Open Structure* and *Closed Structure*. (There are no values associated with these structure types, only probabilities.) For each possible outcome for *Amount of Oil*, a different probability is entered for each structure type.

Value Table for Test Results

PrecisionTree Influence Value Table _ ☐ ✕

| Help | OK | Cancel |

Test Results	Value	Probability	Amount of Oil
Closed Structure		0.6	Soaking
No Structure		0.2	Wet
Open Structure		0.5	Wet
Closed Structure		0.3	Wet
No Structure		0.4	Dry
Open Structure		0.5	Dry
Closed Structure		0.1	Dry
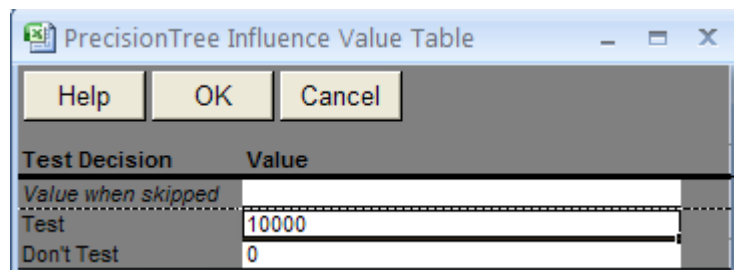
Bayesian Revision

In the influence diagram, probability information was entered for *Test Results* at each possible outcome for *Amount of Oil.* These events, however, occur in the opposite sequence chronologically - you find out the *Test Results* prior to the determining the *Amount of Oil.* In the converted decision tree, the order of these nodes will be "flipped" and revised probabilities calculated using a process known as *Bayesian Revision*. This happens automatically when PrecisionTree calculates the results for an influence diagram or converts your influence diagram to the equivalent decision tree.

Entering Remaining Node Values

To complete the Oil Drilling influence diagram it is necessary to fill in the value tables for the remaining influence diagram nodes. The following tables show the values for each node.

Test Decision Values

PrecisionTree Influence Value Table _ ☐ ✕

| Help | OK | Cancel |

Test Decision	Value
Value when skipped	
Test	10000
Don't Test	0

Drill Decision Values

PrecisionTree Influence Value Table

| Help | OK | Cancel |

Drill Decision	Value
Value when skipped	
Drill	43000
Don't Drill	0

Payoff Node Values

For payoff nodes, formulas can be used to combine values for influencing nodes to calculate node values. These formulas are standard Excel formulas and can reference outcome values listed in the value table or other cells in open worksheets.

PrecisionTree Influence Value Table

| Help | OK | Cancel |

Payoff	Value	Amount of Oil	Drill Decision	Test Decision
	=D4-E4-F4	Soaking	Drill	Test
	=D5-E5-F5	Wet	Drill	Test
	=D6-E6-F6	Dry	Drill	Test
	=-F7		Don't Drill	Test
	=D10-E10-F10	Soaking	Drill	Don't Test
	=D11-E11-F11	Wet	Drill	Don't Test
	=D12-E12-F12	Dry	Drill	Don't Test
	0		Don't Drill	Don't Test

When entering the formula for the *Payoff* node, a formula is entered in the Value cell that sums the *Amount of Oil, Test Decision* and *Drill Decision* cells. In the Value table above, the first cell sums the values for *Dry, Drill* and *Test* outcomes (cells D4, E4 and F4 in the Value table where the labels *Dry, Drill* and *Test* are located; refer to the Name Box in the Excel toolbar for cell references in the Value table). By entering a reference in a formula to a cell where an outcome's name is located, you are instructing PrecisionTree to use the values for the shown outcome when generating the *Payoff* value. This formula can then be copied to the other value cells, just like other Excel formulas. All cell references are automatically updated by Excel.

Model Statistics

Oil Diagram	
Expected Value	$128,000.00
Std. Deviation	$107,373.18
Minimum	-$43,000.00
Maximum	$227,000.00

With all values and probabilities entered for the nodes in the influence diagram, the expected value of the model, along with the minimum, maximum and standard deviation of results can be seen in the upper left of the worksheet. These values are calculated "real-time" just as are other spreadsheet results. Change a value or probability in your diagram and you'll immediately see the impact on the results of your model.

Analyzing a Decision Model

Introduction

PrecisionTree offers two methods for analyzing decision trees and influence diagrams: decision analysis and sensitivity analysis. Decision analysis determines the optimum path through your model, telling you which decisions are the best ones given specific chance outcomes. Sensitivity analysis measures the effect of changes in each input on your model. Please refer to the **Overview of Decision Analysis** and the **Overview of Sensitivity Analysis** for more information.

Real-Time Decision Model Results

A decision analysis supplements the standard statistics on your decision model which are provided real-time as you enter or edit values in your decision tree or influence diagram. These statistics, which include the expected value of the model, along with the minimum, maximum and standard deviation of possible outcomes, are available in the Decision Analysis – Risk Profile feature for a decision tree, or in the top left corner of the worksheet which contains an influence diagram.

Generating a Risk Profile

To run a risk profile, use the **Decision Analysis menu Risk Profile command** on the PrecisionTree menu, or click the **Decision Analysis icon** on the PrecisionTree toolbar. A dialog box appears that allows you to select which decision tree or influence diagram you wish to analyze. If you wish to analyze a small part of a decision tree (a sub-tree), select a node other than the start node in the dialog box.

If your model begins with a decision node, PrecisionTree offers a multi-decision option. In addition to analyzing the optimum decision, PrecisionTree can analyze every other choice for comparison.

During an analysis, PrecisionTree determines every possible path value and the probability associated with each. These results are used to construct a distribution function called a risk profile.

These results can be displayed in a statistical summary report, which lists the risk profile and relevant statistics for each initial decision. The report can be generated in a new workbook or a workbook where the model is located.

*Risk Profile Statistical Summary*
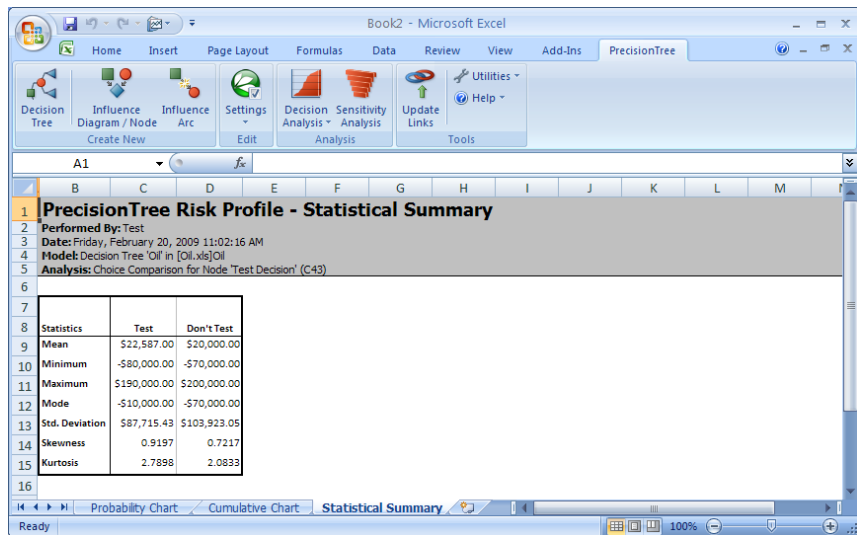
In this example, the two choices for the initial *Test Decision* in the model were analyzed: *Test* and *Don't Test*. The expected value of the tree is 22,587 when the initial decision is to *Test*. When the initial decision is *Don't Test*, the expected value decreases to 20,000. So, based only on expected value, testing seems to be the optimum decision.

Risk Profile Probability Chart

The Risk Profile Probability Chart displays the information as a discrete density distribution for each possible outcome. Each line of the graph shows the probability that the outcome will equal a certain value. The graph is generated in a new chart in a new workbook on a sheet named Probability Chart.
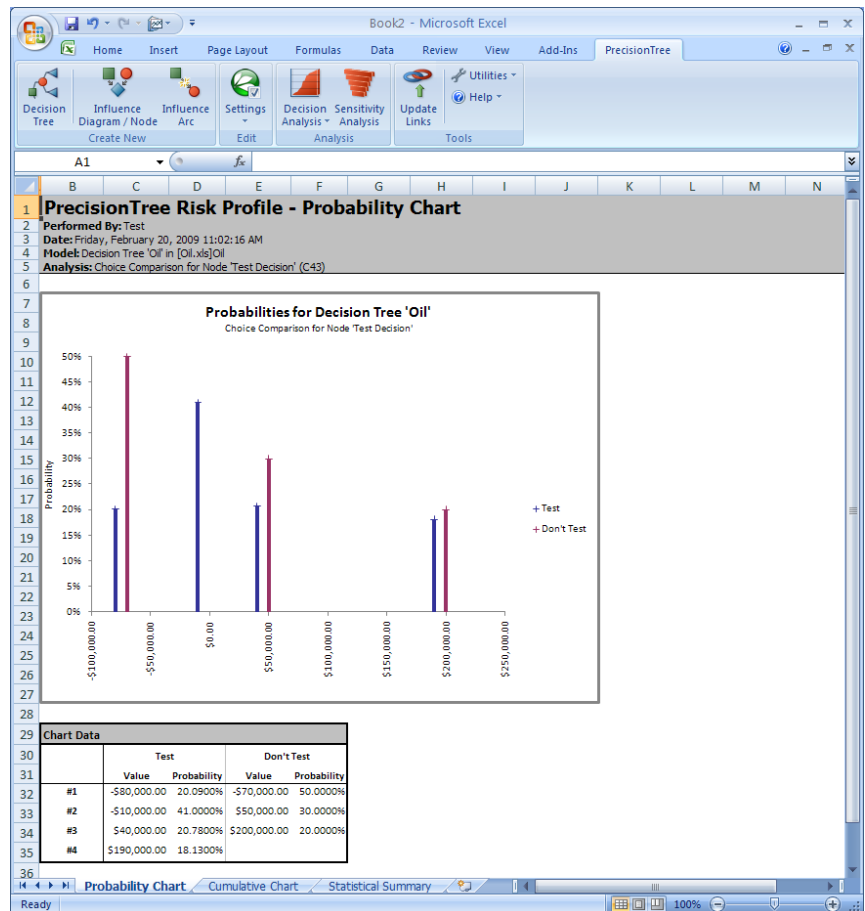
In the Probability Chart above, four possible outcomes are displayed for the *Test* decision and three possible outcomes for the *Don't Test* decision with the probability of each displayed.
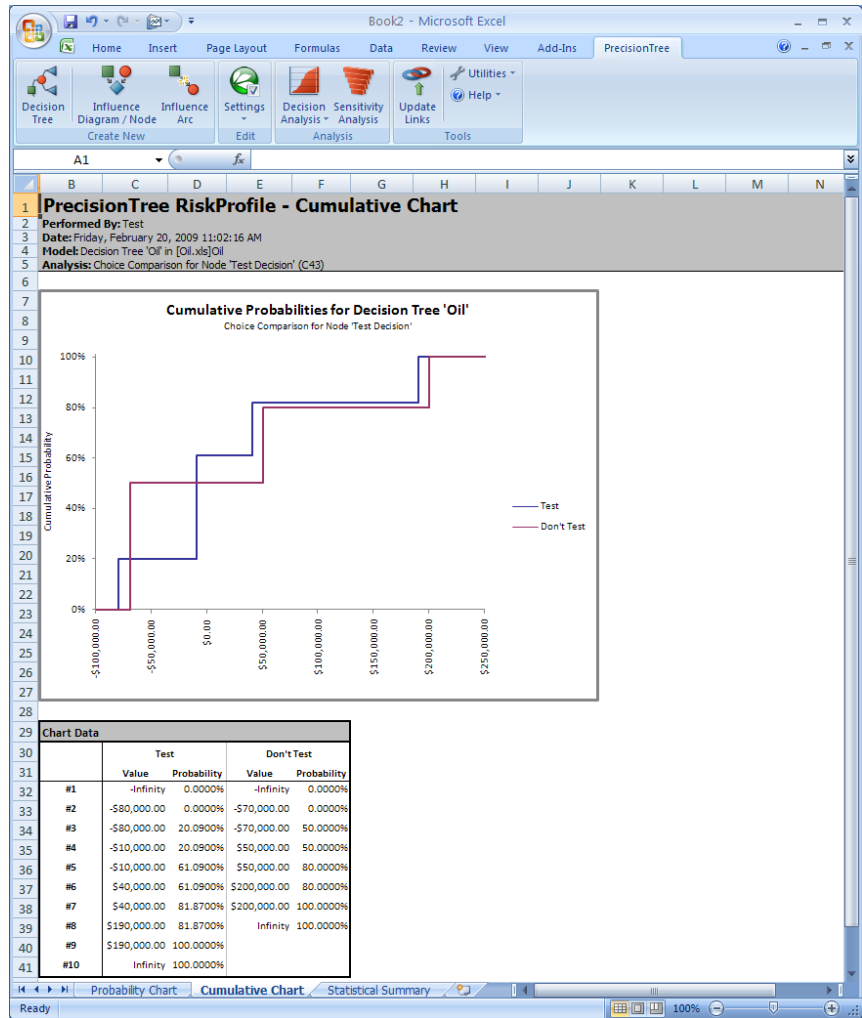
The Risk Profile Cumulative Chart displays a cumulative distribution showing the probability of an outcome less than or equal to a certain value. As with the probability chart, the risk probability cumulative chart is generated in a new chart in a new workbook, on a sheet named Cumulative Chart. The cumulative chart above demonstrates the probability of an outcome of zero is about 60% when testing is done. However, the probability of an outcome of -10,000 falls to about 20% when testing is done.

Policy Suggestion Report

When the **Decision Analysis menu Policy Suggestion command** is selected, PrecisionTree finds the optimum path in order to construct a Policy Suggestion Report. The policy suggestion report is a reduced version of the decision tree which displays only the optimum decisions in your model.
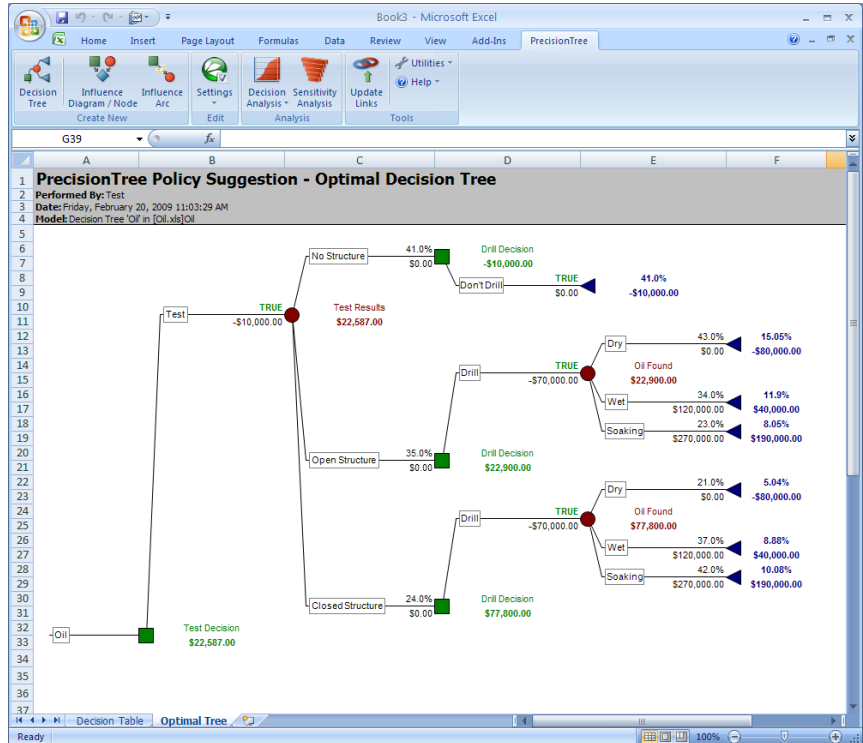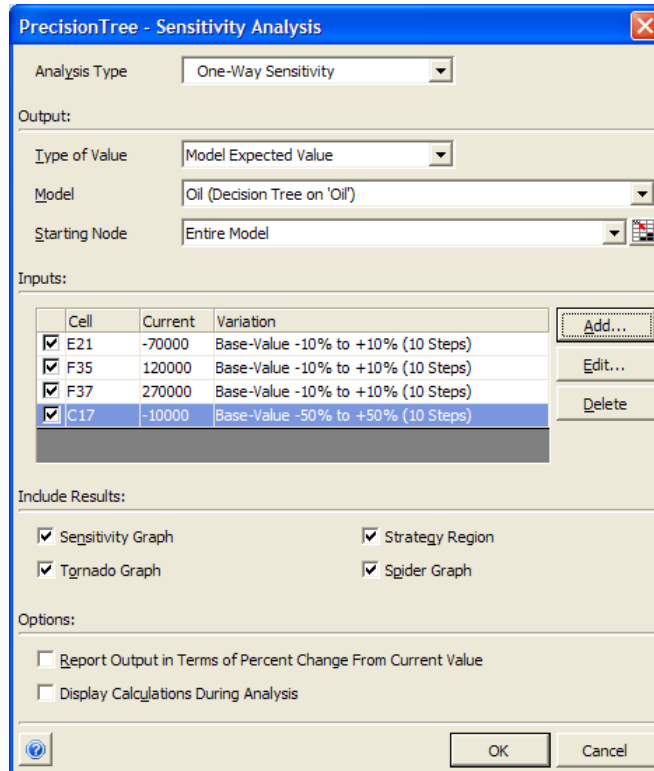
In this example, PrecisionTree suggests deciding to *Test*. Then, depending on the test results, PrecisionTree suggests drilling in some cases ("*Open Structure*" and "*Closed Structure*") and not drilling in others ("*No Structure*"). If we follow these suggestions, there is a 21% chance the well will be "*Dry*", when the test results are "*Closed Structure*" and a 43% chance it will be "*Dry*" when the test results are "*Open Structure*."

The Policy Suggestion Decision Table is also available. This table identifies the optimal choice to be made at each decision node encountered on the optimal path, and provides the arrival probability and benefit of correct choice.

Running a One-Way Sensitivity Analysis

To run a one-way sensitivity analysis, use the **Sensitivity Analysis** command on the PrecisionTree menu or click the **Sensitivity Analysis** icon on the PrecisionTree toolbar. The Sensitivity Analysis dialog box appears, prompting you for information on the cells you wish to include in the sensitivity analysis.

To study the effects of an input on an entire model, choose the default Entire Model for the Starting Node as the Output in the Sensitivity Analysis dialog. To study the effects on a small part of a decision tree (a sub-tree), choose the desired node of the sub-tree from the drop-down list as the Starting Node for the Output.
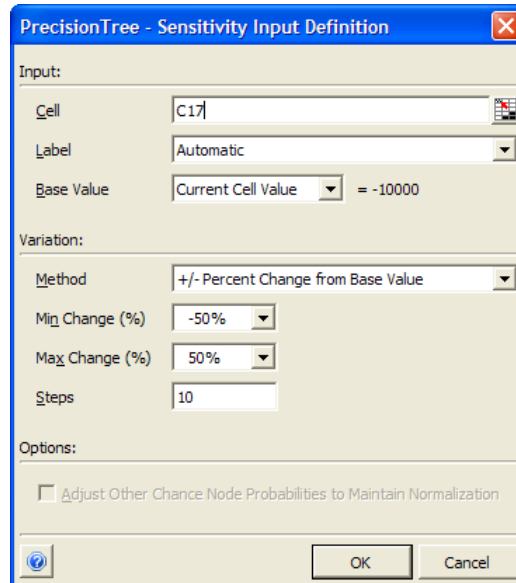
Adding Inputs   Inputs are the cells that will change during the sensitivity analysis. To define Inputs for the sensitivity analysis, click the Add button and then select the desired cells in your model.

Sensitivity Input
Definition

The Sensitivity Input Definition dialog allows you to enter or edit the amount of change you wish to apply to your inputs.

You can select the **Method** of variation desired, such as a **+/- Percent Change from Base Value**, the number of **Steps** or values across that range to test, and the actual change amounts to apply. During a sensitivity analysis, the entered minimum-maximum range is divided by the number of Steps entered, and the Input value is calculated for each step.

Running a
Sensitivity
Analysis

During a sensitivity analysis, PrecisionTree modifies the value(s) of the sensitivity input(s) you specify (Inputs) and records the changes in the expected value of the Output. For one-way sensitivity analyses, one input is changed at a time. Reports generated by this analysis include one-way sensitivity graphs, tornado graphs and spider graphs. The results of many one-way analyses can be compared on the same tornado graph or spider graph.

A one-way sensitivity graph displays the change in the expected value of the output as the input changes. This graph, as well as the other graphs described in this section, is generated in a new worksheet in the location you specify in the Reports section of the Application Settings dialog box, accessed with **Utilities menu Application Settings command**.

One-Way Sensitivity Graph
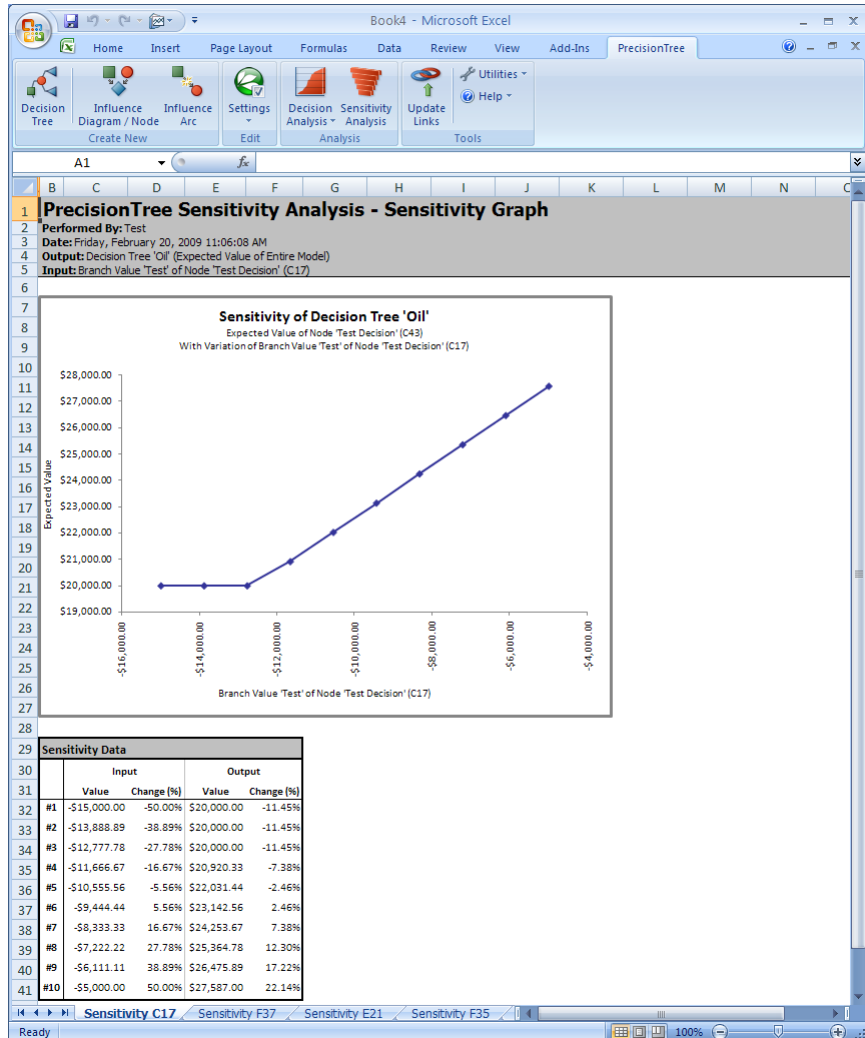
In the example above, the cost of testing was varied. According to the one-way sensitivity graph, the expected value of the model is not affected by the test cost when it exceeds around 13,000 (represented as a negative number as a cost), since "*Don't Test*" becomes the optimum decision.

Analyzing a Decision Model

Tornado Graph

A tornado graph displays the changes in the expected value of the Output for each Input. A new bar is added to the graph for each Input in the one-way sensitivity analysis.
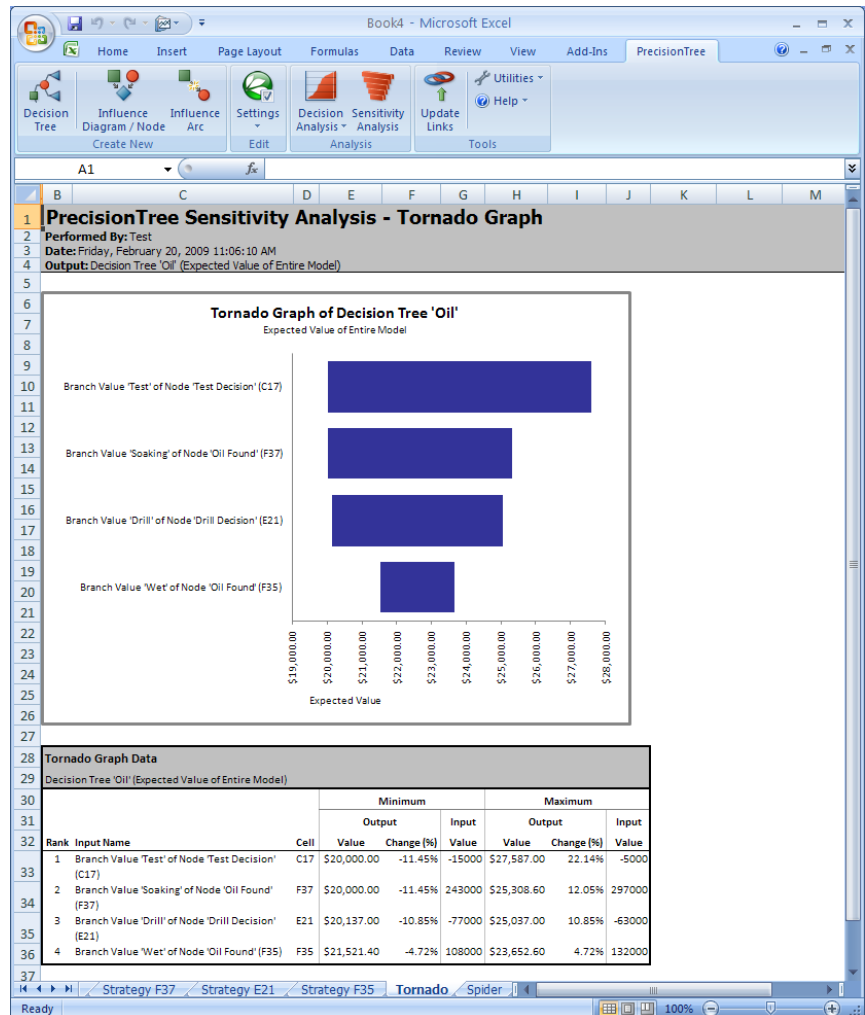
In the tornado graph here, Testing costs, Drilling costs and Soaking and Wet field size were varied by 10%. According to PrecisionTree, the expected value of the model is more sensitive to changes in Testing costs (the largest bar).

Spider Graph

A spider graph displays the percentage change in the expected value of the Output as each Input changes for each analysis. A new line is added to the graph for each Input included in the Sensitivity Analysis.
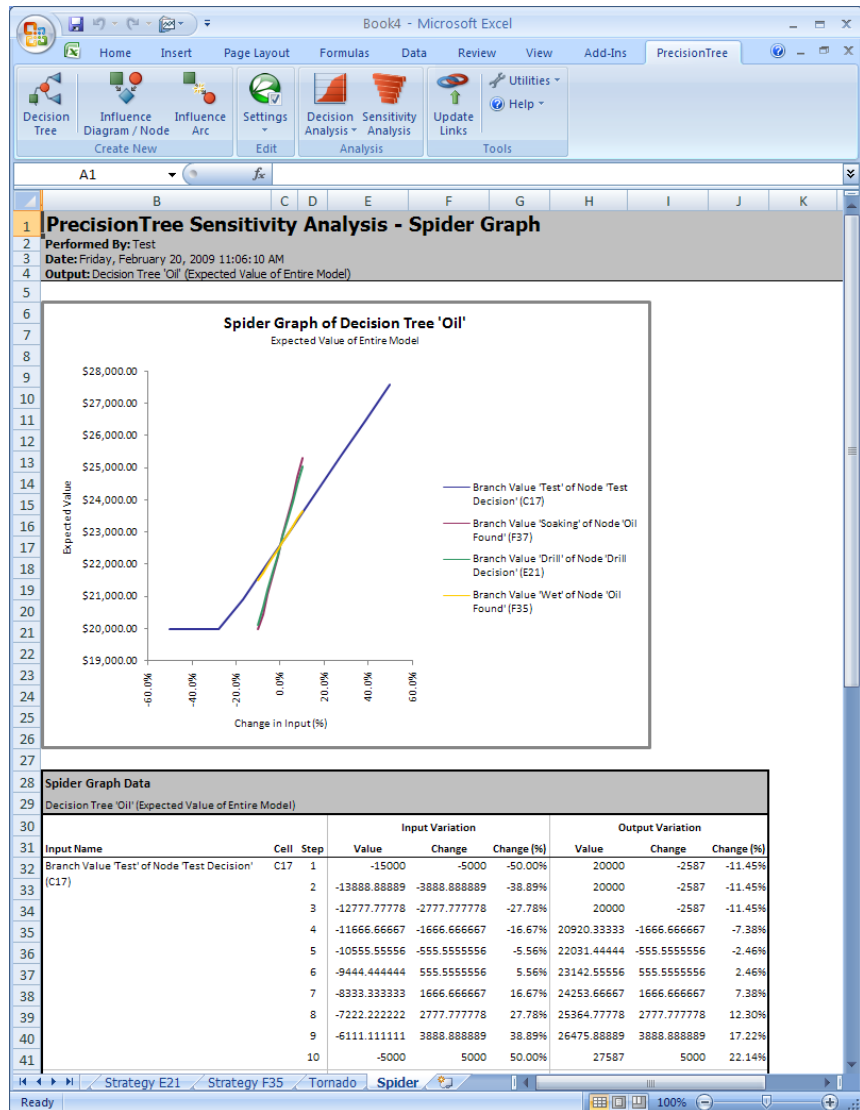
In the spider graph above, Testing costs, Drilling costs and Soaking and Wet field size were varied. According to PrecisionTree, while Testing costs have the most impact on the value of the model across the range of changing values, notice that the slope of the Soaking field size is much steeper. That means a smaller % change in the Soaking field size leads to a larger change in the expected value of the model.

Running a Two-Way Sensitivity Analysis

To run a two-way sensitivity analysis, use the Sensitivity Analysis command on the PrecisionTree menu or click the Sensitivity Analysis icon on the PrecisionTree toolbar. The Sensitivity Analysis dialog box appears, prompting you for information on the cells you wish to include in the sensitivity analysis. For a two-way sensitivity analysis, set Analysis Type to 2-Way Sensitivity.

For a two-way sensitivity analysis, two inputs are changed simultaneously. Reports generated by this analysis include two-way sensitivity graphs and strategy region graphs. During the analysis, PrecisionTree finds the value of the Output at each possible combination of values for the Inputs. PrecisionTree then display the results as a 3D graph, with values for the Inputs on the X and Y axis and the values for the Output on the Z axis.
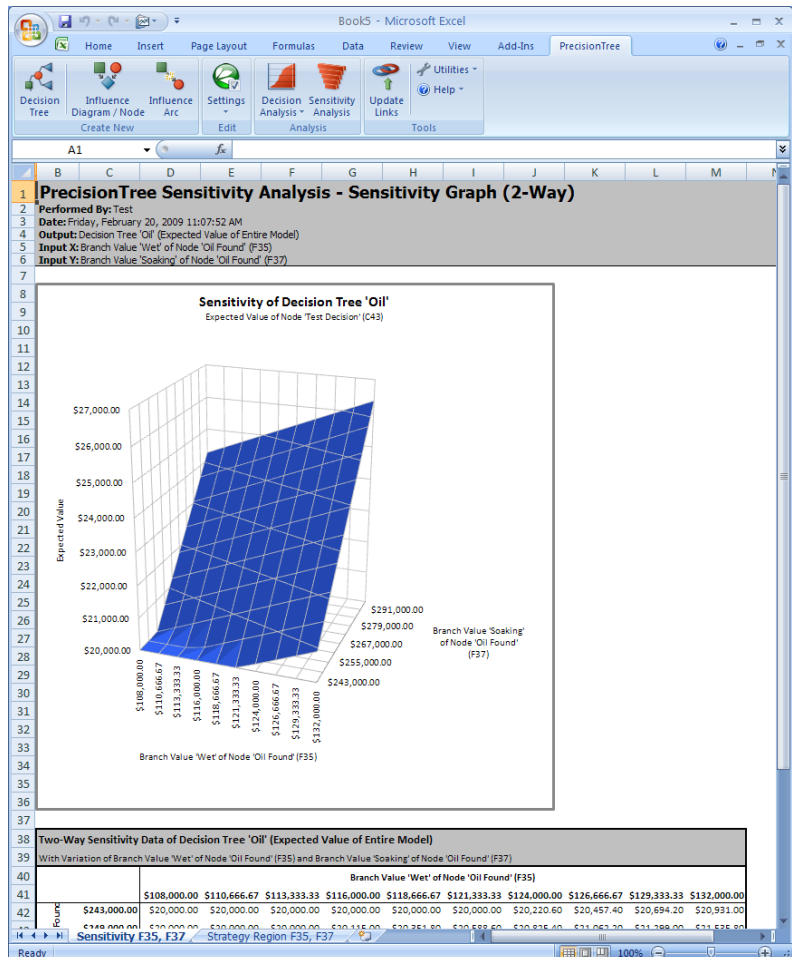
Strategy Region Graphs

Strategy region graphs show regions where different decisions are optimal given changes in two selected inputs. The value of the first input is plotted on the X-axis and the value of the second input is plotted on the Y-axis. The different symbols in the graph denote the optimal decision at various combinations of values for two inputs - in this case, the Wet field value and the Soaking field value.

The strategy region graph here shows the optimal decision for the possible combinations in value for Wet and Soaking. When Wet and Soaking each approach their minimum values, the decision Don't Test becomes optimal.

Analyzing a Decision Model
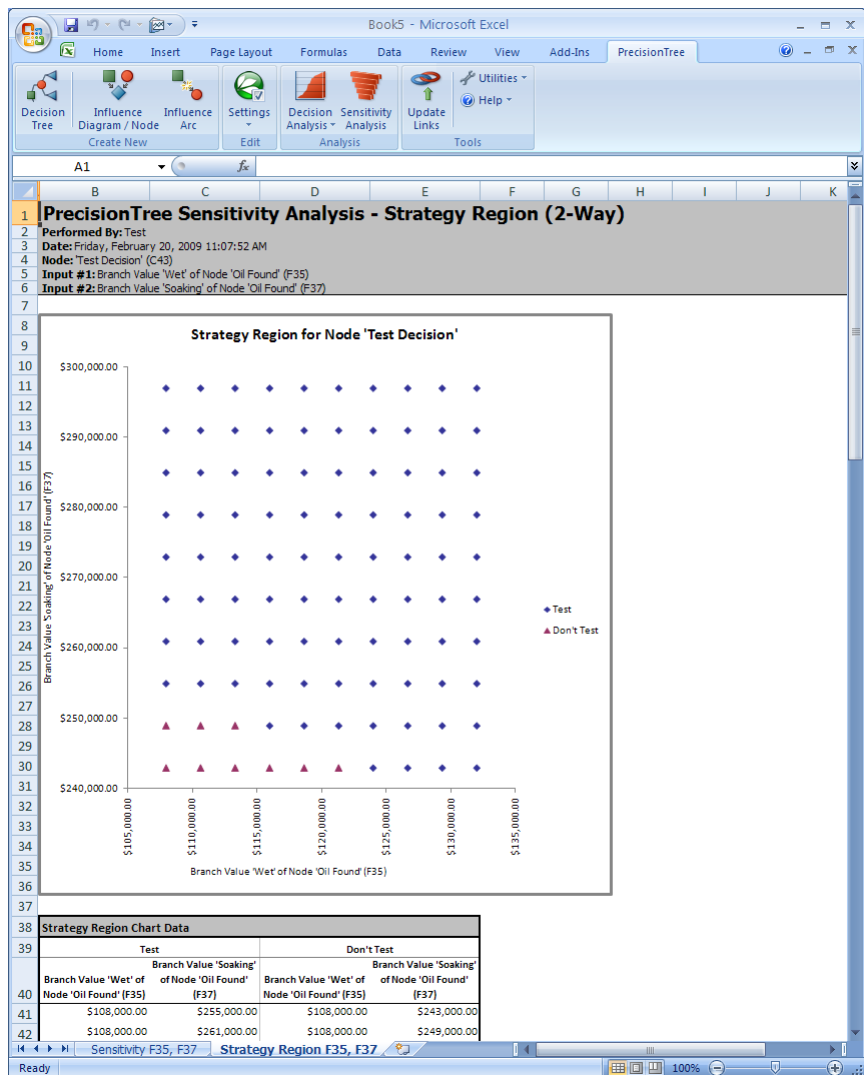
Advanced Features

PrecisionTree offers many advanced features that can greatly enhance your decision models. This section gives an overview of many of these features. For additional information on using the features described here, see **Chapter 4: Modeling Techniques** and **Chapter 5: The PrecisionTree Command Reference.**

Alternate Calculation Methods

The default calculation method for decision trees is the cumulative method, where values for each branch on a path through the tree are simply added together as the payoff value for the end node of the path. Other calculation methods are also available:

Linked trees allow the branch values for a decision tree to be linked to cells in an Excel model that is external to the tree. By linking values, end node payoffs can be calculated by a detailed spreadsheet model. In a linked tree, each node can be linked to an Excel cell reference or range name. When a linked tree is recalculated, branch values on each path in the tree are substituted into the designated cells in the Excel model and the payoff is calculated. End node payoffs are then taken from the cell specified as the location of the payoff value. See the example SIMPLE LINKED TREE.XLS for additional information on working with linked trees.

Payoff formula trees allow end node payoff values to be calculated using a formula. This formula can reference the values and probabilities for branches on the path whose payoff is being calculated. See the example OIL – FORMULA.XLS for additional information on working with formula trees.

VBA macro trees allow you to calculate a decision tree using a VBA macro. See the example OIL – VBA MACRO.XLS for a simple example of this method.

Defining Branch Values, Probabilities and Logic in Cells

Branch values and probabilities entered in the spreadsheet (in the cells above and below a branch) can be defined by entering a value directly in the cell or by entering any valid Excel formula. For branch probabilities, entered values can be normalized so that the sum of all branch probabilities from the node equals one.

Logic Nodes

Logic nodes are a special type of node where the optimum branch is not selected using the PrecisionTree settings for path selection. Instead, decisions are made according to conditions the user defines. The name of the node derives from the fact that the pre-set conditions are usually phrased in a logic statement (using expressions such as "less than", "equal to", etc.). There is a logic statement (in PrecisionTree called "branch logic") associated with each branch from the node. This statement is simply a standard Excel formula that returns a TRUE or

FALSE in your spreadsheet when evaluated. A logic node is symbolized by a purple square. A logic node behaves like a decision node, but it selects the branch whose branch logic formula evaluates to TRUE as the logical (optimal) decision.

Decision Defined by a Logic Node
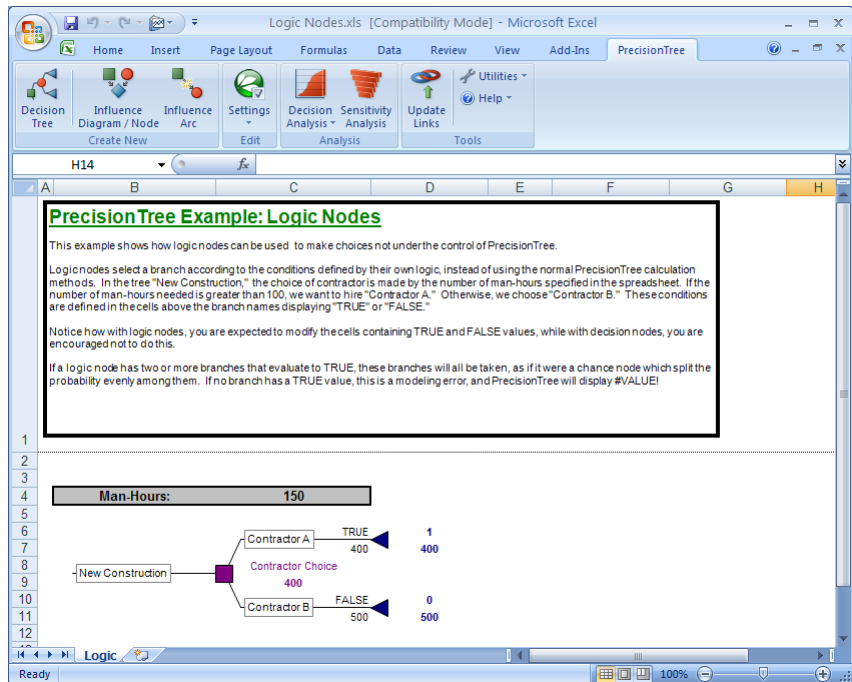
The LOGIC NODES.XLS example contains a variable Man_Hours and a situation where you want to choose Contractor A if Man_Hours is less than 100 and Contractor B otherwise. Using a logic node, the probability of selecting either Contractor A or Contractor B is defined with the formulas:

=Man_Hours>100
=Man_Hours<=100

PrecisionTree selects the first option as the optimum path whenever Man_Hours are greater than 100 and the second option otherwise. The value for the Contractor A branch is 400 while the value for the Contractor B branch is 500.

If two or more branches of a logic node evaluate to TRUE, all TRUE branches are optimal and equally likely to occur. The logic node returns the average of the value for each TRUE path. If all branches evaluate to FALSE, this is a modeling error, and the logic node returns #VALUE.

Using Distribution Functions as Branch Values

@RISK distribution functions allow a range of possible values to be entered for values and probabilities in your decision trees and supporting worksheet models. Wherever values are used in your models, distribution functions may be substituted. During a standard decision analysis, these functions will return their expected values. These are the values that will be used in calculating all decision analysis results.

When a simulation is run using @RISK, a sample will be drawn from each distribution with each iteration of the simulation. The node values in the decision tree will then be recalculated using the new set of samples and the results recorded by @RISK. A range of possible values for nodes selected as simulation outputs will then be displayed by @RISK.

Reference Nodes

Reference nodes can be used to reference a separate tree or a sub-tree with the current tree. The referenced tree can be present in the same worksheet or on a different worksheet in the same workbook. Use reference nodes to simplify a tree, to reference the same sub-tree many times in a tree, or when a tree becomes too large to fit on one spreadsheet. A reference node is symbolized by a gray diamond.
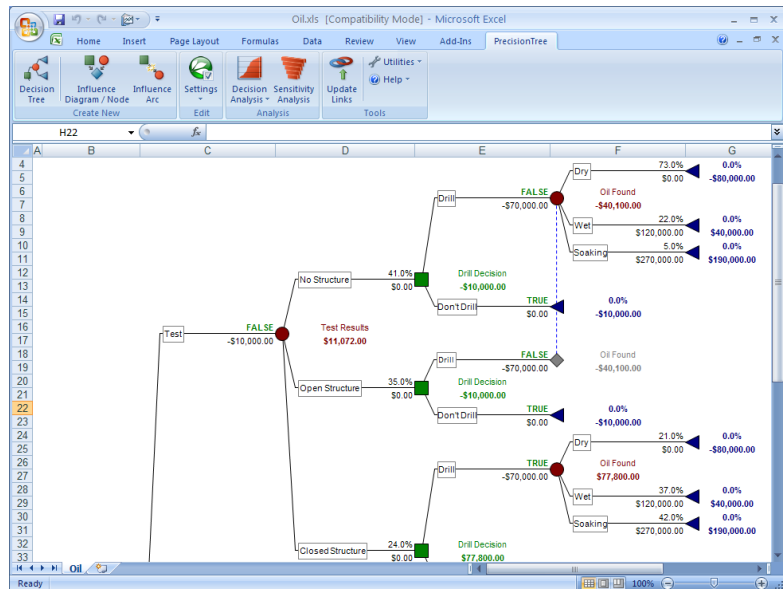
In this example, the sub-tree Oil Found (which follows the *Test\No Structure\Drill* path) is referenced at the end of the *Test\Open Structure\Drill* path. The dashed line shown displays the reference node link.

Collapsing, Expanding and Reducing Trees

Because decision trees can grow large as more nodes and decision options are added, it is important to be able to collapse sections of trees so that important areas can be highlighted. Any node in PrecisionTree can be collapsed, hiding all successor nodes and branches. Collapsed sections are still calculated like visible parts of the tree - they are just hidden from view.
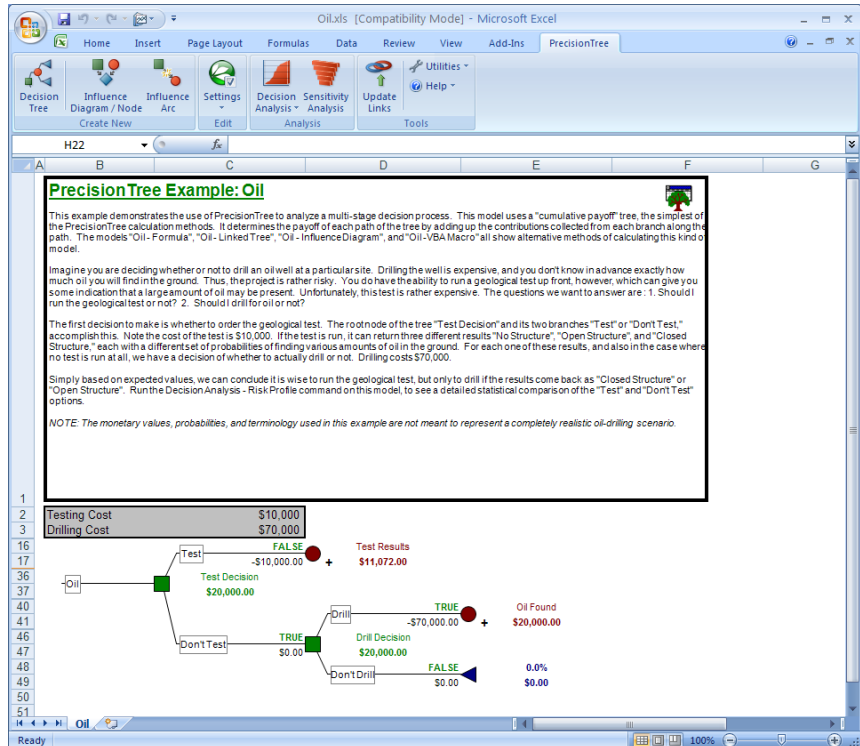
To collapse a section of a tree, right-click on the desired node, and choose Collapse Child Branches. Clicking the small + symbol next to a collapsed node expands the node and all successor nodes and branches back to normal size.

Forced Branches

You can specify that a particular branch must be chosen at a given decision or chance node, regardless of what PrecisionTree has decided would be the optimum path through the node. Use the Force option when a specific (and not necessarily optimal) decision is made, or when a specific chance node outcome occurs.

Chapter 4: Modeling Techniques

Introduction

This chapter demonstrates the process of translating typical decisions into PrecisionTree models. These situations have been identified from real-life modeling problems that decision makers often encounter. As you model decisions, look through the examples and illustrations provided in this chapter. You may find some helpful tips or techniques to make your PrecisionTree models the best representations of your decisions.

Several PrecisionTree techniques are presented here to illustrate common decision modeling situations. To help you understand the modeling techniques employed, example Excel worksheets are provided with your PrecisionTree program. As you work through each modeling technique discussed, look at the corresponding worksheet. It will help you understand the PrecisionTree concepts and techniques involved in modeling each situation.

The example models mentioned in this chapter can be found in the C:\PROGRAM FILES\PALISADE\PRECISIONTREE5\EXAMPLES\ENGLISH directory. You can quickly access these files through the PrecisionTree menu Help command Example Spreadsheets selection.

Cumulative Trees

The default type of decision tree calculation in PrecisionTree is the Cumulative method, which is the simplest method for calculating the payoff values for each path through a decision tree. With the cumulative payoff calculation method, values for each branch on a path through the tree are simply added up in order to calculate the payoff value shown at the end node for the path.

A good place to start for learning about cumulative trees and general concepts about decision trees is with the example file BASIC TREE TERMINOLOGY.XLS. This example looks at a very simple cumulative tree called "Lottery", where a decision is made whether to buy a lottery ticket based on two possible outcomes.
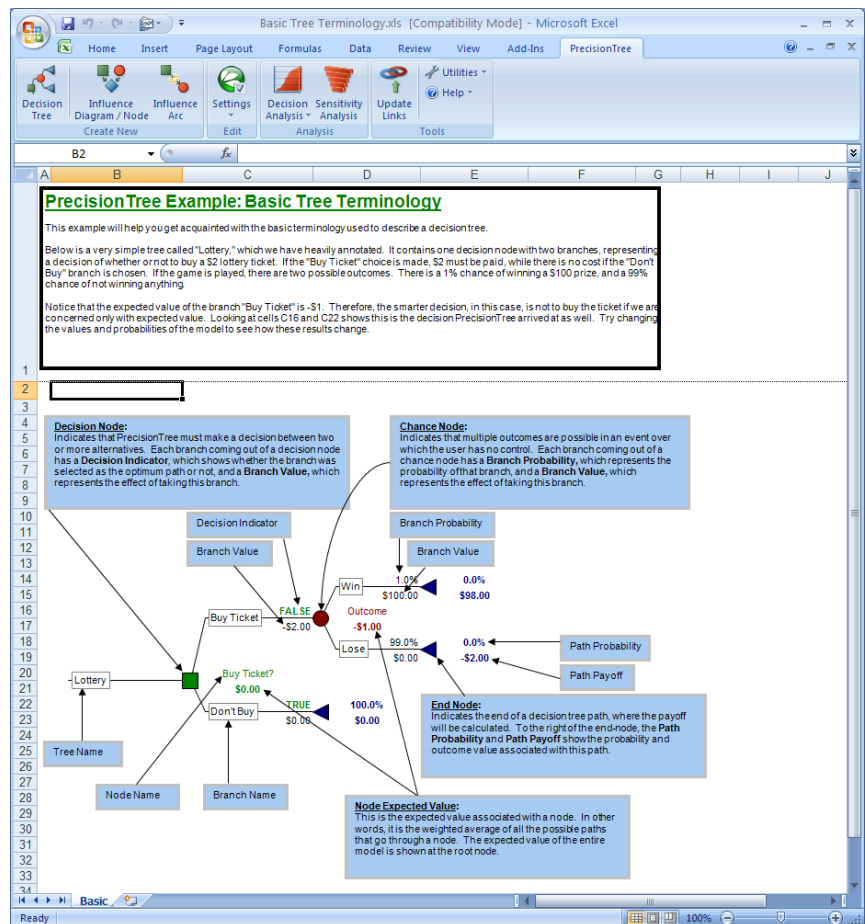
Generating Branch Values with Formulas

There are times when you may wish to display one set of branch values in the spreadsheet but use different values from the branches in payoff calculations. For example, you may wish to enter a formula for a node that converts the branch values for the node to a monetary measure. This allows meaningful branch values to be displayed in your decision tree while alternative values are used for calculating payoffs. This type of tree is a special form of the Cumulative payoff calculation method, which uses a formula for an alternate calculation at the specified node.

The example workbook MODIFYING PAYOFFS WITH FORMULAS.XLS contains the branch value formula example described in this section.

Imagine, for example, that there are three branches from a chance node Barrels of Oil Found, with the values 0 barrels, 1000 barrels and 10000 barrels displayed in the tree. These branch values make clear what the possible outcomes are from the node, and are measured in units that are most relevant to the node, e.g. barrels. What should be used for payoff calculations, however, is a monetary value. This value can be calculated using a branch value formula for the node, which will convert the actual branch values into the monetary values that will be added to the payoff.

In the example file, the price of oil is listed in cell E6, which is named CostOfOil in Excel. This cell will be referenced in our branch value formula.

In this case, a simple branch value formula, =*BranchVal*CostOfOil*, is used at the Barrels of Oil Found node, to convert the displayed branch values to monetary units in the payoff calculations.
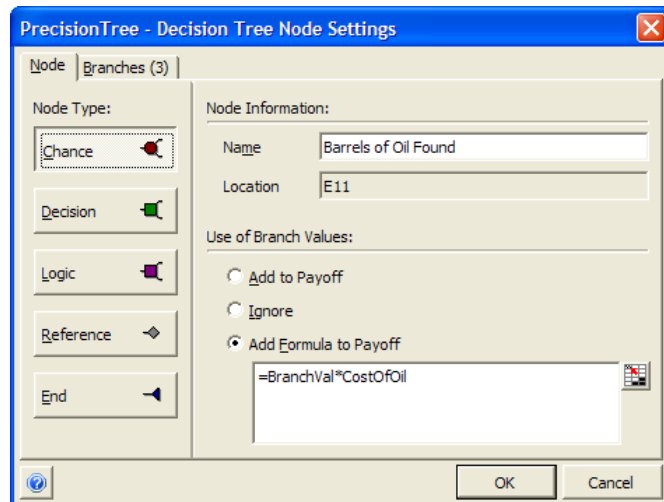
To view the entered branch value formula:

- **Click on the Barrels of Oil Found node in MODIFYING PAYOFFS WITH FORMULAS.XLS.** The Decision Tree Node Settings dialog box is displayed. The branch value formula is shown in the Use of Branch Values section under Add Formula to Payoff.

Tip: To keep the values for a node's branches out of payoff calculations entirely, select Ignore in the Use of Branch Values section.

Even though a branch value may not be directly used in payoff calculations, it still may be referenced by other formulas in the spreadsheet and included in formulas which calculate the value for other branches.

Payoff Formula Trees

Rather than using a simple Cumulative payoff calculation method, payoffs may also be calculated using more complicated payoff formulas by specifying the Payoff Formula calculation method for a tree. The calculation method for the tree is specified in the Model Settings dialog, in the Path Payoff Calculation Method on the Calculation tab.

> *The example workbook OIL - FORMULA.XLS contains the payoff formula example described in this section.*

End Node Payoff Formula

The Payoff Formula method allows end node payoff values to be calculated using a formula. This formula can reference the values and probabilities for branches on the path whose payoff is being calculated. A typical payoff formula would be:

=BranchVal("Price")*BranchVal("Sales Volume")-BranchVal("Costs")

When a payoff for a path is calculated using this formula, the value for the branch on the path from the node Price is multiplied by the value for the branch on the path from the node Sales Volume. Then, the value for the branch on the path from the node Cost is subtracted from the Price * Sales Volume value to give the payoff for the path.

A default payoff formula is entered in the Model Settings dialog box. This formula is automatically applied to each end node in the tree.
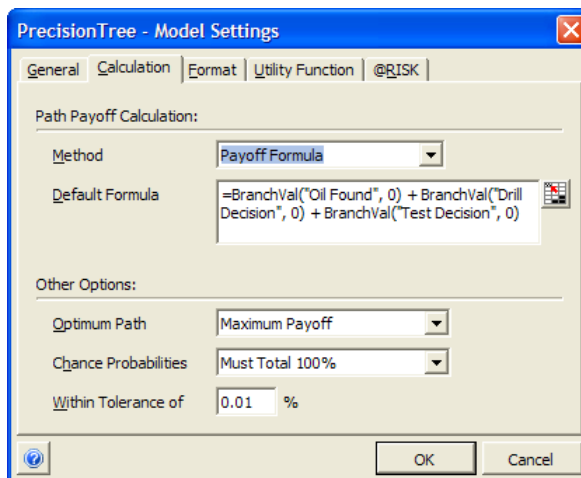
By clicking on an end node, however, the payoff formula for a specific path may be edited or changed as necessary. In the Decision Tree Node Settings dialog, under Path Payoff Calculations, select Use Alternate Formula and enter the appropriate formula for that path. (This selection only appears when Payoff Formula is selected on the Calculation tab of the Model Settings dialog for the decision tree.)
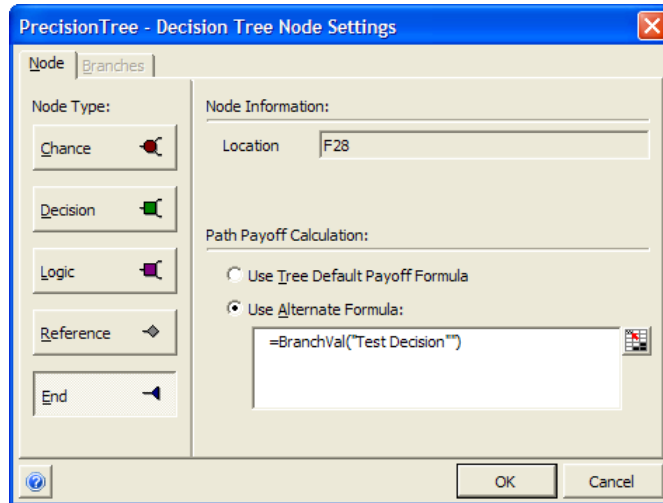
Two functions may be used in a payoff formula (in addition to any standard Excel function, operator or cell reference):

- **BranchVal("node name", missing value)**, which returns the value of the branch of the named node that was followed on the path. The second argument, missing value, is the value that should be used (often 0) if no node with that name exists on that path. An example formula is =BranchVal("Oil Found", 0), which returns the value associated with that branch of the node Oil Found, or else the value 0 if that node is not encountered on a particular path. If the payoff formula contains node names that are encountered on every path, the missing value argument is optional.

- **BranchProb("node name", missing value)**, which returns the probability of the branch of node name that was followed on the path. The second argument, missing value, is the value that should be used (often 0) if no node with that name exists on that path. If the payoff formula contains node names that are encountered on every path, the missing value argument is optional.

Linked Spreadsheet Trees

A decision tree is often built in conjunction with a detailed spreadsheet model that calculates the financial results of each decision option. The decision tree is good for displaying your possible options, but usually a standard spreadsheet model is better for calculating the numeric results of each option. Integrating these two formats in a Linked Spreadsheet tree is key to an effective decision analysis.

A decision tree defines all possible decision options and chance outcomes. In a tree, each possible sequence of events is represented as a path through the tree. At the end of each path is a payoff, or the value received if the sequence of events takes place. Many times, however, this payoff is best calculated by a model in traditional row and column spreadsheet format. This payoff model uses the values from the branches in the tree. But then it combines these values, along with other non-changing values, using Excel formulas to generate a result or payoff. In PrecisionTree, this linking of a decision tree to a payoff model is called a linked spreadsheet tree.

> *The example workbook OIL - LINKED TREE.XLS contains the linked tree example described in this section.*

A linked tree allows you to easily combine a decision tree with a standard Excel model. By using linked trees you combine the strength of the decision tree for illustrating sequences of possible options with the strength of the traditional spreadsheet model for calculating results. To examine a linked tree in action, open the model OIL – LINKED TREE.XLS located in the PRECISIONTREE5\EXAMPLES directory.

The model OIL – LINKED TREE.XLS shows the standard oil drilling model described in Chapter 3: Overview of PrecisionTree as a linked tree. A small Excel model is used to calculate the economic results from the oil drilling project. The branch values from the decision tree are linked to this Excel model to calculate payoffs at the end nodes for the tree.
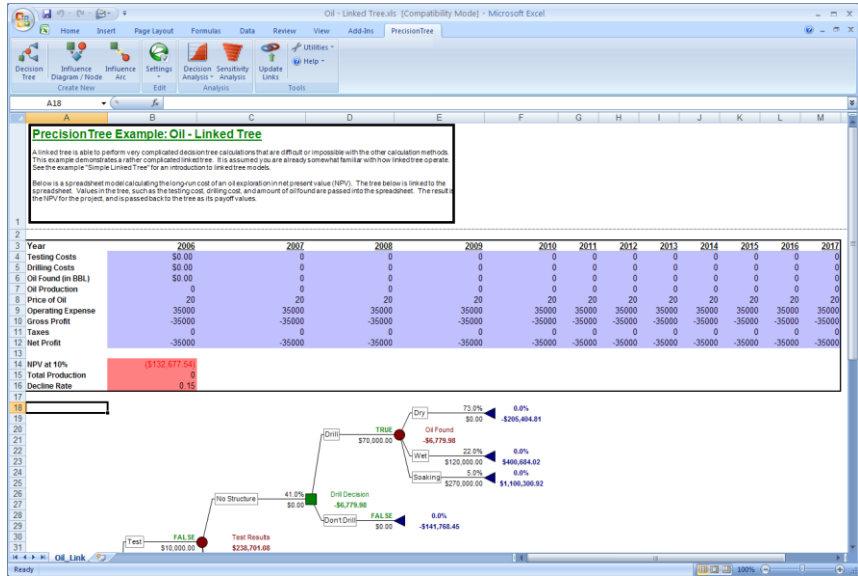
In the linked tree in OIL – LINKED TREE.XLS, the default location for end node payoff values is cell B14, next to the label NPV at 10%. The Drill Decision decision node is linked to cell B5, Drilling Costs. The branch values from this node (70000 and 0) will be placed in cell B6 as PrecisionTree calculates the payoff values of paths through the tree which include these branches. (If you click on the Drill Decision node, you will see in the Decision Tree Node Settings dialog box that the Drill Decision node is linked; the Link Branch Values To field specifies cell B5.)

The screen shown here displays the calculation of the linked model for the path through the tree which terminates at the third end node from the top. This end node displays the value 1100300.92. This path represents the sequence of events, or the scenario, when:

1) A Test is performed

2) No Structure is found

3) A Well is drilled, and

4) Oil Found is soaking.

When using a linked model, each possible path through the decision tree represents one scenario and one recalculation of the linked model. For example, to calculate the payoffs for a decision tree with 500 end nodes (i.e., 500 possible paths through a tree), the linked model will be recalculated 500 times with 500 different sets of branch values. When calculating the value of a path across the tree, PrecisionTree:

1) Inserts the value for each branch on the path into the cell or range specified for it.

2) Calculates the linked model (using the inserted values) to generate a new payoff value.

3) Returns this new payoff value at the end node for the path.

Tips for Using Linked Models

When using linked models, it may help to keep the following points in mind:

- **Check Your Linked Model's Calculation for the Shortest Paths Through the Tree.** Some paths through a tree terminate sooner than others. For example, in OIL – LINKED TREE.XLS, when a no drilling is performed, no values are placed in the linked model for Drilling Costs and Oil Found. This is because the Drilling Costs and Oil Found branches are not encountered when no drilling is performed.

  Make sure that your linked model calculates properly in these situations (so that correct results are generated even though fewer values are linked). In OIL – LINKED TREE.XLS, Drilling Costs and Oil Found are by default set to 0. This insures that short paths (such as those when no drilling is performed) calculate correctly.

- **Turn Off Link Updating.** The Path Payoff Calculation – Link Updating option in the Calculation Tab of the Model Settings dialog specifies whether or not PrecisionTree will automatically update end node payoffs in a linked tree each time the tree or linked model is edited. This option may be set to Manual when a large linked tree is being edited and the continued recalculations slow performance. When Link Updating is set to Manual, click the Update Links icon on the PrecisionTree toolbar to force all end node payoffs to be updated.

VBA Macro Trees

The VBA Macro calculation method allows you to calculate a decision tree using a VBA macro. To use this method, you must be able to write Excel VBA code. A simple example demonstrating the use of a VBA calculation macro is the example model OIL – VBA MACRO.XLS.

Steps to Create a VBA Macro Calculation Tree

In order to create a calculation macro you must perform several steps:

1. In the VBA editor window, create a new code module in the Excel workbook where your model resides.

2. Create a reference from the workbook to the "Palisade PrecisionTree 5.5 Object Library". This reference is made in the VBA editor from the Tools/References menu item. Check the appropriate item as shown below:
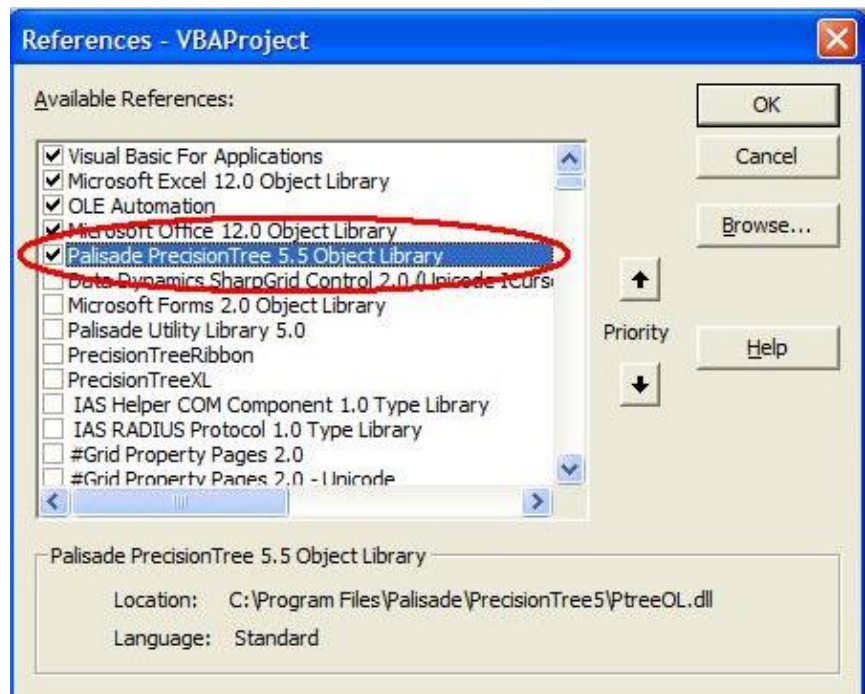
3. Create a public subroutine, with any valid VBA routine name, that takes a "paths" argument of type PTMacroPathCollection. For example, a routine with the name "MyCalcMacro" would have the prototype:

```
Public Sub MyCalcMacro(ByVal paths As
    PTMacroPathCollection)

        'Add calculation code here...

End Sub
```

Your custom calculation code will go in this routine, as described in the next section.

4. In the Model Settings dialog for the tree you wish to calculate using this macro, on the Calculation tab, specify the Path Payoff Calculation Method of "VBA Macro" and the name of the macro. For example, to us the macro defined above, the dialog would appear as:
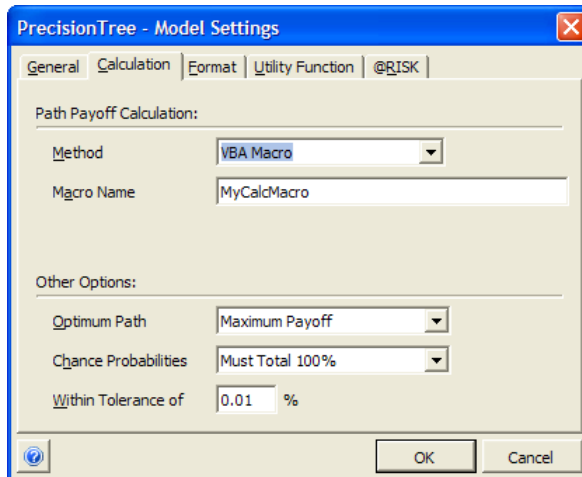
Writing the Macro

As described above, your macro must have the form:

```
Public Sub MyCalcMacro(ByVal paths As
    PTMacroPathCollection)

        'Add calculation code here...

End Sub
```

Within the body of your macro, you must enumerate through all the paths in the collection passed to it, and supply the payoff value associated with each path through the tree. If you neglect to assign a payoff value to one or more paths, your model will generate an error when calculated.

For example, a trivial macro that assigns a payoff value of 10 to each path in the model is:

```
Public Sub MyCalcMacro(ByVal paths As
    PTMacroPathCollection) Dim onePath As PTMacroPath

    For Each onePath In paths
        onePath.PayoffValue = 10

    Next

End Sub
```

Obviously, your own macros will be more complicated, and can make use of the full PrecisionTree 5.5 object model. This manual does not cover the PrecisionTree 5.5 object model in detail. However, PrecisionTree ships with a comprehensive help file PtreeOL5.chm which describes this object model in full. In particular, look at the documentation of the *PTMacroPathCollection* and *PTMacroPath* objects.

Note: Your macro is executed during Excel's recalculation cycle. Thus, the same restrictions that apply during an Excel recalculation apply to your macro. For example, you should not change cell values, add or remove sheets, cell, PrecisionTree objects, etc. If you attempt an invalid operation, your macro will fail.

Chapter 5: PrecisionTree Command Reference

Introduction

When the PrecisionTree add-in is loaded, a new toolbar and menu are created in Excel 2003 and earlier and a ribbon bar is created in Excel 2007. In addition, PrecisionTree creates a "context" menu that appears when you right-click on a PrecisionTree object in your model – such as a node or branch.

This chapter details the available commands as they appear on these PrecisionTree menus. The PrecisionTree toolbar icons can be used to perform many of the available commands. The PrecisionTree Icon Reference section of this chapter gives the command equivalents for each PrecisionTree toolbar icon.

How Toolbar Descriptions are Organized

Toolbar icons are displayed as they appear in the PrecisionTree toolbar. The following information is provided for each toolbar icon:

- Picture of icon
- Description of command
- Equivalent menu command

How Command Descriptions are Organized

Command descriptions are listed as they appear in the PrecisionTree menu. The following information (where applicable) is provided for each command:

- Description of command
- Equivalent toolbar icon
- Description of dialog boxes that appear
- Explanation of input boxes, options and command buttons included in dialog boxes

PrecisionTree Toolbar Icons

PrecisionTree icons are used to quickly and easily perform tasks necessary to set up and run decision analyses. PrecisionTree icons appear in a new Excel toolbar in Excel 2003 and earlier and a ribbon bar in Excel 2007. This section briefly describes each icon, outlining the functions they perform and the menu command equivalents for the icon. All of the commands also may be found in the PrecisionTree menu on the Excel menu bar.

PrecisionTree Ribbon in Excel 2007
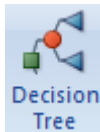
__Icon__	__Functions Performed and Command Equivalent__
Decision Tree	**Creates a new tree.**
Influence Diagram / Node	**Creates a new influence diagram or node.**
Influence Arc	**Creates a new influence diagram arc.**
Settings	**Edit model, node or arc settings.** *Equivalent to the right-click menu Model, Node or Arc Settings commands.*
Decision Analysis	**Runs a decision analysis on a decision tree or influence diagram.** *Equivalent to the right-click menuDecision Analysis menu Risk Profile or Policy Suggestion commands.*
Sensitivity Analysis	**Starts a sensitivity analysis on a cell.** *Equivalent to the right-click menuSensitivity Analysis command.*
Update Links	**Updates all payoff values for a linked decision tree or influence diagram.** *Equivalent to the right-click menu Update Model Links command.*
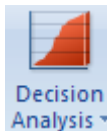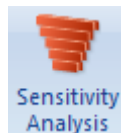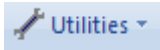
Utilities	**Displays PrecisionTree Utilites, including Find and Model Errors.**	
	Equivalent to the right-click menu Utilities menu commands.	
Help	**Displays PrecisionTree Help options.**	
	Equivalent to the right-click menu Help menu commands.	
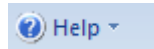
PrecisionTree Toolbar in Excel 2003 and Earlier

Icon	Functions Performed and Command Equivalent
	Creates a new tree.
	Equivalent to the New menu Decision Tree command.
	Creates a new influence diagram or node.
	Equivalent to the New menu Influence Diagram Node command.
	Creates a new influence diagram arc.
	Equivalent to the New menu Influence Diagram Arc command.
	Edit model, node or arc settings.
	Equivalent to the Edit menu commands.
	Runs a decision analysis on a decision tree or influence diagram.
	Equivalent to Decision Analysis menu Risk Profile or Policy Suggestion commands.
	Starts a sensitivity analysis on a cell.
	Equivalent to the Sensitivity Analysis command.
	Updates all payoff values for a linked decision tree or influence diagram.
	Equivalent to the Update Model Links command.
	Displays PrecisionTree Utilites, including Find and Model Errors.
	Equivalent to the Utilities menu commands.
	Displays PrecisionTree Help options
	Equivalent to the Help menu commands.

PrecisionTree Menu

Loading PrecisionTree creates a new toolbar and a new menu for working with decision trees and influence diagrams. The commands appear in a new menu labeled "PrecisionTree" which is added to the right of the existing menus displayed in the Excel menu bar in Excel 2003 and earlier. In addition, PrecisionTree creates "context" menus that appear when you right-click on a PrecisionTree object in your model, such as a node or branch.

Some of the icons on the PrecisionTree toolbar can be used to perform many of the commands described here. The section titled PrecisionTree Toolbar Icons provides the menu equivalents for each icon.
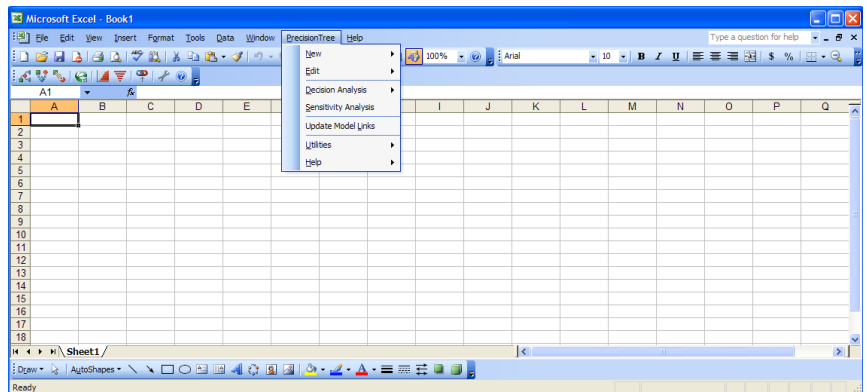
This section details the available commands as they appear in the PrecisionTree menu and PrecisionTree context menu.

New Menu

Decision Tree Command

Creates a new decision tree on the active worksheet.

The **New menu Decision Tree command** creates a new decision tree. After selecting the command or clicking the **Create New Decision Tree** icon, a tree is started at the cell the user selects in the worksheet. A new tree has a default name of *New Tree (n)* (where *n* is the current number of trees in the active workbook) and a single branch terminating in an end node.

When a new decision tree is created, the Model Settings dialog box is displayed, allowing you to enter the name of the model and specify other settings for the model.

To later change either the name of a decision tree or its settings:

- Click the box showing the tree name in your spreadsheet, or

- Click the **Edit icon** and select **Model Settings** or select the PrecisionTree **Edit menu Model Settings command**. (To be able to use the Model Settings command, the active cell of the Excel spreadsheet must be within the rectangle formed by the left-most, right-most, top and bottom nodes of the decision tree.)

Influence Diagram Node Command

Creates a new influence diagram or node on the active worksheet.

The **New menu Influence Diagram Node command** creates a new influence diagram node. If there is no influence diagram in the current worksheet a new diagram is created as well. A new diagram has a default name of *New Diagram (n)* (where *n* is the current number of diagrams in the active workbook). A new node is created by clicking the cursor at the position in the worksheet where the new node is desired.

When a new influence diagram is created, the Model Settings dialog box is displayed, allowing you to enter the name of the model and specify other settings for the model.

To later change either the name of an entire influence diagram or its settings:

- Click the box showing the influence diagram name in your spreadsheet, or

- Click the **Edit** icon and select **Model Settings**, or select the **Edit menu Model Settings** command. (To be able to use the Model Settings command, the active cell of the Excel spreadsheet must be within the rectangle formed by cell A1 and the right-most and bottom nodes of the influence diagram.)

Influence Diagram Arc Command

Creates a new influence diagram arc on the active worksheet.

The **New menu Influence Diagram Arc command** creates a new influence diagram arc between two nodes in the current influence diagram. Once you select the Influence Diagram Arc command, the Create New Influence Arc dialog allows you to select the nodes in the diagram that the arc will connect.
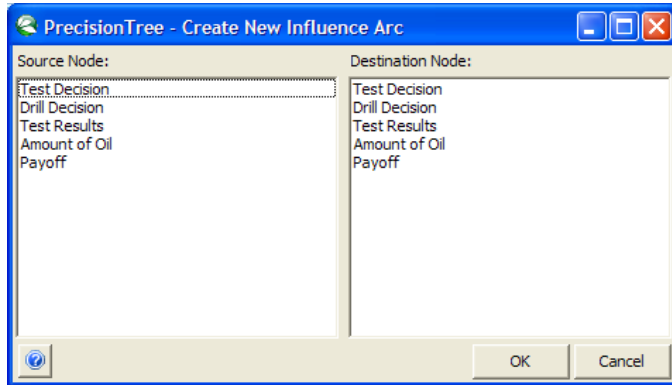
Once you select the Source and Destination nodes and click OK, the Influence Arc Settings dialog box is displayed. This allows you to specify the type of influence between the two nodes. For more information on types of influence, see the Edit menu Influence Arc Settings command in this chapter.

Edit Menu

Edits the settings for the selected model, node, branch or arc.

The Edit menu commands display the current settings for a model (decision tree or influence diagram), decision tree or influence diagram node, or influence diagram arc. The settings displayed depend on whether a decision tree, influence diagram, node, branch or arc is selected.

Displaying Settings by Selecting Items in a Worksheet

Settings can also be displayed by clicking on the object representing an item in a decision model in a worksheet. This is done as follows:

- For settings on a **decision tree**, click on the decision tree name shown at the root of the tree.

- For settings on an **influence diagram**, click on the influence diagram name shown at the top left of the worksheet which contains the diagram.

- For settings on a **decision tree or influence diagram node**, click on the name of the node in the decision tree or influence diagram.

- For settings on a **decision tree branch or influence diagram arc**, click on the branch or arc itself in the worksheet.

Displaying Settings with the Edit Icon

When the Edit icon is clicked or a PrecisionTree Edit menu command is selected, the settings are displayed for the model or node based on the current cell selection in the worksheet.

Model Settings Command

Displays the settings for the selected model (decision tree or influence diagram).

The available Model Settings include model name, payoff calculation options, path selection, number formats, utility function specification and @RISK options. These options are available on individual tabs in the Model Settings dialog.

To use the Model Settings command with a decision tree, the active cell of the Excel spreadsheet must be within the rectangle formed by the left-most, right-most, top and bottom nodes of the decision tree.

To use the Model Settings command with an influence diagram, the active cell of the Excel spreadsheet must be within the rectangle formed by cell A1 and the right-most and bottom nodes of the influence diagram.

Tip: to quickly access the Model Settings dialog box, just click on the name of the tree at the root of the decision tree, or the name of the influence diagram in the upper left corner of the spreadsheet.

General Tab – Model Settings Command

Displays general settings for the selected model.
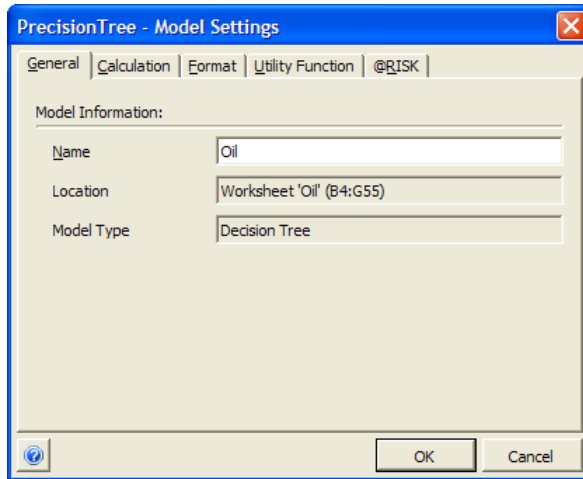
Options on the General tab of the Model Settings dialog box include:

- **Name**. The Name entry specifies the name that will be used to identify your model in the spreadsheet. This name is also used when selecting a model to analyze and for labeling reports and graphs.

Calculation Tab- Model Settings Command

Displays calculation settings for the selected model.

Options on the Calculation tab of the Model Settings dialog box include Path Payoff Calculation Method and Other Options.
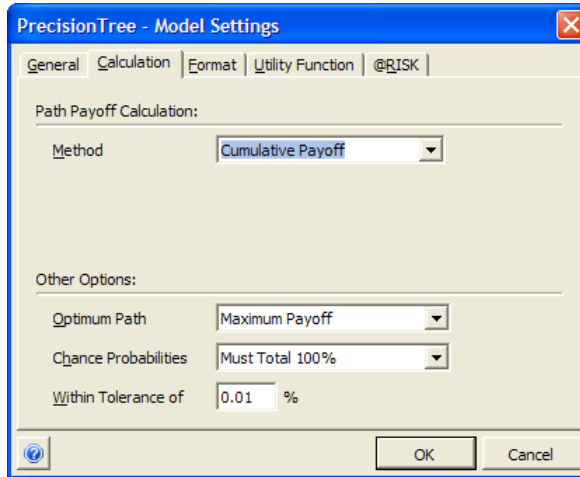
Path Payoff Calculation

Path Payoff Calculation Method specifies the calculation method to be used for calculating payoff values for each path through a model. For a decision tree, four options are available for payoff calculation – **Cumulative Payoff, Payoff Formula, Linked Spreadsheet** and **VBA Macro.** For an influence diagram, only the default **Influence Diagram** calculation method is available.

The Path Payoff Methods for decision trees are:

- **Cumulative Payoff** - The Cumulative method for payoff calculation is the simplest method for calculating the payoff values for each path through a decision tree. With the cumulative method, values for each branch on a path through a tree are simply added up in order to calculate the payoff value shown at the end node for the path. The branch values used can be modified with the cumulative payoff calculation options in the Decision Tree Node Settings dialog box for each node. For more information on these options, see Use of Branch Definition in the Edit menu Decision Tree Node Settings Command in this chapter.

- **Payoff Formula** - The Payoff Formula method for payoff calculation allows end node payoff values to be calculated using a formula. This formula can reference the values and probabilities for branches on the path whose payoff is being calculated. A typical payoff formula would be:

  =BranchVal("Price", 0)*BranchVal("Sales Volume", 0)-BranchVal("Costs", 0)

  When a payoff for a path is calculated using this formula, the value for the branch on the path from the node *Price* is multiplied by the value for the branch on the path from the node *Sales Volume*. Then, the value for the branch on the path from the node *Cost* is subtracted from the *Price * Sales Volume* value to give the payoff for the path.

  A default payoff formula is entered in the Model Settings dialog box. This formula is automatically applied to each end node in the tree. By clicking on an end node, however, the payoff formula for a specific path may be changed as necessary with the option Use Alternate Formula.

  Two functions may be used in a payoff formula (in addition to any standard Excel function, operator or cell reference):

  - **BranchVal("node name", missing value)**, which returns the value of the branch of node name which was followed on the path. The missing value is the number that should be used (typically 0) if no node with that name exists on that path. If the payoff formula contains node names that are encountered on every path, the missing value argument is optional. See the example file OIL – FORMULA.XLS for an illustration.

  - **BranchProb("node name", missing value)**, which returns the probability of the branch of node name which was followed on the path. The missing value is the number that should be used (typically 0) if no node with that name exists on that path. If the payoff formula contains node names that are encountered on every path, the missing value argument is optional.

- **Linked Spreadsheet**. The Linked Spreadsheet method for payoff calculation allows both branch and payoff values in a decision tree to be linked to cells in an Excel model that is external to the tree. By linking values, end node payoffs can be calculated by a detailed spreadsheet model.

In a linked tree, each node can be linked to an Excel cell reference or range name. When a linked tree is recalculated, branch values on each path in the tree are substituted into the designated cells in the Excel model and the payoff is calculated. End node payoffs are then taken from the cell specified as the location of the payoff value. See the example file OIL – LINKED TREE.XLS for an illustration.

For linked trees, two additional linked model settings are available – Link Updating and Default Cell.

- **Link Updating** specifies whether or not PrecisionTree will automatically update end node payoffs in a linked tree each time the tree or linked model is edited. This option may be set to Manual when a large linked tree is being edited and the continued recalculations slow performance. When Link Updating is set to Manual, click the Update Model Links icon on the PrecisionTree toolbar to force all end node payoffs to be updated.

- **Default Cell** specifies a default payoff cell reference or range name. This cell reference will initially be used for all newly created end nodes in the decision tree. The default payoff reference may be changed on an end node-specific basis when payoffs should be read in from a different cell for the linked tree.

- **VBA Macro.** The VBA Macro method for payoff calculation allows you to calculate a decision tree using a VBA macro. To use this method you must be able to write Excel VBA code. For more information, see the VBA Macro Trees section of Chapter 4: Modeling Techniques, and the example model OIL – VBA MACRO.XLS.

Other Options   **Other Options** on the Calculation tab of the Model Settings include:

- **Optimum Path**. Specifies the criteria PrecisionTree will use for selecting the optimum path at each node in the model. Two options are available for selecting the optimum path at each decision node in a model. If Maximum Payoff is selected, PrecisionTree will follow the path that has the highest expected value or utility at a decision node. If Minimum Payoff is selected, PrecisionTree will follow the path that has the lowest expected value or utility from a decision node.

- **Chance Probabilities.** Specifies how chance node probabilities are entered. Two options are available:
    - **Must Total 100%.** This specifies that the probabilities for a chance node add up to 100%, within the entered Within Tolerance of amount, or else an error message is displayed.
    - **Automatically Normalized**. PrecisionTree will normalize entered probability values for a chance node so they add up to 1. This was how branch probabilities were handled in earlier versions of PrecisionTree.

Format Tab - Model Settings Command

Displays number format settings for the selected model.
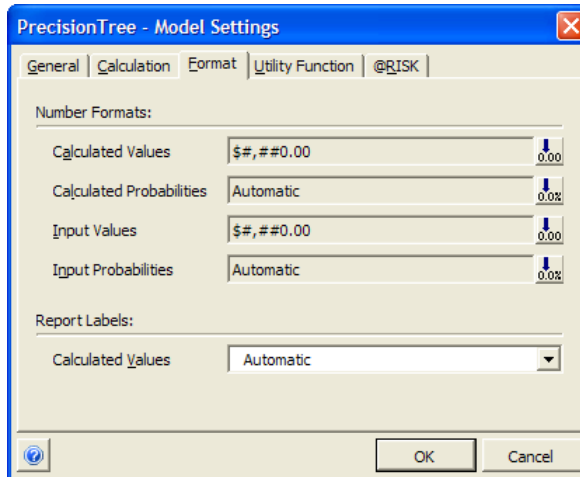
Number Formats options on the **Format Tab** of the Model Settings include:

- **Calculated Values**. Specifies the number formatting to be applied to calculated values in the model. These values are any that are calculated and returned by PrecisionTree, such as payoff values.

- **Calculated Probabilities**. Specifies the number formatting to be applied to calculated probabilities in the model. These probabilities are any that are calculated and returned by PrecisionTree, such as payoff probabilities.

- **Input Values**. Specifies the number formatting to be applied to input values (such as those entered by the user) in a model.

- **Input Probabilities**. Specifies the number formatting to be applied to input probabilities in a model.

The **Report Labels** option is:

- **Calculated Values.** This label will be given to calculated output values shown in PrecisionTree reports and graphs. This is useful for adding a descriptive label – such as *Project Profits* – to reports. **Automatic** specifies that PrecisionTree will automatically use labels from your model where necessary in reports. To use your own label, just enter the desired text in the Calculated Values field.

Utility Function Tab - Model Settings Command

Displays utility function settings for the selected model.

The Utility Function options in the Model Settings dialog box specify settings employed when utility functions are used in a decision model. A utility function converts a model's monetary payoffs into a different measure – expected utilities. This is done to include a decision maker's attitude toward risk in a decision analysis.

Utility functions are used because an individual's attitude towards risk can change a decision from that which would be chosen if only expected values are considered. In other words, the optimum decision may not be the one that maximizes expected monetary value when risk is taken into account.
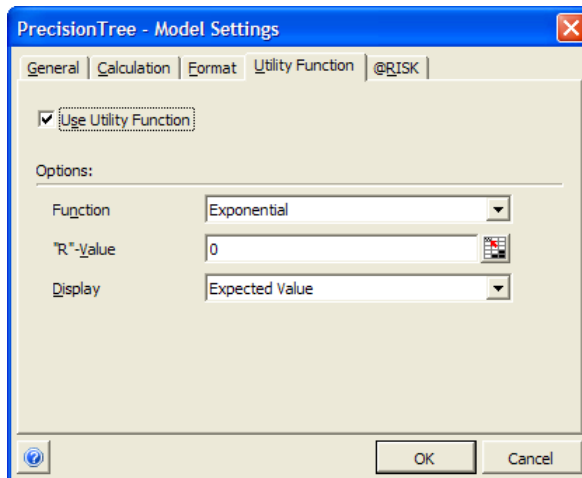
Options on the Utility Function tab of the Model Settings dialog include:

- **Use Utility Function**. Specifies using a utility function to convert the decision tree's monetary payoffs into expected utilities

- **Function**. Specifies the utility function to use – **Exponential**, **Logarithmic** or the **name of a custom utility function** you have defined in VBA that starts with the name UTILITY_.

- **"R" Value**. Specifies the R coefficient desired for the selected utility function. (The R value can be an Excel cell reference.)

- **Display.** Specifies the type of calculated value to be displayed in the tree and in reports for models that are using a utility function:

  - **Expected Value** displays calculated values in the tree as is normally done.

  - **Expected Utility** uses the specified utility function to calculate expected utilities and displays those values in the tree.

  - **Certainty Equivalent** calculates expected utilities and then converts those calculated values into monetary amounts that you would accept to avoid a risky decision.

Using Utility Functions

The utility function used, along with the entered R, or risk coefficient, describes the decision maker's attitude toward risk. In PrecisionTree, a utility function is selected on a tree-specific basis. For each tree, you may select a unique utility function and R coefficient.

PrecisionTree includes a predefined Exponential and Logarithmic utility function for your use. You can even define your own utility function using Excel's built-in programming language, VBA (Visual Basic for Applications). Once a utility function is selected, optimal paths in a decision tree will be selected using certainty equivalents instead of expected values.

To apply a utility function to a decision tree's calculations:

1) Click the check box **Use Utility Function**

2) Select an available Utility Function from the dropdown list or type in the name of your own custom utility function

3) Enter the R coefficient desired for the selected utility function

For more information about working with utility functions, see Appendix C: Utility Functions.

Defining Your Own Utility Function

PrecisionTree will recognize any public VBA function present in an open Excel file whose name starts with UTILITY_ as a valid user-defined utility function. For example, the function UTILITY_SQUAREROOT would be a valid utility function name. A second function whose name begins with INVERSE_, such as INVERSE_SQUAREROOT, must also be supplied. If you have defined a custom utility function, simply enter its name in the drop down list. For more information on defining your own utility functions, see the section **Custom Utility Functions** in **Appendix C: Utility Functions.**

@RISK Tab - Model Settings Command

Displays @RISK settings for the selected model.

@RISK is a Monte Carlo simulation add-in to Excel, available separately from Palisade or as part of the entire DecisionTools Suite. The @RISK tab options control how @RISK will recalculate during a Monte Carlo simulation of a decision tree or influence diagram. Two sets of options are available affecting 1) the type of recalculation performed during each iteration of the simulation and 2) how decisions can change during a simulation.
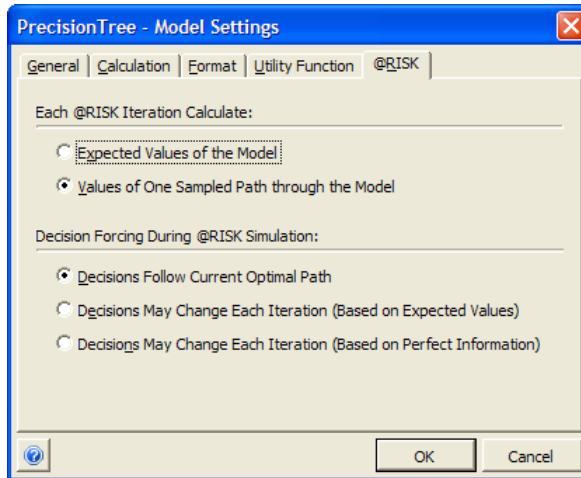
Each @RISK Iteration Calculate

Two options are available for recalculation during a simulation performed with @RISK:

- **Expected Values of the Model** causes @RISK to sample all distribution functions in the model and supporting spreadsheets with each iteration. Then, the model is recalculated using the new sampled values to generate new expected values. Typically the output from the simulation is the cell containing the expected value of the model. At the end of the run an output distribution which reflects the range of possible expected values for the model and their relative likelihood of occurrence is generated.

- **Values of One Sampled Path through the Model** causes @RISK to randomly sample a single path through the model with each iteration of a simulation. The branch to be followed from each chance node is randomly selected based on the branch probabilities entered. This method does not require that distribution functions be present in the model; however, if they are used, new samples are returned with each iteration and used in path value calculations. The output from the simulation

should be the cell containing the value of the model, such as the value of the root node of a decision tree. At the end of the run an output distribution reflecting the range of possible output values for the model and their relative likelihood of occurrence is generated.

Decision Forcing During Simulation options "force" PrecisionTree to select a specific branch from a decision node with each iteration of an @RISK simulation, overriding the automatic path selection normally performed by PrecisionTree. This keeps the optimum path for a decision node from changing when values for uncertain chance events following the node change during the simulation. Forced decisions keep the path selected from decision nodes exactly the same as was identified when the tree was analyzed using expected values.

Forced decisions can also be entered on a node-specific basis by using the Force option in the Branches tab of the Decision Tree Node Settings dialog. This would be done if you wanted to analyze a tree when a specific, and not necessarily optimal, decision is made at a specific node.

Three options are available for Decision Forcing During Simulation:

- **Decisions Follow Current Optimal Path** specifies that all decision nodes follow the path selected when the decision tree is calculated using expected values. With each iteration of a simulation the optimal decision for each decision node will not change.

- **Decisions May Change Each Iteration (Based on Expected Values)** allows all decision nodes in the simulated tree to follow, with each iteration, the optimum path as determined using the expected values that were calculated in that iteration. This calculation first finds the expected values of all chance nodes using the samples that were returned for distribution functions in that iteration. A path or branch is selected from each decision node using these chance node expected values.

- **Decisions May Change Each Iteration (Based on Perfect Information**) allows all decision nodes in the simulated tree to follow, with each iteration, the currently identified optimum path based on the value of branches selected from chance nodes. That is, a path or branch is selected from each decision node using the advance knowledge of each chance node branch's outcome. This allows decisions to change based on outcomes for uncertain future events, an occurrence that could never take place. However, this option lets you calculate the Value of Perfect Information; that is, the value of your model if you knew exactly what was going to occur in the future.

Note: The *Decisions May Change Each Iteration (Based on Perfect Information)* **option may only be used when the** *Each @RISK Iteration Calculate* **option is set to** *Values of One Sampled Path Through the Model.*

Decision Tree Node Settings Command

Displays settings for the selected decision tree node.

The **Edit menu Decision Tree Node Settings command** displays the current definition for the selected decision tree node. The settings available include node name, number of branches, the cell reference to link branch values to (linked trees only), branch definitions for the node, and, for end nodes, a payoff formula. Some of the options for Node Settings change depending on the type of node being defined.

A quick way to display the Decision Tree Node Settings dialog box is to click on the desired decision tree node. Alternatively you can use the Edit menu Decision Tree Node Settings command when the active cell is either the cell containing the name of the node or the cell containing the expected value of the node (located to the right of the node).

Node Tab - Decision Tree Node Settings Command

Displays general settings for the selected decision tree node.
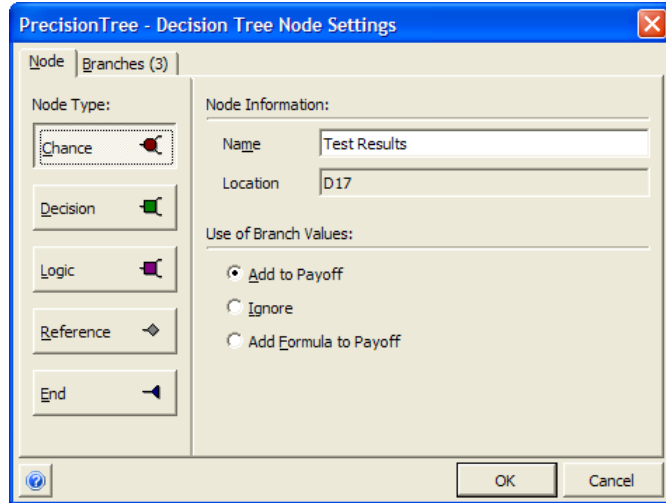
Options on the Node tab of the Decision Tree Node Settings dialog include:

- **Name.** The Name entry specifies the name that will be used to identify the node in the spreadsheet. This name can also be edited by typing the name directly in spreadsheet cell where the node name is displayed.

- **Node Type.** The **Node Type** selection changes the type of node used for the current node. The five available node types are:

    - **Chance** - a red circle representing an event with a set of possible outcomes over which the decision maker has no control.

    - **Decision** - a green square representing an event where the decision maker must choose one of a number of options.

    - **Logic** - a purple square representing an event similar to a decision node, except that the decision chosen (i.e., the branch followed) is determined by a logical formula assigned to each option. (A logical formula in Excel, such as =A10>1000, is a formula that returns either the value TRUE or FALSE.)

– **Reference** - a grey diamond representing a link to a set of events described in a separate decision tree or a sub-tree in the current tree.

– **End** - a blue triangle that represents the end point of a path through a decision tree.

A node's type may be changed at any time. Where applicable, branch values and probabilities will be retained when a node's type is changed.

Other options in the Node tab change depending on the Node Type selected and also the Calculation Method specified under Model Settings.

Use of Branch Values

The **Use of Branch Values** options specify how node values will be used in calculating path payoffs. This is used for Decision, Chance and Logic nodes in a model where the Model Settings Path Payoff Calculation option is set to Cumulative Payoff. The options available are:

- **Add to Payoff.** Simply adds the branch value to any path through it. For example, when a value of 100 is entered in the spreadsheet for a branch value, PrecisionTree will add 100 to the payoff value of any path through the tree which includes the branch.

- **Ignore.** Branch values for a node may be completely removed from cumulative payoff calculations by selecting the Ignore option. This is done when you wish to display a set of branch values in your decision tree to help portray the different decision or chance options, but ignore these values during cumulative payoff calculations.

- **Add Formula to Payoff.** In some cases you may wish to display a set of branch values in the spreadsheet but use different values in payoff calculations. This is done by selecting the **Add Formula to Payoff** option, and entering the desired formula. For example, there may be three branches from a chance node named *Daily Oil Well Production*, with the values 1000 barrels/day, 2000 barrels/day and 3000 barrels/day displayed in the spreadsheet. These branch values make clear what the possible outcomes are from the node and are measured in units that are most relevant to the node. What is used for payoff calculations, however, should be a monetary unit. In this case, a simple payoff formula:
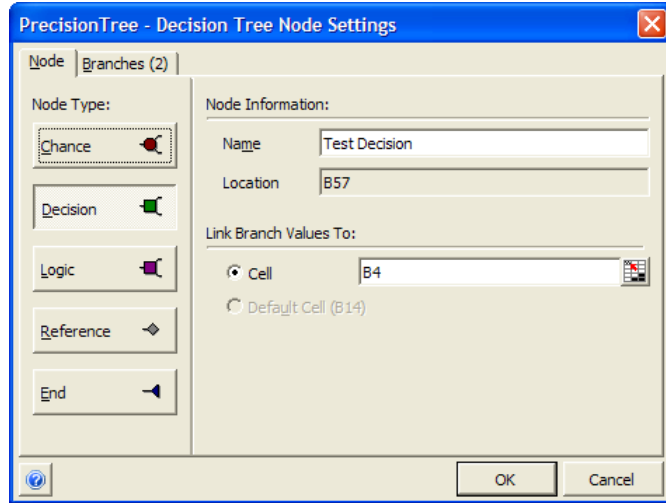
*=BranchVal*70*

where 70 is the price of oil per barrel. This would convert the displayed branch values to monetary units in the payoff calculations.

Link Branch Values To

The linked Cell specifies the cell reference to be linked with the current node in a linked decision tree. This option is used for Decision, Chance and Logic nodes in a model where the Model Settings Path Payoff Calculation option is set to Linked Spreadsheet.

When a linked tree is created, values for nodes are linked to cell references in an Excel model. For all node types, the Node Settings dialog box displays the **Link Branch Values To: Cell** option. For end nodes, the Node Settings dialog box also displays the **Default Cell** option showing the default linked cell which is used to return values to an end node payoff option.

How is Linking Performed?

A linked tree calculates end node payoffs by placing branch values in designated locations in an Excel spreadsheet model. For branches from Decision, Chance and Logic nodes, the branch values for the node are inserted in the cell specified with the linked Cell option. For end nodes, the value calculated in the cell specified in the linked Cell option (usually the linked Default Cell of the model) is returned to the end node.

When calculating the value of a path through the tree, PrecisionTree inserts the value for each branch on the path into the cell specified for it. A new payoff (using the inserted values) is then calculated by Excel and returned to the end node for the path. See the example file SIMPLE LINKED TREE.XLS for an illustration of linked trees.

Reference Options

For reference nodes, the **Reference Options** specify the location of the tree or sub-tree that the node references.

Two options are available for referencing trees -- **Node of this Tree** or **Other Tree**. **Node of this Tree** is a sub-tree that begins at another node in the tree where the reference node is located. **Other Tree** refers to a unique decision tree with its own start node. Enter a cell reference by clicking on the cell containing the node's name or value. Note: when referencing another decision tree, both trees must have the same Path Payoff Calculation method (in the Model Settings dialog).

Path Payoff Calculation

The Path Payoff Calculation specifies whether to use the **Default Payoff Formula** or an **Alternate Formula** when calculating payoff values in a formula tree. This option is used for End nodes in a model where the Model Settings Path Payoff Calculation option is set to Payoff Formula.

Branches Tab - Decision Tree Node Settings Command

Displays branch information for the selected decision tree node.
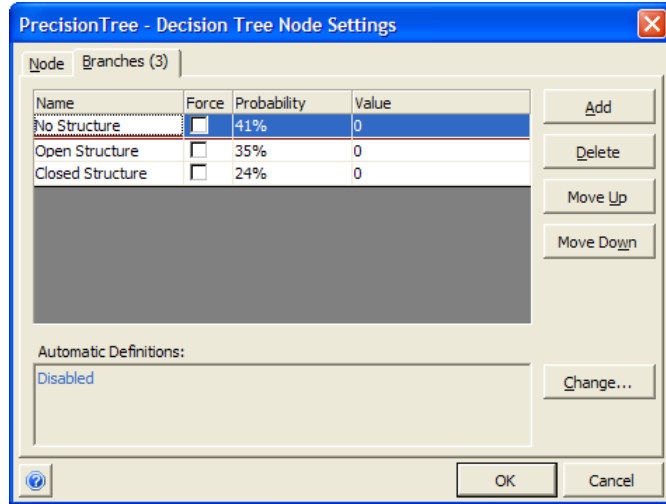
Names, values and probabilities for branches may be edited in the displayed table. Changes made are not applied to your decision tree until the Node Settings dialog is exited.

Options on the Branches tab of the Decision Tree Node Settings dialog include:

- **Add.** Adds a new branch to the displayed table.
- **Delete.** Deletes the selected branch from the displayed table.
- **Move Up or Down.** Changes the position of the selected branch. The double line in the table represents the location of the node. In the tree, branches above the line will be shown above the node in the tree, and branches below the line will be shown below the node.
- **Force.** This checkbox in the displayed table is used to force this branch to be followed regardless of what PrecisionTree has determined would be the optimum path. When forced, the path is shown in red and all calculated values in the model are updated to show that the forced branch is always used. Forcing a branch is especially useful when a sequence of events represented in the tree has already occurred and you know the outcomes that have taken place.

- **Automatic Definitions.** Clicking the **Change** button displays the Automatic Definitions dialog where Automatic Definitions can be defined for the branches for a node.
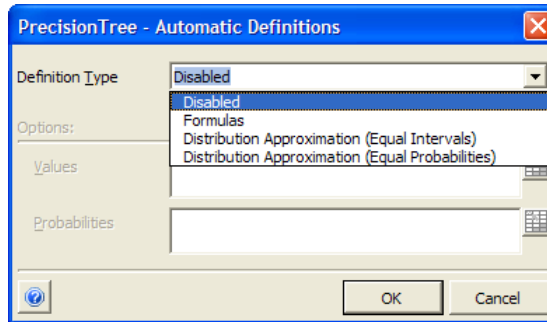
For a Chance node, PrecisionTree can automatically determine branch probabilities using a probability distribution function you specify. This is called a Distributed Chance Node. It is used when you want branch probabilities to follow the relative shape of the probabilities described by a continuous probability distribution.

Select the desired probability distribution from the Definition Type dropdown list in the Automatic Definitions dialog. For each of the displayed distribution types, you enter a set of distribution arguments to define the distribution PrecisionTree will use to calculate branch probabilities. These distributions use the same nomenclature and syntax as Palisade's @RISK software.

Options for a distributed chance node include:

- **Distribution Approximation (Equal Intervals).** This option creates equally spaced "bins" across the maximum and minimum range of the distribution you specify. The number of bins is the number of branches originating from the chance node. It then calculates the probabilities associated with these bins, and normalizes them to unity. The midpoints of these bins become the chance node's branch values, while the normalized probabilities become the branch probabilities. If a distribution is asymptotic (in other words there is no finite minimum or maximum value) then the minimum value is where the cumulative distribution function reaches 1% and the maximum value is where the cumulative distribution reaches 99%.

- **Distribution Approximation (Equal Probabilities).** This option divides 100% by the number of branches to get the probability for each branch. To determine the corresponding values, the cumulative distribution function is divided into equally sized "bins" of probability. The value associated with each branch is the corresponding midpoints of each of these bins.

- **Formula.** For Decision, Chance and Logic nodes, a user defined formula can be used to quickly assign branch values and probabilities for all branches from the current node. The formula can be any standard Excel formula and can include any valid Excel function, cell reference or operator. In addition, custom keywords can be used to change the value the formula calculates by branch. For example, using the custom **BranchNum** entry (for a branch number), a formula can calculate a value that changes by branch. For example, the value formula:

    *=BranchNum*1000*

    would automatically enter the value of 1000 in the top branch from a node, 2000 in the second, 3000 in the third and so on.

Custom Keywords Available for Branch and Payoff Formulas

A set of custom keywords are available that can be embedded in formulas for branch value, probability and payoffs. Some of these keywords are only available for certain formulas. For example, the *BranchVal* keyword cannot be used in a formula which defines branch value. The available keywords include:

- **BranchNum** - the number of the branch for which the formula is being evaluated. Branch numbers start at the top branch (1) and increase with each additional branch.

- **BranchVal** - the value of the branch for which the formula is being evaluated. (Branch Probability and Payoff Formula only)

- **BranchProb** - the probability of the branch for which the formula is being evaluated. (Branch Value and Payoff Formula only)

- **TotalBranches** - the total number of branches from the node

Note: Any valid Excel formula notation can be used in a branch formula.

Influence Node Settings Command

Displays the settings for a selected influence diagram node.

The **Edit menu Influence Node Settings** command displays the settings for the selected influence diagram node. The settings available include node type, node name, number and names of outcomes, and an option to display the value table for the node.

Node Tab - Influence Node Settings Command

Displays general settings for the selected influence diagram node.
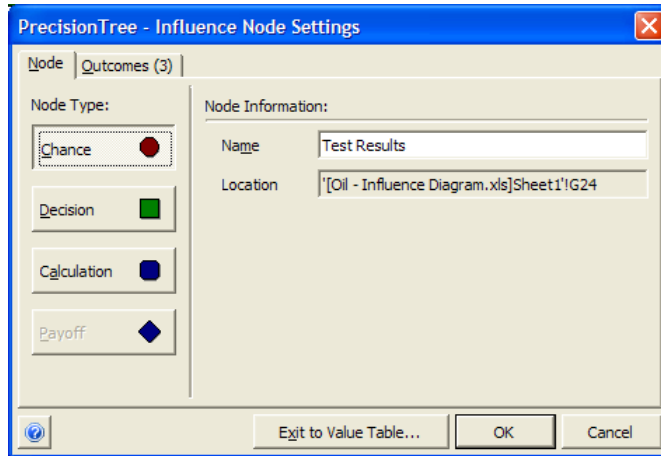
Options on the Node tab of the Influence Node Settings dialog include:

- **Node Type.** The **Node Type** icon changes the type of node used for the current influence diagram node. A node's type may be changed at any time. Where applicable, outcome names, values and probabilities will be retained when a node's type is changed. The four available node types are:

    - **Chance** - a red circle representing an event with a set of possible outcomes over which the decision maker has no control.

    - **Decision** - a green square representing an event where the decision maker must choose one of a number of options.

    - **Calculation** - a blue rounded rectangle representing a calculation that takes values from predecessor nodes and combines them using formulas to generate new values. There is no uncertainty or different options associated with a calculation node.

    - **Payoff** - a blue diamond representing the final payoff calculation or result from the model.

- **Name.** The Name entry specifies the name that will be used to identify the node in the spreadsheet. This name can also be edited by clicking on the current node name in the node symbol.

Outcomes Tab - Influence Node Settings Command

Displays outcome names for the selected influence diagram node.
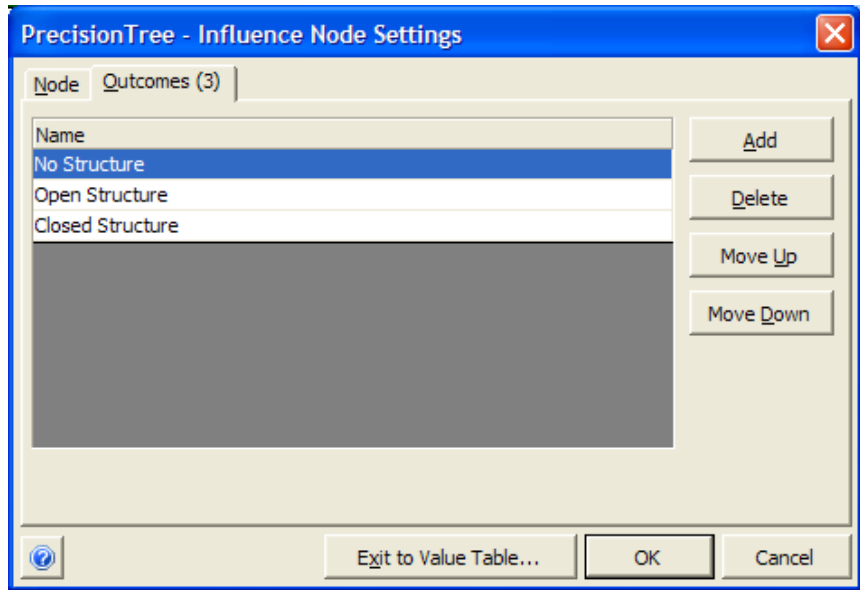
Outcome names for the selected influence diagram node are entered or edited in the table on the Outcomes tab. Options on the Outcomes tab of the Influence Node Settings dialog include:

- **Add.** Adds a new outcome to the displayed table.
- **Delete.** Deletes the selected outcome from the displayed table.
- **Move Up or Down.** Changes the position of an outcome. The order of the outcomes determines the order of branches when an influence diagram is converted to a decision tree.

Influence Arc Settings Command

Displays the settings for a selected influence diagram arc.

PrecisionTree allows three types of influence to be specified for an arc between nodes in an influence diagram - **Value**, **Timing** and **Structure**. Clicking on an arc in an influence diagram displays the Influence Arc Settings dialog which allows you to specify the type of influence that the predecessor node has on the successor node.
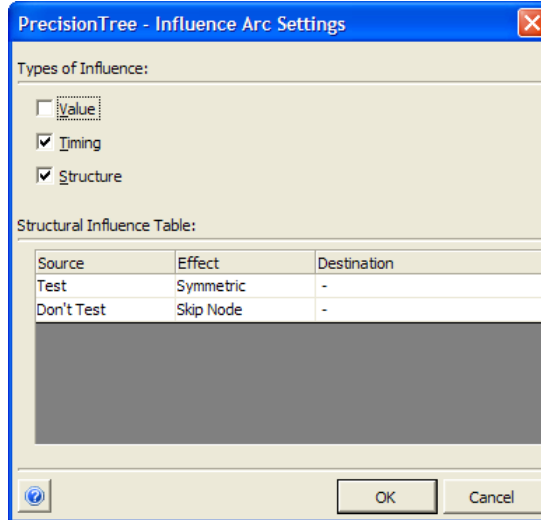
Depending on the type of node used for the predecessor and successor nodes, and the influence that exists between them, you may be required to select multiple types of influence. For example, a chance node which influences the values of a decision node also must influence the timing of the decision node; that is, the chance event must precede the decision.

The type of influence selected is shown in the type of arc displayed in an influence diagram, as follows:

A **solid black line** indicates a **value** influence, and a **dashed line** indicates that there is **no value** influence.

A **filled arrowhead** indicates a **timing** influence, and an **unfilled arrowhead** indicates that there is **no timing** influence.

A **dashed line (no value** influence**)** with an **unfilled arrowhead (no timing** influence**)** indicates a **structure**-only influence.

Types of Influence	The types of influence options are:

- **Value Influence**. A Value influence specifies that the values for the successor node will be influenced by the outcomes of the predecessor node. If the successor node is a decision node, only values can be influenced; if it is a chance node, both values and probabilities can be influenced.

  When a Value influence exists you enter different values at each successor node outcome for each predecessor node outcome. For example, examine the case where a predecessor chance node Price has two outcomes, Low and High. This node has a Value influence on a chance node Sales Volume that has three possible outcomes, Low, Medium and High. Because of the Value influence, at each Sales Volume outcome you will enter a value and probability for each of the predecessor node Price levels.

  All arcs entering a calculation node must have a value influence. This is because a calculation node by definition combines the values of outcomes from predecessor nodes to calculate new values. No new outcomes or uncertainty are associated with calculation nodes.

- **Timing Influence.** A Timing influence specifies that the arc between two nodes in an influence diagram implies timing; that is, the predecessor node always occurs prior to the successor node in time. When a node has a Timing influence on another, the predecessor node will be placed prior to (i.e., to the left) of the successor node in a decision tree created from the influence diagram.

- **Structure Influence**. Structure influence specifies that the structure of the outcomes of the successor node is affected by the outcome of the predecessor node. Structure influence is specified by outcome of the predecessor node, i.e. each possible outcome of the predecessor node can have an influence on the type of outcomes that occur for the successor node.

  With a Structure influence, successor node outcomes can be forced or skipped depending on the outcome that occurs for the predecessor node. For example, in a Price - Sales Volume influence (where Price is the predecessor node and Sales Volume is the successor node), a Low Price may force the High Sales Volume outcome to occur.

Structure influence can be used to convert influence diagrams into "asymmetric" decision trees, or trees where all the possible branches (as specified by all possible outcomes defined in the influence diagram) are not drawn. Asymmetric trees are quite common. The Oil Drilling example described in the chapter Overview of PrecisionTree is an asymmetric tree, as the decision Don't Test, followed by the decision Don't Drill, does not have the same node and branch structure as the section of the tree where the decision is made to Test.
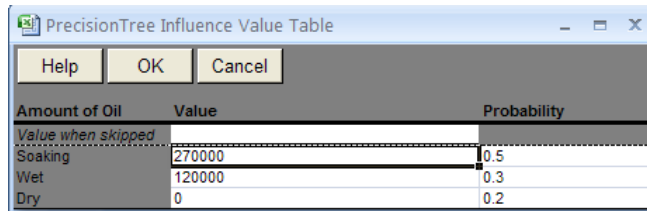
Structure Influence Options

The following types of structure influence can be specified for an outcome of the predecessor node on the outcomes of the successor node. When you select structure influence in the Influence Arc Settings dialog, you describe the type of structure in the **Effect** column of the **Structural Influence Table**.

- **Symmetric** - this is the default where no structural influence exists. If the specified outcome occurs and symmetric is selected, all outcomes of the successor node are possible. In a converted decision tree, all branches from the successor node will be shown when the path identified by the specified outcome is followed.

- **Skip Node** - indicates that all outcomes for the successor node should be skipped if the specified outcome occurs. In a converted decision tree, the successor node will not be included when the path identified by the specified outcome is followed.

- **Goto Payoff** - indicates that all subsequent nodes and outcomes will be eliminated if the specified outcome occurs. In a converted decision tree, the path identified by the specified outcome will terminate at an end node.

- **Force** - indicates that a specific outcome for the successor node will occur if the specified outcome for the predecessor node occurs. The outcome for the successor node is selected from the Destination Outcome entry in the table.

- **Eliminate** - indicates that a specific outcome for the successor node will be eliminated if the specified outcome for the predecessor node occurs. The outcome to be eliminated from the successor node is selected from the Destination Outcome entry in the table.

Influence Value Table Command

Displays the value table for the selected influence diagram node.

The **Edit menu Influence Value Table command** displays the Value table for an influence diagram node. The Value table can also be displayed by right-clicking on an influence diagram node and selecting **Influence Value Table**. A Value table is used to enter the values for the possible outcomes for the node (and, for a chance node, probabilities of those outcomes). A value is entered for each possible combination of values of the predecessor, or influencing, nodes.

Value tables are standard Excel spreadsheets and can include values, formulas and cell references (refer to the Name Box in the Excel toolbar for cell references in the Value table). Values and formulas can reference both other cells in the displayed value table (including the outcomes shown for predecessor cells) and other cells in open worksheets. Standard Excel commands for copying values and formulas can be used in a value table.

By entering a reference in a formula to a cell where an outcome's name is located, you are instructing PrecisionTree to use the values for the selected outcome when generating the appropriate value in the Value table.

The **Model Settings dialog Calculation tab Chance Probabilities option** specifies how chance node probabilities are entered. If Automatically Normalized is selected, PrecisionTree will normalize entered probability values for a chance node so they add up to 1. This was how branch probabilities were handled in earlier versions of PrecisionTree.

Options in the Influence Value Table include:

- **Value When Skipped**. The Value When Skipped entry specifies the value to use for the node in payoff calculations when the node is skipped due to the structure influence of arcs coming into the node. For example, in an influence diagram of an oil drilling model, the *Amount of Oil* node will be skipped when the outcome of the *Drill Decision* node is *Don't Drill*. In this case the *Value When Skipped* for *Amount of Oil* is 0, and 0 would be used in the payoff calculation formula *Amount of Oil-Cost of Testing-Cost of Drilling*. The *Value When Skipped* is in effect a "default" value for the node; in many cases, it is zero but it also may be non-zero if necessary.

Payoff Node Values

For Payoff nodes, formulas can be used to combine values for influencing nodes to calculate node values. As with other types of nodes, these formulas are standard Excel formulas and can reference outcome values listed in the Value table or other cells in open worksheets (refer to the Name Box in the Excel toolbar for cell references in the value table).

In the example above, the formula for the Payoff node sums the Amount of Oil, Test Decision and Drill Decision cells. In the Value table above, the first cell sums the values for Dry, Drill and Test outcomes (cells D4, E4 and F4 in the Value table where the labels Dry, Drill and Test are located). By entering a reference in a formula to a cell where an outcome's name is located, you are instructing PrecisionTree to use the values for the shown outcome when generating the Payoff value. This formula can then be copied to the other value cells, just like other Excel formulas. All cell references are automatically updated by Excel.

Decision Tree Node Context Menu

A popup menu is displayed when a decision tree node is right-clicked. This menu includes additional commands to add branches and copy, paste and delete subtrees.
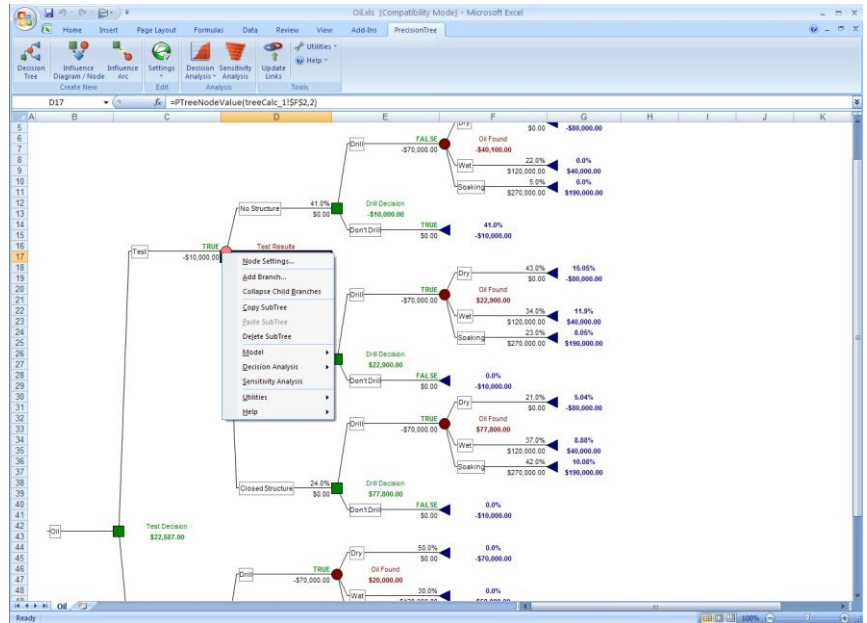
Add Branch Command

Adds a branch to the selected decision tree node.

The Decision Tree Node Context Menu Add Branch command adds a branch to the current node. Prior to adding you can name the branch.

Collapse/ Expand Child Branches Commands

Collapses or expands all branches and successor nodes that follow a node.

The **Collapse Child Branches** and **Expand Child Branches** commands allow you to collapse all branches and successor nodes that follow a node, or expand collapsed branches and nodes. Collapsed branches and successor nodes may also be expanded by clicking the + symbol shown next to a node.

Copy/ Paste/ Delete Sub-tree Commands

Copies, pastes or deletes a sub-tree that follows a node.

The **Copy SubTree, Paste SubTree** and **Delete SubTree** commands allow you to copy, paste or delete a sub-tree, or all branches and successor nodes that follow a node. Pasting a sub-tree replaces any current branches and successor nodes that follow a node.

Decision Tree Branch Context Menu

A popup menu is displayed when a decision tree branch is right-clicked. This menu includes additional commands to rename or move a branch and to force the selection of branches.
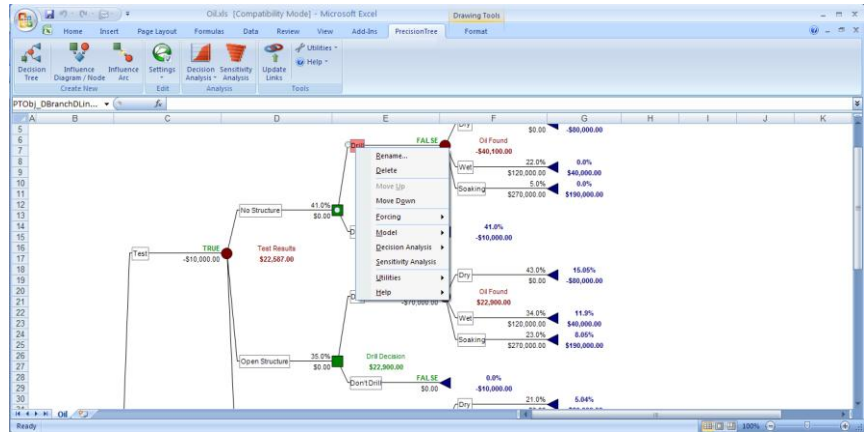
Rename Command

Renames a branch from a decision tree node.

The Decision Tree Branch context menu **Rename** command allows you to rename the selected branch.

Move Up/ Move Down Commands

Repositions the selected branch among all the branches from the current node.

The **Move Up** and **Move Down** commands allow you to change the position of a branch.

Force and Unforce Branch Command

Forces or unforces the selected branch from the current node.

The **Force Branch** command "forces" PrecisionTree to use the selected branch from a node. When forced, the branch is shown in red and all calculated values in the model are updated to show that the forced branch is always used.

Force Path Command

Forces or unforces the path in the tree prior to the selected branch along with the branch itself.

The **Force Path** command "forces" PrecisionTree to use the selected path in the tree, up to and including the selected branch. When forced, the path is shown in red and all calculated values in the model are updated to show that the forced branch is always used. Forcing a path is especially useful when a sequence of events represented in the tree has already occurred and you know the outcomes that have taken place.

Force All Decisions Command

Forces all decisions in the tree to the optimal decisions.

The **Force All Decisions** command "forces" PrecisionTree to use the branch from each decision node which represents the optimal decision. When forced, the path is shown in red and all calculated values in the model are updated to show that the forced branches are always used.

Clear All Forcing Command

Removes all branch forcing from the entire decision tree.

Influence Diagram Context Menus

Similar to the decision tree context menus, popup menus are displayed when influence diagram components, such as a node, arc or the name of an influence diagram, are right-clicked. These menus include commands to access node and arc settings, rename nodes, delete nodes and arcs, and more.
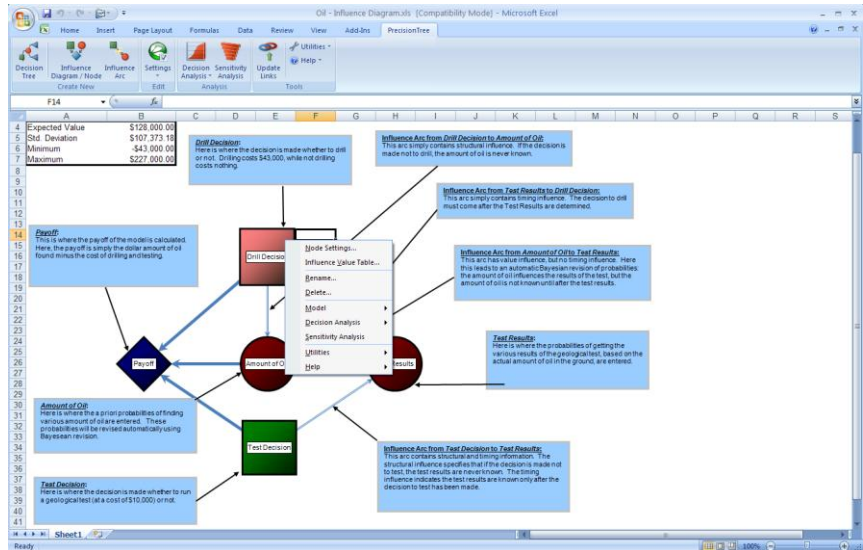
Convert to Decision Tree Command

Converts an influence diagram into a decision tree.

The Influence Diagram context menu **Model – Convert to Decision Tree** command allows you to convert an influence diagram into a decision tree.
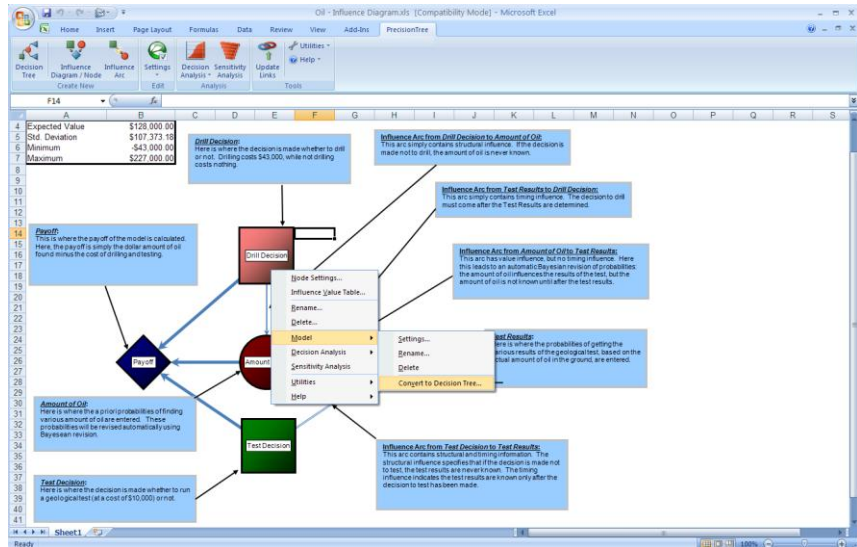
Decision Analysis Menu

Risk Profile Command

Performs a decision analysis on a decision tree or influence diagram.

The **Decision Analysis menu Risk Profile command** runs a complete decision analysis on the selected model. During an analysis, PrecisionTree determines every possible path value and the probability associated with each. These results are used to construct a distribution function called a risk profile.

When the Risk Profile command is selected, or the Decision Analysis icon is clicked and Risk Profile is selected, a dialog box appears, prompting the user for the name of the model to analyze and the name of the starting node (for decision trees or sub-trees) of the model to analyze.
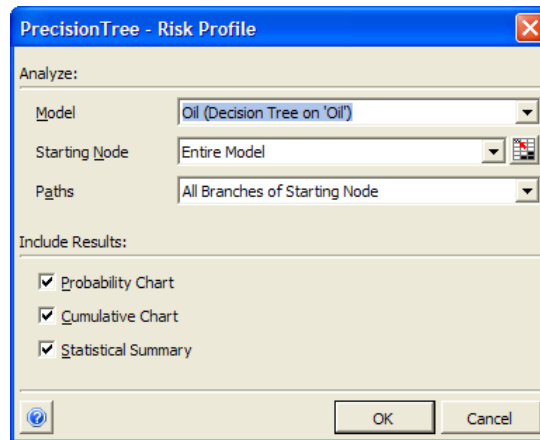

The **Analyze** options in the Risk Profile dialog box include:

- **Model**. Selects the model to be analyzed from all available models in the active workbook.

- **Starting Node**. Selects the starting node for the analysis; only applies to decision trees or sub-trees. If the default **Entire Model** is selected, the entire decision tree or influence diagram is analyzed. If an individual node is selected, the analysis is done on that node's value, using the subtree with all paths from that node onward. Note: if the Risk Profile command is selected through the popup menu shown when a node is right-clicked on, the Starting Node defaults to the selected node.

- **Paths**. Controls whether the analysis will be performed on only the optimal path through the model, or if all choices of an initial decision will be analyzed and compared (only applies to decision trees that start with a decision node).

The **Include Results** options in the Risk Profile dialog box include:

- **Probability Chart.** Selects to create a report with a Risk Profile Probability chart.

- **Cumulative Chart.** Selects to create a report with a Risk Profile Cumulative Probability chart.

- **Statistical Summary.** Generates a statistical summary report of the decision analysis.

Risk Profile Probability Chart

The Decision Analysis menu Risk Profile command generates a graph of the model's risk profile. The risk profile graph displays each possible end node payoff and the probability of each payoff occurring. Each line of the graph shows the probability that the payoff will equal a certain value. If your tree begins with a decision node, PrecisionTree analyzes each possible decision from the node and overlays the risk profile for each on the same graph.
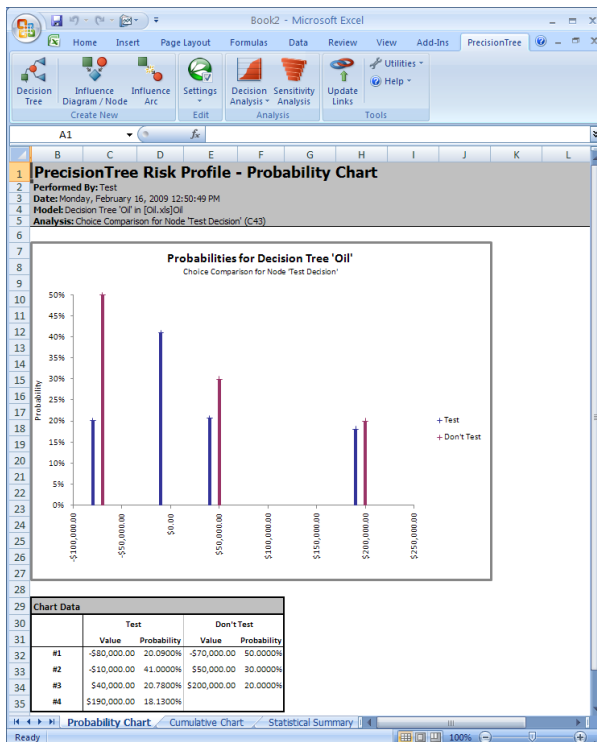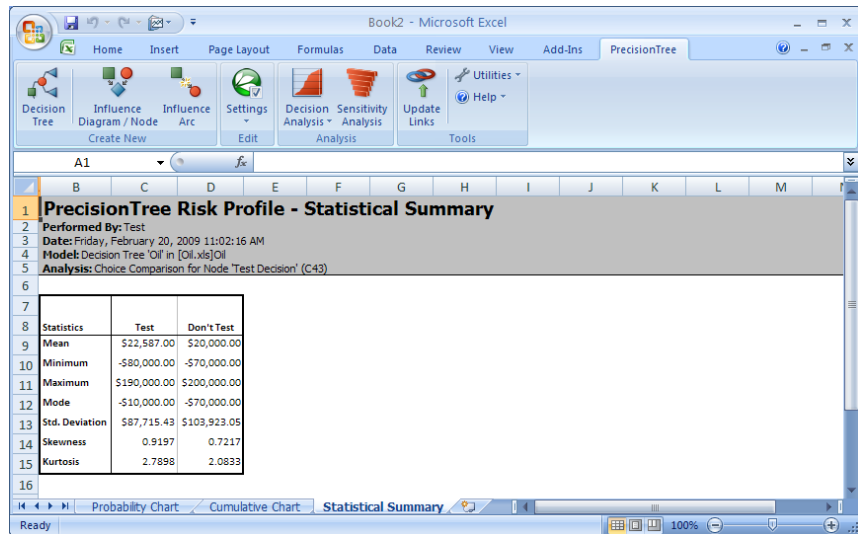
The Decision Analysis menu Risk Profile command generates a graph of the model's cumulative risk profile. If your tree begins with a decision node, PrecisionTree creates a risk profile cumulative chart for each possible decision from the node. This graph displays a cumulative distribution showing the probability of any payoff less than or equal to a certain value. The graph is created as an Excel chart and can be customized using any of Excel's chart formatting commands.
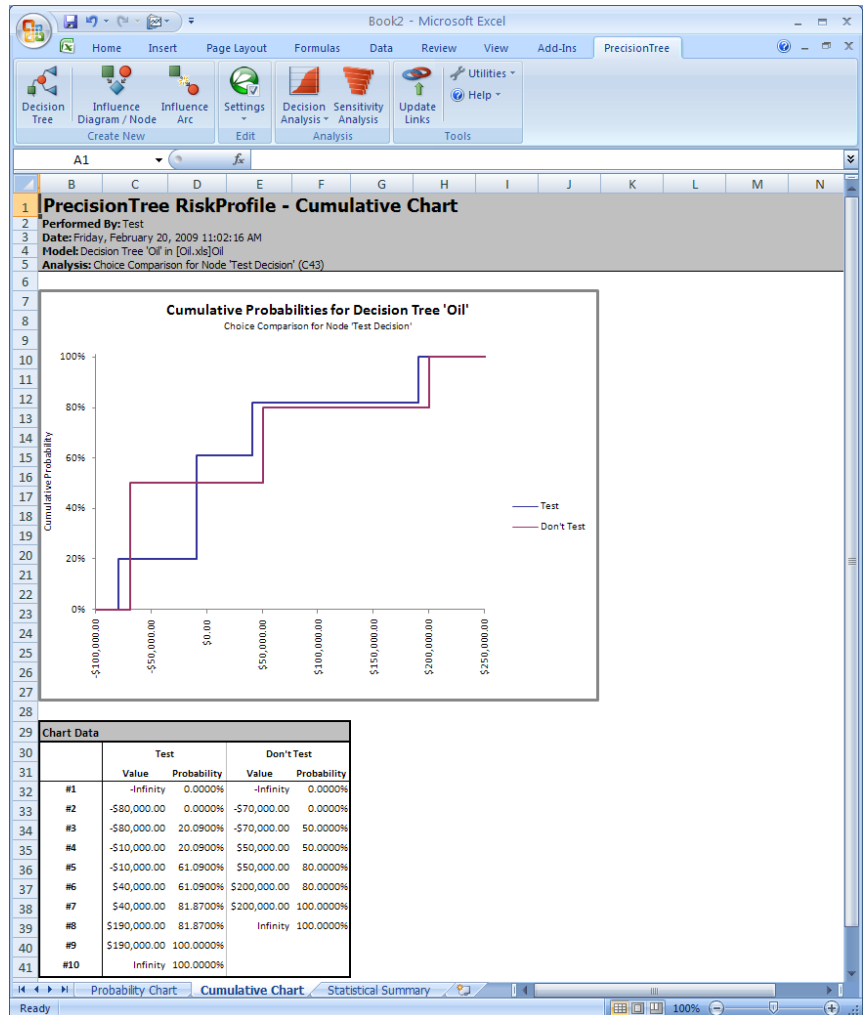
The Decision Analysis menu Risk Profile command generates a statistical report after the analysis is run. The report displays general statistics for the decision model, including mean, standard deviation, etc. If your Starting Node is a decision node and the Paths option is set to **All Branches of Starting Node**, PrecisionTree will analyze each possible decision from the node.

Policy Suggestion Command

Performs a decision analysis on a decision tree to generate a Policy Suggestion report.

The **Decision Analysis menu Policy Suggestion command** generates a policy suggestion for the selected model. This feature shows which option was chosen at each node, illustrating the optimal path in a reduced version of your decision tree, along with a decision table identifying the optimal decisions by node.

When the Decision Analysis menu Policy Suggestion command is selected, or the Decision Analysis icon is clicked and Policy Suggestion is selected, a dialog box appears, prompting the user for the name of the model to analyze and the name of the starting node of the model to analyze.
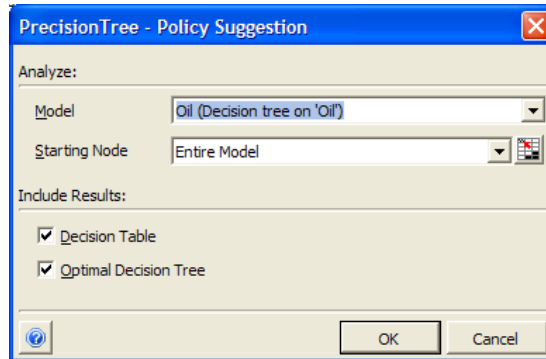
The **Analyze** option in the Policy Suggestion dialog box includes:
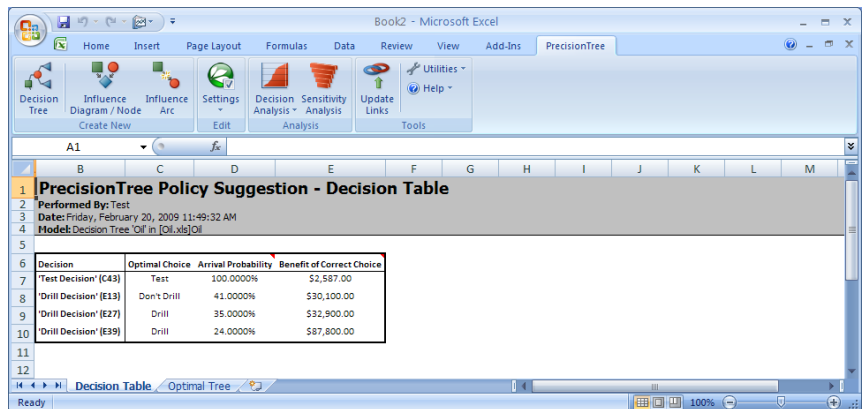
- **Model**. Selects the model to be analyzed from all available models in the active workbook.

- **Starting Node.** Selects the starting node for the analysis. If the default Entire Model is selected, the entire decision tree is analyzed. If an individual node is selected, the analysis is done on that node's value, using the subtree with all paths from that node onward. Note: If the Policy Suggestion command is selected through the popup menu shown when a node is right-clicked on, the Starting Node defaults to the selected node.

The Include Results options in the Policy Suggestion dialog box include:

- **Decision Table.** Creates a report showing the optimal decisions by node and the benefit associated with making the best choice for each decision.

- **Optimal Decision Tree.** Generates a reduced version of the decision tree showing only the nodes that possibly can be encountered along the optimal path.

Policy Suggestion Decision Table

The **Policy Suggestion Decision Table** identifies the optimal choice to be made at each decision node encountered on the optimal path. In addition to the **Optimal Choice**, the **Arrival Probability** (or the probability of reaching the listed node) and the **Benefit of Correct Choice** (or the value associated with making the correct choice at the node) are also shown.

Policy Suggestion Optimal Decision Tree

The **Policy Suggestion Optimal Decision Tree** displays a reduced version of the decision tree showing only the nodes that can be encountered on the optimal path.

Sensitivity Analysis Command

Performs a sensitivity analysis on a decision model.

The **Sensitivity Analysis command** runs a sensitivity analysis on a decision model. The goal of a sensitivity analysis is to identify which inputs in your model have the most effect on your results. In a sensitivity analysis, the values in selected Inputs are changed and the effect of that variation on the value of the Output is recorded. One cell may be varied at a time (a "one-way" sensitivity analysis) or two cells may be varied together (a "two-way" sensitivity analysis). The reports generated by a sensitivity analysis include tornado graphs, spider graphs, one-way and two-way sensitivity analysis graphs, and strategy region graphs.

When the Sensitivity Analysis command is selected or the Sensitivity Analysis icon is clicked, the Sensitivity Analysis dialog box appears, prompting the user for the type of analysis as well as information on the Output to be analyzed. In addition, **Inputs** to be included in the analysis can be entered and desired reports and graphs specified.

Analysis Type	The Analysis Type option specifies whether a **One-Way** or **Two-Way** sensitivity analysis will be performed. In a one-way sensitivity analysis, one or more Inputs are changed across their Minimum-Maximum range. For each new value tested for the Input, a new value for the Output is calculated. In a two-way sensitivity analysis, two Inputs are changed simultaneously and each possible combination of values for the two cells is tested. The effect of each combination on the Output is recorded.
Output	The **Output** section specifies the type of value and model to be analyzed, along with the starting node in the model for the analysis. Output options include:

- **Type of Value.** Either the result of a model as a whole (i.e., the value of the selected starting node) or an individual spreadsheet cell may be selected as an output for the sensitivity analysis.

- **Model**. Selects the model to be analyzed from all available models in the active workbook.

- **Starting Node**. Selects the starting node for the analysis. If the default Entire Model is selected, the entire decision tree or influence diagram is analyzed. If an individual node is selected, the analysis is done on that node's value, using the sub-tree with all paths from that node onward. Note: If the Sensitivity Analysis command is selected through the popup menu shown when a node is right-clicked on, the Starting Node defaults to the selected node.

Inputs

The **Inputs** section identifies the cell(s) to change in the sensitivity analysis and the values to test for those cells. Any number of Inputs may be tested in a single sensitivity analysis. When a two-way sensitivity analysis is run, two of the Inputs are varied at the same time. The Inputs table shows the cells to be varied along with a summary of the variation defined for each.

Options in the Inputs section include:

- **Add.** Adds a new input for the sensitivity analysis. For information on adding inputs, see the section **Sensitivity Input Definition Dialog** later in this chapter.

- **Edit.** Displays a previously defined input in the Sensitivity Input Definition dialog for editing.

- **Delete.** Deletes a previously defined input.

Check boxes displayed next to each input select either the inputs to include in the One-Way sensitivity analysis or the input to display on the X-axis and Y-axis of graphs from a Two-Way sensitivity analysis.

Include Results   The **Include Results** section specifies the type of reports and graphs to be generated by the sensitivity analysis. These options change depending on whether a One-Way sensitivity analysis or Two-Way sensitivity analysis is selected. Include Results options for a One-Way sensitivity analysis include:

- **Sensitivity Graph.** This graph displays a line graph showing the change in output value as an input value is varied

- **Strategy Region Graph.** Displays how the value of the each possible initial decision of the model changes at each value tested in a one-way sensitivity analysis. The output must be the value of a decision node for this analysis to be performed.

- **Tornado Graph.** This graph summarizes the effect of each input on the output, with bars showing the output change caused by each input.

- **Spider Graph**. This graph summarizes the effect of each input on the output, with a line showing the output change caused by each input.

Include Results options for a Two-Way sensitivity analysis include:

- **Two-Way Sensitivity Graph.** This 3-D graph displays the change in output value at each tested combination of input values.

- **Strategy Region Graph**. Shows regions where different decisions are optimal given changes in two selected inputs. This graph is only generated when the output is the value of a decision node.
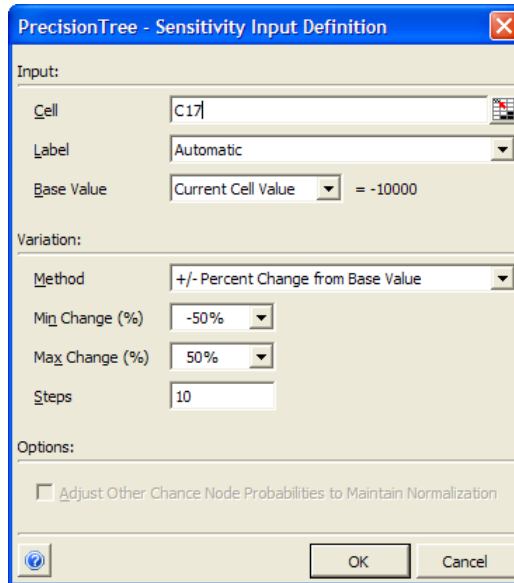
Options   The **Options** section includes:

- **Report Output in Terms of Percent Change From Current Value.** Displays sensitivity graphs in terms of percent change from current value for the output, as opposed to actual change in value.

- **Display Calculations During Analysis.** Causes PrecisionTree to update the display in Excel as it calculates values during a sensitivity analysis.

Sensitivity Input Definition Dialog

The **Sensitivity Input Definition** dialog is used to identify the cells to change in the sensitivity analysis and the values to test for those cells. This dialog is displayed when the **Add** or **Edit** button is clicked in the **Inputs** section of the **Sensitivity Analysis** dialog.

Options in the **Input** section of the Sensitivity Input Definition dialog include:

- **Cell.** Specifies the reference of the input value to be varied in the sensitivity analysis. You can click on the Select Excel Reference icon to jump to the spreadsheet and select the desired cell.

- **Label.** Specifies the label to be used to identify the input. **Automatic** specifies that the label will be taken from the name of a node or branch associated with the input or from labels for the cell in your worksheet. Alternatively, you can create your own label by entering it directly in the Label field.

- **Base Value.** Specifies the base value to be used for the input before varying (i.e., the value the input will take during the analysis when it is not being varied). **Current Cell Value** specifies that the base value will be the cell's current value; alternatively any other base value may be entered.

Options in the **Variation** section of the Sensitivity Input Definition dialog include:

- **Method.** Selects the type of variation from the Base Value as detailed in Min Change and Max Change. Options are:

  - **+/- Percent Change from Base Value,** where the entered **Min Change** and **Max Change** are percentage reductions or increases in the Base Value. This option cannot be used if your input has a base value of 0.

  - **+/- Actual Change from Base Value,** where the entered **Min Change** and **Max Change** are actual reductions or increases from the Base Value.

  - **Actual Min and Max,** where the entered **Min** and **Max** are actual minimum and maximum values for the range of possible values for the input.

- **Minimum** or **Min Change**. Specifies the minimum value to use for the selected Input, using the selected **Method** of variation.

- **Maximum** or **Max Change**. Specifies the maximum value to use for the selected Input, using the selected **Method** of variation.

- **Steps.** Specifies the number of steps or intervals to test across the entered minimum-maximum range for the selected Input. During a sensitivity analysis, the entered minimum-maximum range is divided by the # of Steps entered and the Input value at each step is calculated. This value is then placed in the Input and a new value for the Output is calculated.

Sensitivity Analysis on Probabilities

The **Adjust Other Chance Node Probabilities to Maintain Normalization** option is available when you are defining a sensitivity input that is a probability value for a chance node. When you conduct a sensitivity analysis on a probability, other probabilities for the node need to be adjusted when the input's value is changed. This allows probabilities for all branches for the node to total 100%, even though the input probability was increased or decreased.

For example, assume there are four branches from a chance node, each with a 25% probability value. One of these probability values is selected as a sensitivity input, with a minimum possible value of 20% and a maximum possible value of 30%. During the sensitivity analysis, when the input's probability value is decreased by 5% to 20%, each of the other branches has their probability increased by 1.6667% (3 x 1.6667% = 5%, or the amount of probability subtracted from the input). *Note: When you are defining a sensitivity analysis*

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*input that is a probability value, only the **Actual Min and Max** method of variation is available.*

Results of a One-Way Sensitivity Analysis

When PrecisionTree runs a one-way sensitivity analysis, the following graphs and reports are generated:

One-Way Sensitivity Graph

This graph is a simple line graph displaying values for the Output at each value tested for an Input. A one-way sensitivity graph is generated for each Input specified for the sensitivity analysis. The graph is created as an Excel chart and can be customized using any of Excel's chart formatting commands.
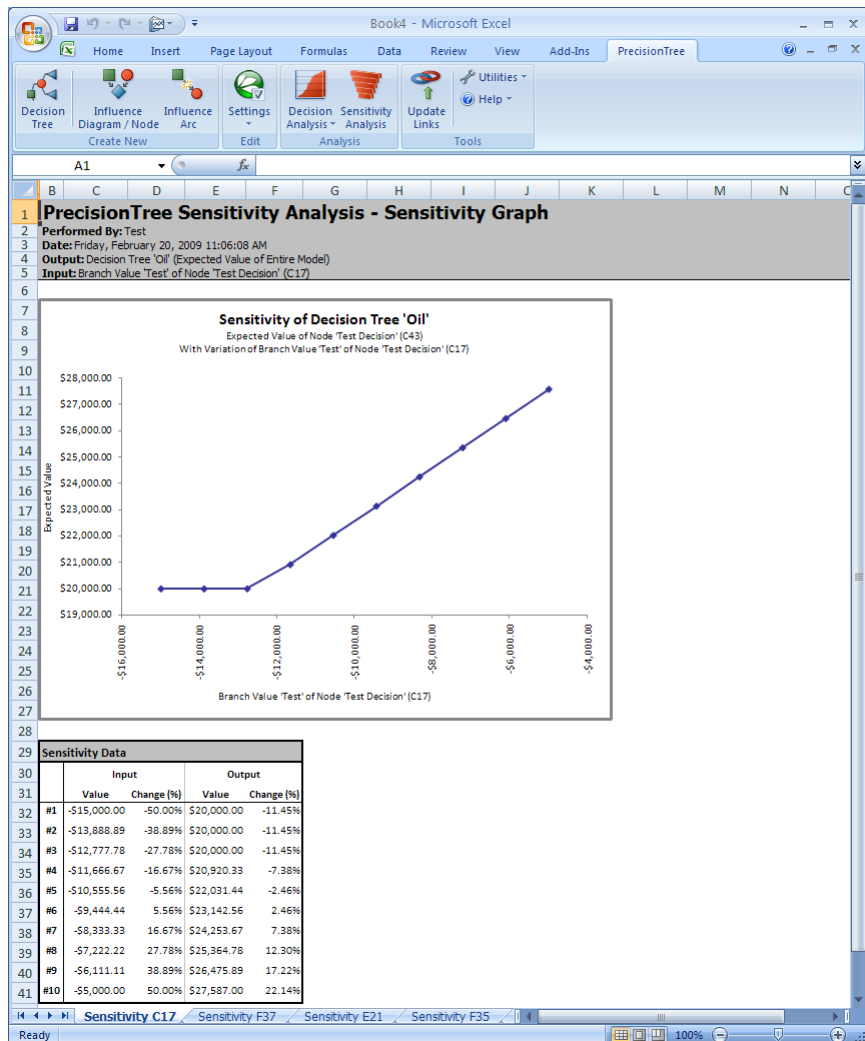
One Way Strategy Region Graph

A one-way strategy region graph displays the results of each possible initial decision at each value tested in a one-way sensitivity analysis The Output must be the value of a decision node for this analysis to be performed.
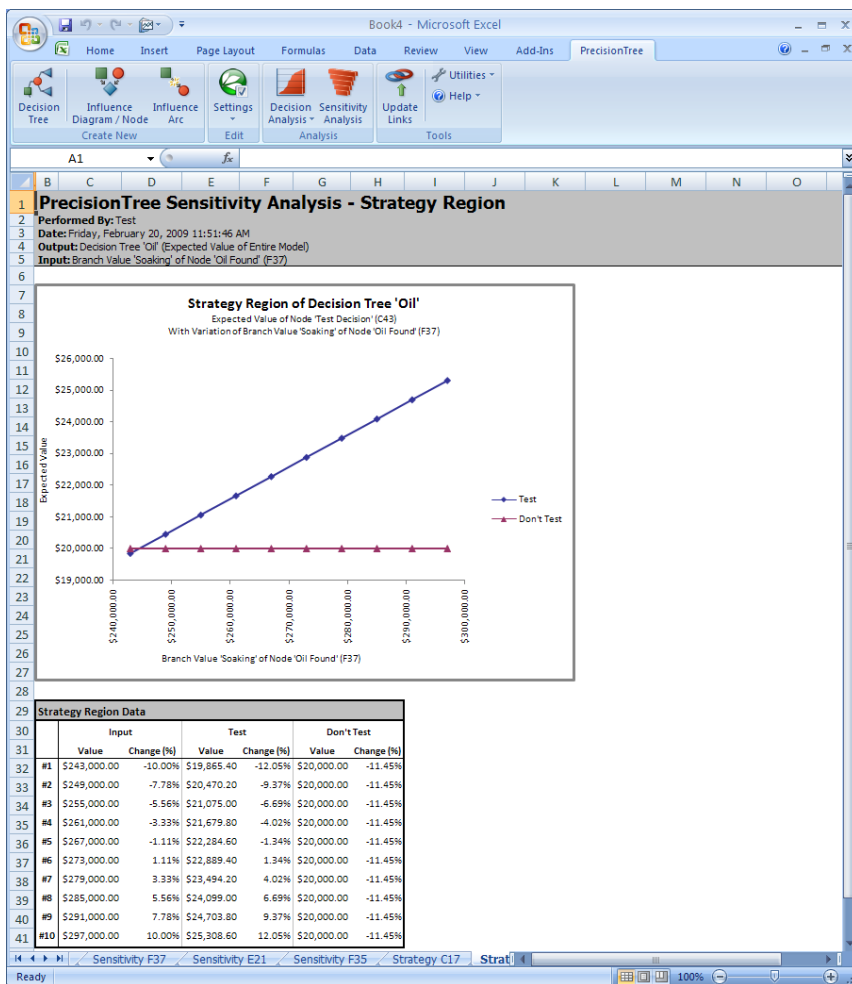
Tornado Graph   A single tornado graph is created for a one-way sensitivity analysis. This graph summarizes the effect of each Input on the Output. A bar in the tornado graph is created for each Input, and you must have at least 2 Inputs to generate this graph. This bar shows the total change in the Output which was caused by varying the Input. The longer the bar, the greater the impact of the Input on results, and thus the more significant that input is in your model. The diagram is created as an Excel chart and can be customized using any of Excel's chart formatting commands.
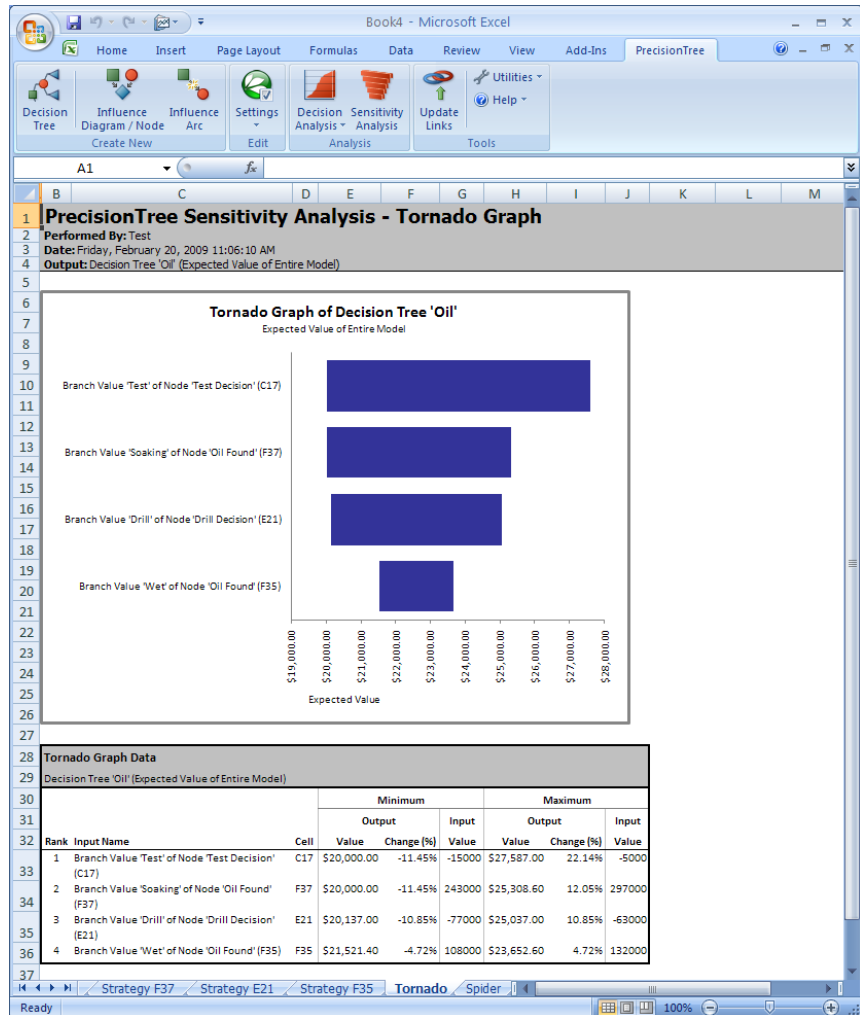
Spider Graph   A single spider graph is created for a one-way sensitivity analysis. This graph summarizes the effect of each Input on the Output. A line in the graph is created for each Input, and you must have at least 2 Inputs to generate this graph. Each line shows the change in the Output over the range of the corresponding Input's values. The steeper the line, the greater the impact of the Input on results, and thus the more significant that Input is in your model. The diagram is created as an Excel chart and can be customized using any of Excel's chart formatting commands.
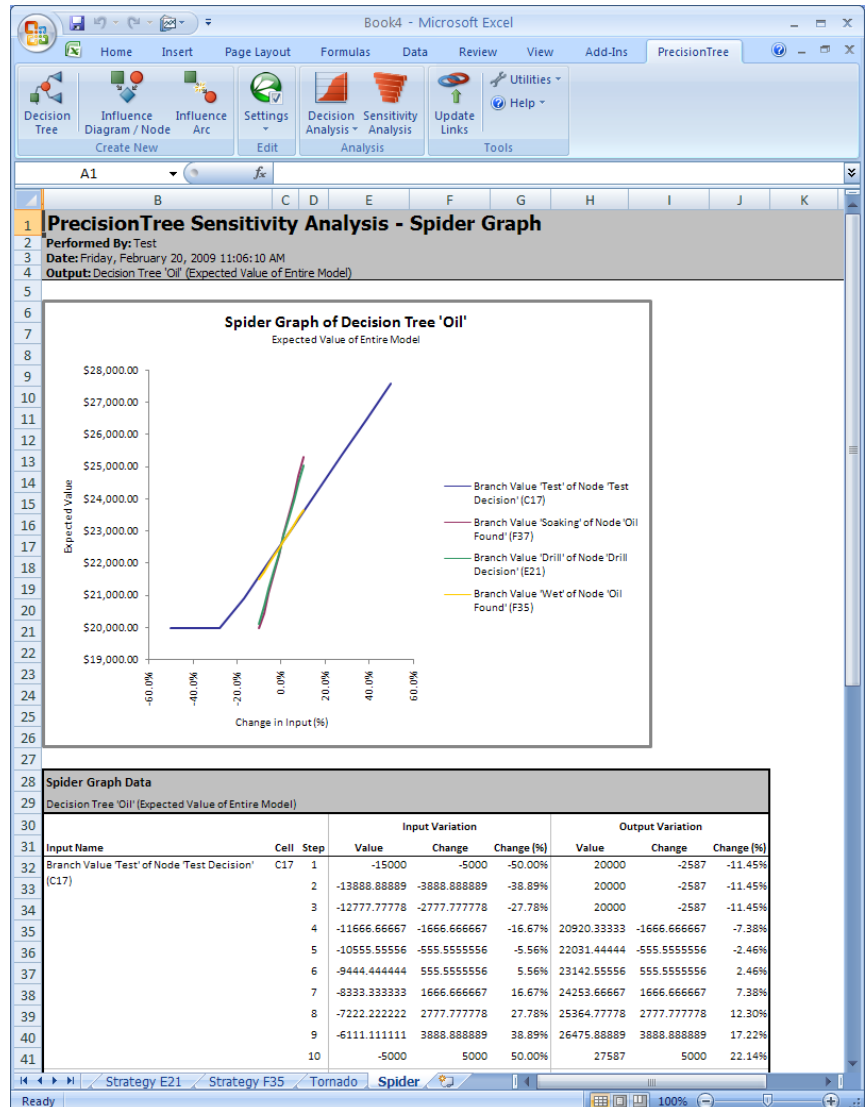
Results of a Two-Way Sensitivity Analysis

When PrecisionTree runs a two-way sensitivity analysis, the following graphs and reports are generated:

Two-Way Sensitivity Graph

When selected, this option generates a two-way sensitivity graph. This is a three dimensional chart that displays the value for the Output at each possible combination of value of the Inputs. The Inputs are shown on the X and Y axes and the values for the Output are shown on the Z axis.
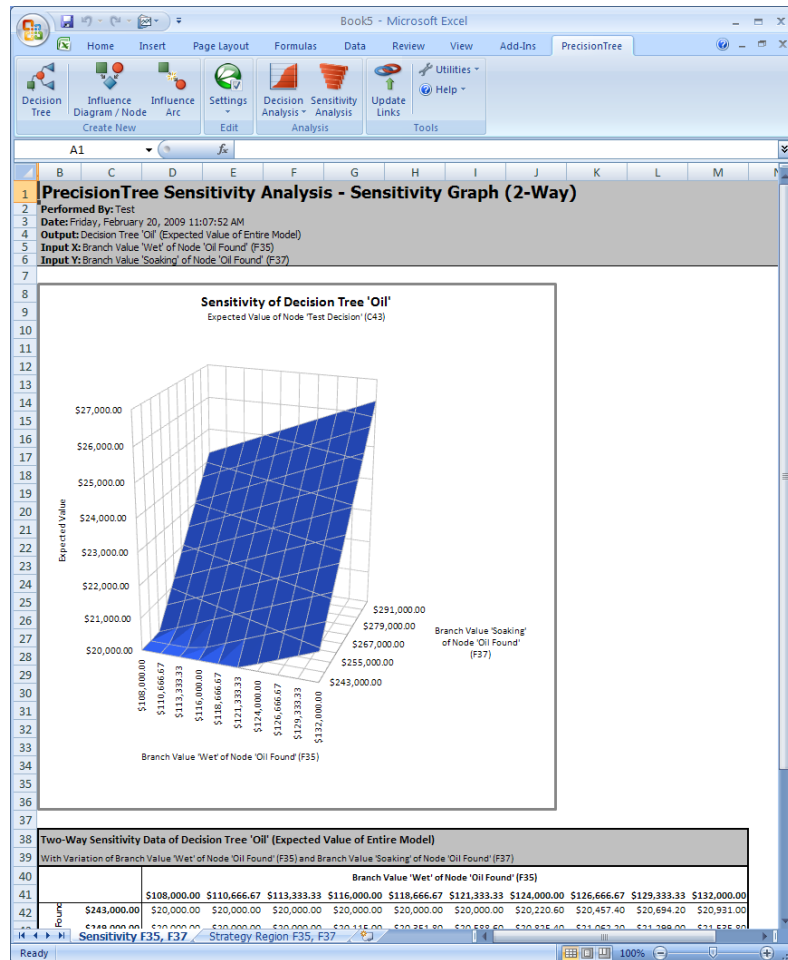
Two-Way Strategy Region Graph

Strategy region graphs show regions where different decisions are optimal given changes in two selected inputs. The value of the first input is plotted on the X-axis and the value of the second input is plotted on the Y-axis. The different symbols in the graph denote the optimal decision at various combinations of values for two inputs - in the case below, the Wet field value and the Soaking field value. This graph is only generated when the Output is the value of a decision node.
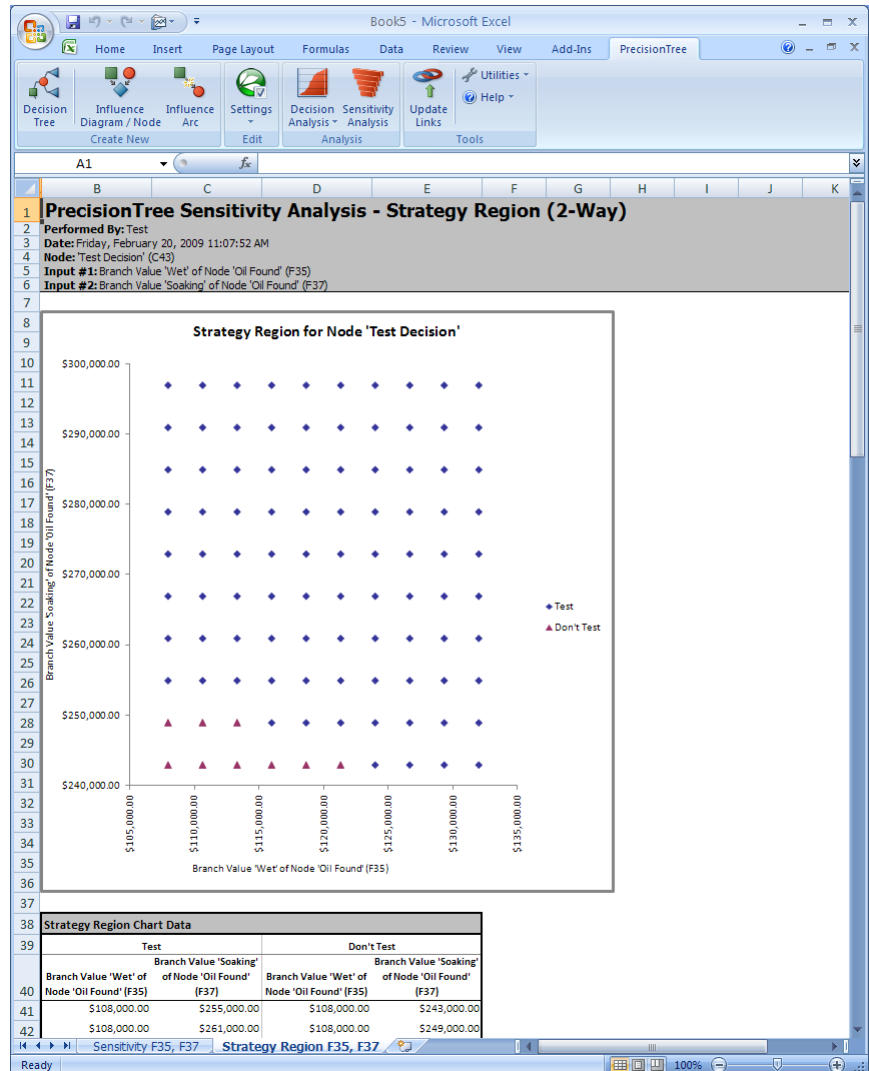
Update Model Links Command

Updates the linked values in a linked model.

Selecting the **Update Model Links command** or clicking the **Update Model Links icon** forces all end node payoffs in all open linked trees to be updated. This only has effect when the Path Payoff Calculation Method is set to Linked Spreadsheet on the Calculation tab of the Model Settings dialog, and the Link Updating option there is set to Manual. Updating model links manually can be useful when editing large linked trees, where continued recalculations might slow performance.

Utilities Menu

The **Utilities menu** commands allow you to quickly review and go to any node in a model, and specify how model errors are reported.

Application Settings Command

Displays the Application Settings dialog where program defaults can be set

A wide variety of PrecisionTree settings can be set at default values that will be used each time PrecisionTree runs. These include defaults for model calculation, utility functions, reporting options and others.
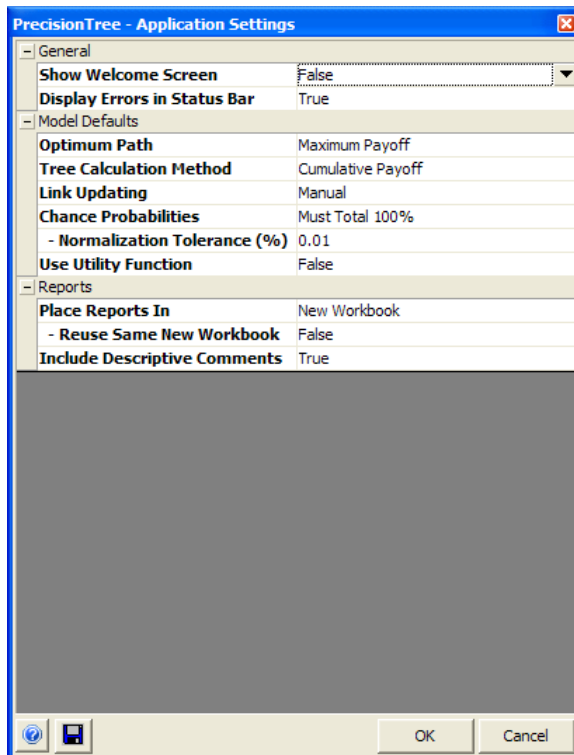
Most options in the Application Settings dialog, such as **Optimum Path**, **Tree Calculation Method** and **Link Updating**, are default settings for **Model Settings** or **Node Settings** dialog boxes. Information on those settings can be found elsewhere in this manual. Application Settings not covered in other sections include:

- **Include Descriptive Comments.** Include cell comments in reports that describe details of various elements in each report.

Find Command

Displays a table with all nodes and branches (or arcs) in a model.

The **Utilities menu Find command** displays a table with all nodes and branches (or arcs) in a model. As nodes are clicked on, the worksheet selection in Excel is moved to the selected node. The Zoom feature allows you to temporarily resize the model to get a better view of nodes and sub-trees while using the Find dialog. Clicking OK exits the dialog box with the worksheet selection now at the highlighted node.
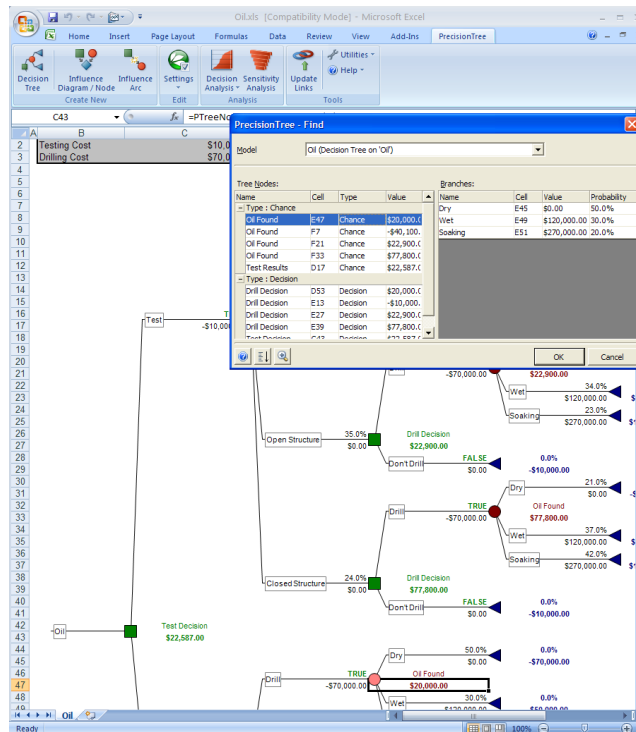
Options in the Find dialog include:

- **Model.** Selects the model in the active workbook for which nodes and branches (or arcs) will be displayed.

- **Arrange.** Clicking the Arrange icon specifies the sort order and grouping of nodes and branches by type, name or cell.

- **Zoom.** Clicking the Zoom icon sets the worksheet display to the specified zoom % while using the Find dialog.

Model Errors Command

Displays a table with all errors found in open models.

The **Utilities menu Model Errors command** window displays all errors found in open models, allowing you to debug problems and quickly jump to nodes with errors. The status bar in Excel displays errors as they occur. The Model Errors window displays all errors in open models.
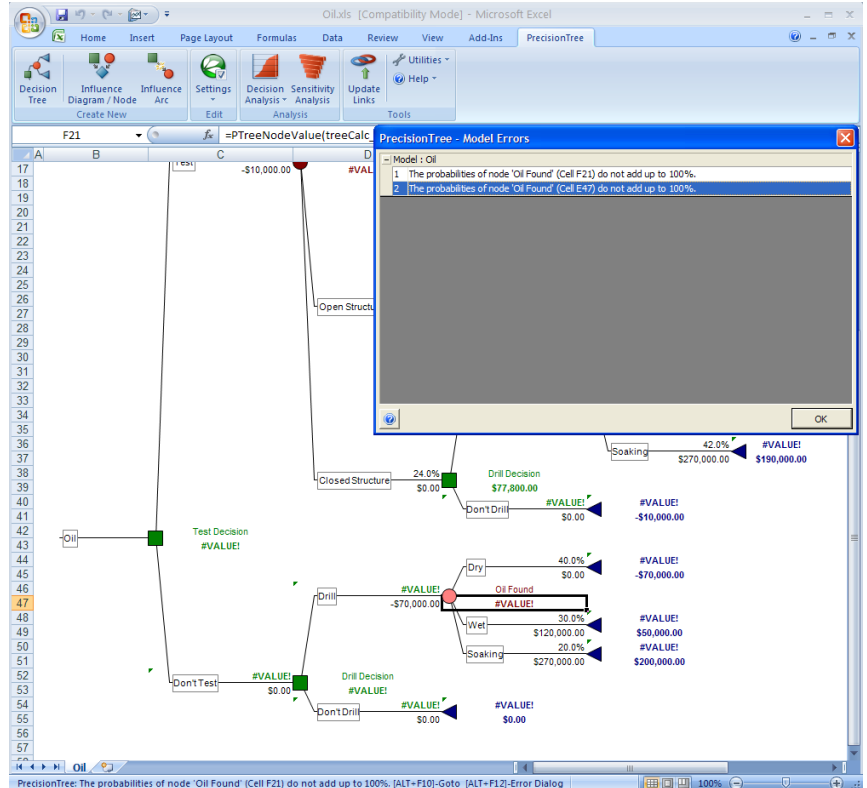
Help Menu

PrecisionTree Help Command

Displays the on-line help for PrecisionTree.

The **Help menu PrecisionTree Help command** opens PrecisionTree's on-line help file. PrecisionTree's features and commands are described in this file.

Online Manual Command

Opens the on-line manual for PrecisionTree

The **Help menu Online Manual command** opens this manual on-line in PDF format. You must have Adobe Reader installed to view the on-line manual.

Example Spreadsheets Command

Displays an Explorer window showing available PrecisionTree example spreadsheet files

The **Help menu Example Spreadsheets command** displays a Windows Explorer window, listing the example models that are included with your copy of PrecisionTree.

License Activation Command

Displays licensing information for PrecisionTree and allows the licensing of trial versions

The Help menu License Activation command displays the License Activation dialog box, listing the version and licensing information for your copy of PrecisionTree. Using this dialog box you can also convert a trial version of PrecisionTree into an licensed copy.

For more information on licensing your copy of PrecisionTree, see **Chapter 1: Getting Started** in this manual.

About Command

Displays version and copyright information about PrecisionTree

The **Help menu About command** displays the About dialog box, listing the version and copyright information for your copy of PrecisionTree.

Appendix A: Technical Notes

Calculation Algorithm for Decision Trees

This is a brief outline of the process PrecisionTree uses to calculate the values displayed in models.

1. Expand all reference nodes (internal and external).
2. Enumerate all the possible paths through the tree.
3. For each path calculate the end value associated with the path.

    Cumulative Trees:
    The end value is the sum of all the branch values on that path. If a payoff formula is specified for any of the nodes, this is applied to the branch before the summation.

    Formula Trees:
    The end value is calculated by evaluating either the default formula specified at the tree root or the custom formula specified at the end node.

    Linked Trees:
    Working through the tree along the path, from left to right, substitute each branch value into the cell specified as the linked cell for the parent node (i.e. the node from which the branches originate). The old contents of the cells which are replaced by these branch values are stored internally so they can be restored at the end of the calculation. When an end node is reached, the spreadsheet is recalculated, and the end value for that particular node is taken from the cell specified for the end node. Note that if two branch values along a path are sent to the same cell, the first one is overwritten by the second, and thus the first value will have no effect.

    VBA Macro Trees:
    Call the custom VBA macro specified to retrieve the end node values.

3. If a utility function was specified, convert each of the end values into their corresponding utility.
4. Next "rollback" the tree by following these steps:

    A) For each node which only has end nodes as successors, determine the expected value (or expected utility) by

    Chance Nodes: Take the average of the end values weighted by their corresponding probabilities.

Decision Nodes: Use the value of the optimal branch (maximum or minimum). Ties are always decided by selecting the topmost branch.

Logic Nodes: Use the expected value of the path specified as "TRUE" by the branch logic statements. If no branches are "TRUE", an error value is returned. If more than one logic statement evaluates to "TRUE", then the expected value is the average of all the branches that are "TRUE" (in other words, the logic node is treated like a Chance node with probabilities equally distributed among all the branches that evaluate to "TRUE").

B) The value (or utility) calculated in A) is displayed next to the node. The optimal branch chosen for any Decision node is indicated by a "TRUE" or "FALSE" statement next to the branches.

C) Once all such nodes have been resolved, conceptually convert the calculated nodes into end nodes, with end values (or utilities) equal to the values determined in A).

D) Repeat Step A), rolling backwards until there is only a single end node left in the tree.

5. If a utility function is used and the output display is set to "Certainty Equivalent", the expected utilities are mapped back into "value units" before being displayed by using the inverse utility function.

6. For each path, determine the end probabilities by multiplying all the probabilities of each branch along that path. If a branch emanates from a decision or logic branch which was not taken, the probability is zero.

Appendix B: Bayes' Theorem

Introduction

We mentioned in the *Overview of Decision Analysis* that conditional arcs are reversible. That must mean that we can exchange the order of two chance events. Let's consider a decision including two chance events; Rain in Boston and Rain in New York. You have decided that the two events are dependent - if it rains in Boston, it is more likely that it will rain in New York. On the other hand, can't you say that if it rains in New York, it is more likely that it will rain in Boston?

Rainy Day Model

Here's how the events appear on an influence diagram:

And a decision tree:
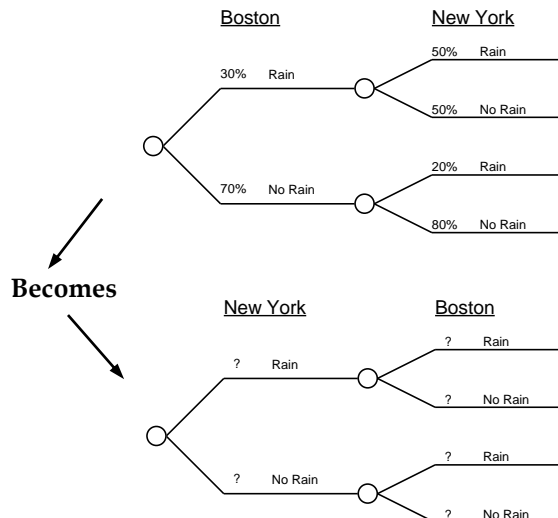
This process is sometimes called "flipping" a probability tree. But now we need to redefine the probabilities associated with each event. That's where Bayes' theorem comes in handy. Bayes' theorem is an algebraic formula that describes the relationship among the probabilities of dependent events.

Definition of Terms

If your memory of probability theory is rusty, here's a quick review of the notation used in this appendix.

P(A) *the probability that an event A will occur*

P(AB) *the probability that events A and B will both occur (A and B), is equal to* P(BA)

P($A|B$) *the probability that event A will occur if B occurs (A given B), does not equal* P($B|A$)

P($\tilde{A}$) *the probability that event A will not occur (not A), equals 1 -* P(A)

Derivation of Bayes' Theorem

Bayes' theorem is easy to derive using simple probability theory. First, we'll start with two basic rules:

i. $$P(A|B) = \frac{P(AB)}{P(B)}$$

ii. $$P(A) = P(AB) + P(A\tilde{B})$$

When we flip a tree, we typically know the probability of event X and the probability of event Y given the occurrence of event X ($P(X)$ and $P(Y|X)$). We usually need to calculate the probability of event X given the occurrence of event Y ($P(X|Y)$) in terms of what we already know. We can construct the following expression from equation **i**:

iii. $$P(X|Y) = \frac{P(XY)}{P(Y)}$$

Using equation **ii**, we can say:

iv. $$P(Y) = P(XY) + P(\tilde{X}Y)$$

We can combine this expression with equation **iii**:

v. $$P(X|Y) = \frac{P(XY)}{P(XY) + P(\tilde{X}Y)}$$

But, we may not know $P(XY)$ and $P(\tilde{X}Y)$, so we can use equation **i** to find new expressions for them:

vi. $$P(XY) = P(Y|X)P(X)$$

vii. $$P(\tilde{X}Y) = P(Y|\tilde{X})P(\tilde{X})$$

We can substitute these expressions into equation **v** to get Bayes' theorem:

Bayes' Theorem   viii. $$P(X|Y) = \frac{P(Y|X)P(X)}{P(Y|X)P(X) + P(Y|\tilde{X})P(\tilde{X})}$$

Bayes' theorem describes the probability of event X given the occurrence of event Y using values we already know.

Another value that may be useful is the probability of event Y. It may be found by combining equations **i** and **ii**. Let's start by using equation **ii**:

ix. $$P(Y) = P(XY) + P(\tilde{X}Y)$$

We can find $P(XY)$ and $P(\tilde{X}Y)$ using equation **i**:

x. $P(XY) = P(Y|X)P(X)$

xi. $P(\tilde{X}Y) = P(Y|\tilde{X})P(\tilde{X})$

Combining these equations leads to the expression:

xii. $P(Y) = P(Y|X)P(X) + P(Y|\tilde{X})P(\tilde{X})$

Using Bayes' Theorem

All of these equations are great, but how do they apply to your decision tree? Let's use Bayes' theorem on the example we described earlier. First, let's add probability notation to our two trees.

Rainy Day Model with Probability Notation
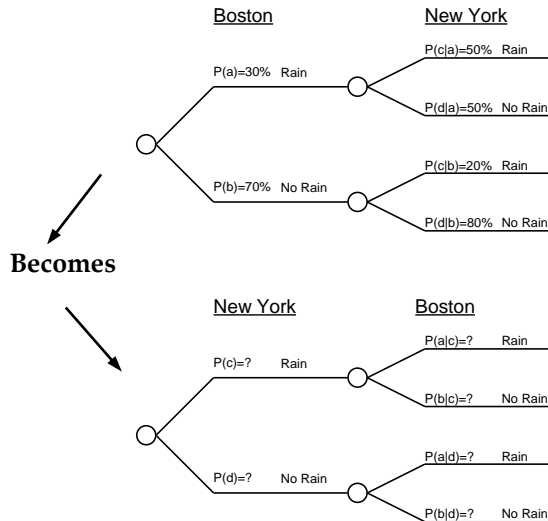
For our new tree, we need to calculate the probability that it will rain in Boston if it rains in New York, or $P(a|c)$. Let's substitute our variables into Bayes' theorem:

xiii. $$P(a|c) = \frac{P(c|a)P(a)}{P(c|a)P(a) + P(c|\tilde{a})P(\tilde{a})}$$

For this example, $P(\tilde{a}) = P(b)$ since there are only two events corresponding to the chance node:

xiv. $$P(a|c) = \frac{P(c|a)P(a)}{P(c|a)P(a) + P(c|b)P(b)}$$

Fortunately, we know all the values needed to solve this equation:

xv. $$P(a|c) = \frac{.5 \times .3}{(.5 \times .3) + (.2 \times .7)} = .52$$

We can use the same method to solve for $P(b|c)$, $P(a|d)$ and $P(b|d)$. But, what about $P(c)$? That's easy! All we need to do is use equation **xii** (remember that $P(\tilde{a}) = P(b)$):

xvi. $$P(c) = P(c|a)P(a) + P(c|\tilde{a})P(\tilde{a}) = P(c|a)P(a) + P(c|b)P(b)$$

Fortunately, we know all the values needed to solve this equation:

xvii. $P(c) = (.5 \times .3) + (.2 \times .7) = .29$

We can use the same method to solve for $P(d)$. Here's what our decision tree looks like once we've solved for all the missing values:

Solution to Rainy Day Model
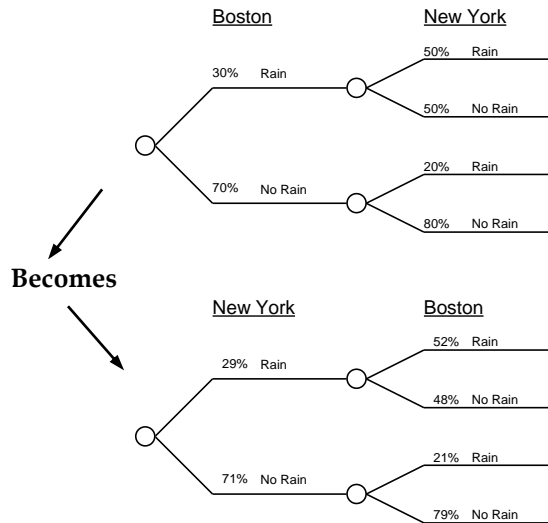
As you can see, the probabilities at each chance node still sum to 1. The two trees describe the same situation using different probability values.

Bayes' theorem may be used in any situation where you need to calculate conditional probabilities after collecting data. Decision makers who assign probability distributions to the parameters of a model and use Bayes' theorem to make inferences about the model are making what's known as Bayesian revisions to their model. PrecisionTree uses Bayesian methods to solve influence diagrams.

Appendix C: Utility Functions

What is Risk?

Risk derives from our inability to see into the future, and indicates a degree of uncertainty that is significant enough to make us notice it. This somewhat vague definition takes more shape by mentioning several important characteristics of risk.

Risk Can be Objective or Subjective

Flipping a coin is an objective risk because the odds are well known. Even though the outcome is uncertain, an objective risk can be described precisely based on theory, experiment, or common sense. Everyone agrees on the description of an objective risk. Describing the odds for rain next Thursday represents a subjective risk. Given the same information (theory, computers, etc.), weatherman A may think the odds of rain are 30% while weatherman B may think the odds are 65%. Neither is wrong. Describing a subjective risk is open-ended in the sense that you can always refine your assessment with new information, further study, or by giving weight to the opinion of others. Most of the risks in your decision models are subjective.

Deciding that Something is Risky Requires Personal Judgment

Consider the following decision between two investments:

Investment Model
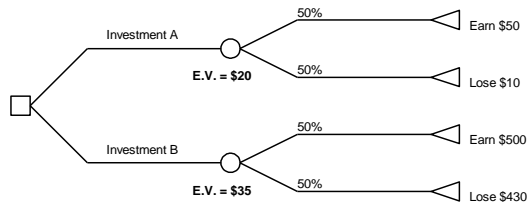
This example describes a decision between two investments of varying risk. Investment B has the highest expected value, and would be selected if expected value was the only criteria for the decision. But, Investment B seems to be much riskier than Investment A. Most people would choose Investment A over Investment B. But, how can we place a quantitative measurement on the riskiness of a situation?

Risks are Things We Can Often Choose to Accept or Avoid

Individuals differ in the amount of risk they willingly accept. For example, two individuals of equal net worth may react quite differently to the investment decision above − one may choose Investment A while the other chooses Investment B. One decision maker may be risk averse; he prefers a small spread in possible results, with most of the probability associated with desirable results. A risk taker, on the other hand, accepts a greater amount of spread, or possible variation in the outcome distribution. Of course, a person may be risk neutral; he or she does not consider risk when making decisions, only expected value.

Measuring Risk with Utility Functions

You probably have an idea of how much risk is acceptable to you, but how do you express your risk preference in a decision model? Ideally, you would like to look at a decision and weigh both the expected value and risk of a decision. And, you would like to consider your preference for risk as well. That's where utility functions come in handy.

A utility function is an expression that explains risk by converting the payoff of a decision to utility units. The utility of one decision is then compared to that of another decision to select the optimum decision.

Typical Utility Functions for Different Decision Makers
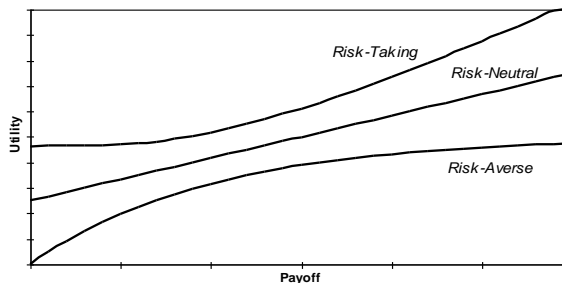
The above example contains typical utility functions for risk averse, risk tolerant and risk neutral decision makers. The typical risk-neutral utility curve is linear (indicating no special weight given to risky situations), while the risk-averse curve is convex.

Expected Utility

Let's go back to the investment example we discussed earlier. For simplicity, the following utility function is used:

Utility Function

$$U(x) = \ln(x + 500)$$

In addition to calculating the expected values of the two investment decisions, we can also calculate the expected utilities, which are the weighted averages of the utility units for each outcome.

Expected Utility for Investment Model
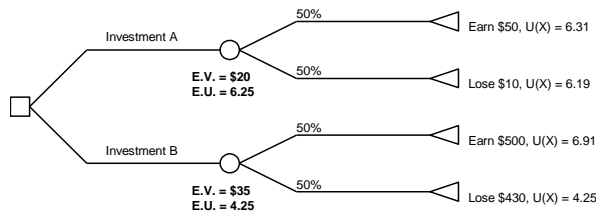
For this example, the expected utility of Investment A is greater than that for Investment B. Even though the expected value of Investment B is greater, Investment A is a better choice. Expected utility seems like a

meaningless number. You can't say to your boss "Let's choose Investment A since it has a utility value of 6.25." You need to express utility in units that mean something to others.

Certainty Equivalent

The certainty equivalent is the value you place on an uncertain situation. It is the amount of money (in cash) that you would accept to avoid a risky decision. The certainty equivalent of a chance node is calculated using the inverse of the utility function and the expected utility of the node. Instead of making our decision based on the expected utility, we can select the option with the highest certainty equivalent. This always produces the same decision, but uses units we understand.

For our example, we would calculate the certainty equivalent with the following formula:

$$X = \exp(E.U.) - 500$$

This formula is the inverse of our utility function. Placing the results into our tree produces:
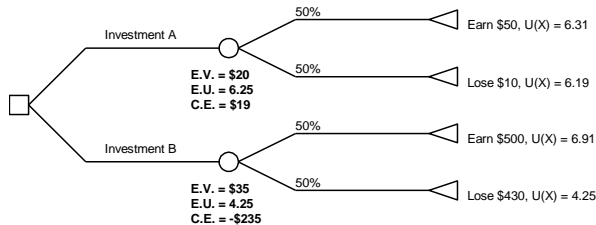
In this model, Investment A has the highest certainty equivalent. This is not surprising since it also has the highest expected utility.

Risk Premium

How much are you willing to give up to avoid risk? The risk premium is the difference between the expected value and the certainty equivalent of an event. The higher the risk premium for an event, the more risk averse the decision maker is. If the risk premium is a negative number, the decision maker is a risk taker. For a risk neutral situation, the risk premium is zero.

In our example, the risk premium associated with Investment B is $270. We are willing to give up that much money to avoid the risk associated with this investment. But, we would only give up $1 to avoid the relatively small risk associated with Investment A.

PrecisionTree and Utility Functions

PrecisionTree allows you to define a different utility function for every chance node in your model. When you create a new node, PrecisionTree automatically assigns it the default utility function (defined by you). You can change the utility function of a node at any time during the modeling process.

To define a risk neutral decision, simply enter a risk coefficient of zero or set the decision model to expected value. PrecisionTree will base its decisions strictly on expected value.

Exponential Utility Function

The most common utility function is the exponential utility function. This function is built-in to PrecisionTree and is defined as:

$$U(x) = 1 - \exp(-x/R)$$

R is the decision maker's risk tolerance (also called the risk coefficient). A small value of R indicates risk aversion. As R increases, the decision maker becomes more risk tolerant.

Typical Exponential Utility Curves
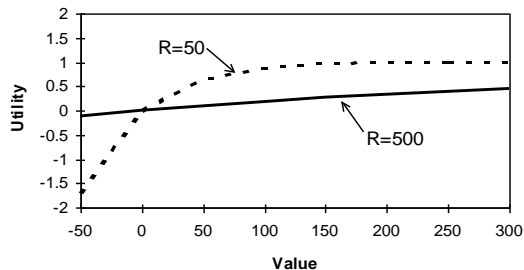
The above example plots two exponential utility curves, one with a risk coefficient of 50 and another with a risk coefficient of 500. The curve with the larger risk coefficient is flatter, thus more risk tolerant than the other curve.

How to Select a Risk Coefficient

There are many ways to determine the value of R that is right for you. Some industries have a higher tolerance for risky ventures than others. Some companies even have a pre-defined formula for identifying risk tolerance. It is up to you, the decision maker, to determine how much risk you can tolerate for a given decision.

Drawbacks   One drawback of the exponential utility function is that it assumes
constant risk aversion. In other words, you would view a risky situation
the same way no matter how much money you had. This may be a
good approximation for some situations, such as when sensitivity
analysis determines that varying risk tolerance does not significantly
affect the model. But, what do we do when our attitudes toward risk
change?

Custom Utility Functions

PrecisionTree offers a default exponential utility function. But, using Excel's Visual Basic for Applications, you can easily construct your own custom utility function. This section discusses some widely-used utility functions and explains how to use them in your own models.

Logarithmic Utility Function

Some utility functions take into account the fact that risk becomes more attractive when you have more money (decreasing risk aversion). The logarithmic utility function is commonly used in this case:

$$U(x) = \ln(x + R)$$

The constant R is added to the expression to insure that PrecisionTree never has to take the log of a negative number (which returns an error). If it is possible that your values of x could be negative, chose a value of R large enough so that x + R can never be less than zero.

Logarithmic Utility Curves
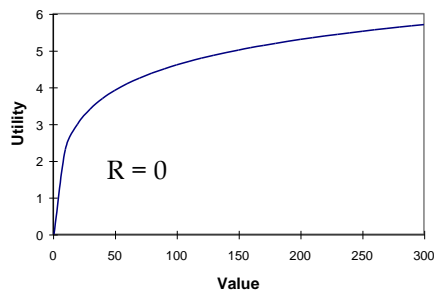
The example above contains a logarithmic utility curve with a risk coefficient of 0. If you change the R value, the curve merely "shifts" a distance equal to R along the x-axis.

Square-Root Utility Function

The square-root utility function also demonstrates decreasing risk aversion. Its formula is:

$$U(x) = +\sqrt{x + R}$$

As with the logarithmic function, the constant R is added to the expression to insure that PrecisionTree never has to take the square root of a negative number (which returns an error). If it is possible that your values of x could be negative, choose a value of R large enough so that x + R can never be less than zero.

The example above displays two square-root utility curves, one with a risk coefficient of 0 and another with a risk coefficient of 50. They are both the same shape; the R value merely "shifts" the curve along the X-axis.

Defining Custom Utility Functions

To create your own utility function, write a user-defined function in Excel (see the Excel User's Guide for instructions). Then, write another function for the inverse utility, which converts expected utility to a certainty equivalent. For example, you might use the following functions for a square-root utility function:

Utility_SquareRoot(X,R)

Inverse_SquareRoot(EU,R)

Where X is the expected value of a node, R is the risk coefficient and EU is the expected utility of a chance node.

There are three steps involved in incorporating utility function into your model:

❶ *Use the utility function to calculate utility for each chance outcome.*

❷ *Calculate the expected utility of the chance node.*

❸ *Convert the expected utility to a certainty equivalent using the inverse utility function.*

Note: for more information on defining utility functions, see the example model UTILITY FUNCTIONS.XLS.

To demonstrate these techniques, let's look at a portion of the oil drilling example:

Drilling Decision for Open Test Results
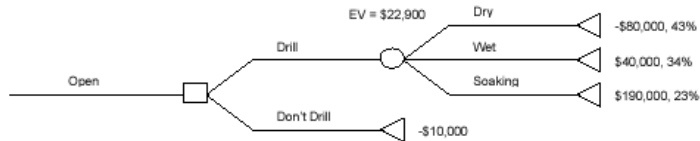
Based on expected value, the optimum decision is to drill. But, will that decision remain the same when the risk of drilling is considered?

With **Utility_SquareRoot** and **Inverse_SquareRoot** functions created in VBA and present in an open VBA module, simply type in Utility_SquareRoot and enter a Risk coefficient. PrecisionTree then recalculates the tree, returning a certainty equivalent at each node.

Drilling Decision With Certainty Equivalents

The final decision tree looks like this:
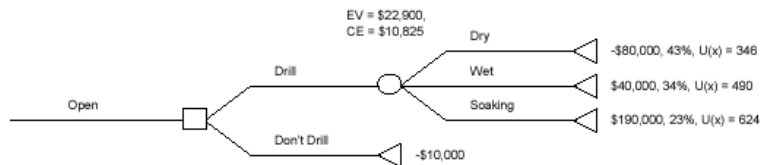
The optimum decision is still to Drill, but the certainty equivalent is significantly smaller than the expected value. So, while our decision has not changed, we are now aware that the risk involved in our decision makes the option less attractive than it once seemed.

Appendix D: Recommended Readings

Books and Articles on Decision Analysis

The PrecisionTree manual has given you a start on understanding the concepts of decision analysis and simulation. If you're interested in finding out more about the decision analysis techniques and the theory behind them, here are some books and articles which examine various areas in the decision analysis field.

Introduction to Decision Analysis

- Baird, Bruce F. Managerial Decisions Under Uncertainty: An Introduction to the Analysis of Decision Making. New York: John Wiley and Sons, 1989. (*)

- Clemen, R.T. Making Hard Decisions: An Introduction to Decision Analysis. Boston: PWS-Kent Publishing Company, 1991.(*)

- Raiffa, Howard. Decision Analysis: Introductory Lectures on Choices Under Uncertainty. Reading, MA: Addison-Wesley, 1968.

Technical References to Decision Trees and Influence Diagrams

- Cockett, J. R. B., and J. A. Herrera. 1990. "Decision Tree Analysis." Journal of the Association for Computing Machinery. 37: 815-842.

- Oliver, Robert M., and James Q. Smith, eds. Influence Diagrams, Belief Nets and Decision Analysis. New York: John Wiley and Sons, 1990.

- Shachter, R. D. 1986. "Evaluating Influence Diagrams." Operations Research. 34: 871-882.

Technical References to Sensitivity Analysis

- French, S. 1992. "Mathematical Programming Approaches to Sensitivity Calculations in Decision Analysis" Journal of the Operational Research Society. **43**: 813-819.

Examples and Case Studies Using Decision Analysis

- Howard, Ronald A., and James E. Matheson, eds. <u>The Principles and Applications of Decision Analysis</u>. Vols. I and II. Menlo Park: Strategic Decisions Group, 1989.

- Newendorp, Paul and Schuyler, John, Decision Analysis for Petroleum Exploration, 2nd Ed.: Planning Press, Aurora, Colo., 2000.

The titles marked with an * can be purchased through Palisade Corporation. To order or to request more information on these and other titles relating to decision analysis, call us at (800) 432-7475 (toll-free US & Canada) or (607) 277-8000, fax us at (607) 277-8001, email us at sales@palisade.com, visit our web site at http://www.palisade.com or write to us at:

Palisade Corporation
798 Cascadilla St
Ithaca, NY 14850 USA

Appendix E: Using PrecisionTree with Other DecisionTools

The DecisionTools Suite

Palisade's DecisionTools Suite is a complete set of decision analysis solutions for Microsoft Windows. With the introduction of DecisionTools, Palisade brings you a decision-making suite whose components combine to take full advantage of the power of your spreadsheet software.

The DecisionTools Suite focuses on providing advanced tools for any decision, from risk analysis to sensitivity analysis to distribution fitting. Software packaged with the DecisionTools Suite includes:

- **@RISK** — risk analysis using Monte-Carlo simulation
- **TopRank** — sensitivity analysis
- **PrecisionTree** — decision analysis with decision trees and influence diagrams

While all the tools listed above can be purchased and used separately, they become more powerful when used together. Analyze historical and fit data for use in an @RISK model. Or use TopRank to determine which variables to define in your @RISK model.

This chapter explains many of the ways the components of the DecisionTools suite interact and how they will make your decision making easier and more effective.

Purchasing Information

All of the software mentioned here, including the DecisionTools Suite, can be purchased directly from Palisade Corporation. To place an order or receive more information, please contact one of Palisade's offices:

If you want to contact Palisade Corp. (for North and South America):

- *Telephone us at* **(800) 432-7475** *(U.S. & Canada) or* **(607) 277-8000** *any weekday from 8:30 AM to 5:00 PM, EST*

- *Fax us at* **(607) 277-8001**

- *E-mail us at* **sales@palisade.com** *or* **ventas@palisade-lta.com**

- *Visit us on the World Wide Web at* **http://www.palisade.com** *or* **http://www.palisade-lta.com**

- Mail us a letter at:

   Palisade Corporation
   798 Cascadilla St
   Ithaca, NY 14850 USA

If you want to contact Palisade Europe:

- *Telephone us at* **+44 1895 425050** *(UK)*

- *Fax us at* **+44 1895 425051** *(UK)*

- *E-mail us at* **sales@palisade-europe.com**

- *Visit us on the World Wide Web at* **http://www.palisade — europe.com**

- *Mail us a letter at:*

   Palisade Europe
   31 The Green
   West Drayton
   Middlesex
   UB7 7PN
   United Kingdom

If you want to contact Palisade Asia-Pacific:

- *Email us at* [*sales@palisade.com.au*](mailto:sales@palisade.com.au)

- *Telephone us at + 61 2 9252 5922 (AU).*

- *Fax us at + 61 2 9252 2820 (AU).*

- *Mail us a letter to:*

   Palisade Asia-Pacific Pty Limited
   Suite 404, Level 4
   20 Loftus Street
   Sydney NSW 2000
   Australia

Palisade's DecisionTools Case Study

The Excelsior Electronics Company currently makes desktop computers. They are working on a laptop computer, the Excelsior 5000, and want to know whether or not the company will profit from this venture. They built a spreadsheet model which spans the next two years, each column representing one month. The model takes into account production costs, marketing, shipping, price per unit, units sold, etc. The bottom line for each month is "Profit". Excelsior expects some initial setbacks on this venture, but as long as they are not too great and profits are up towards the end of two years, they will go ahead with the E5000.

Run TopRank First, Then @RISK

TopRank is used on the model to find the critical variables. The "Profit" cells are selected as outputs, and an automatic What-if analysis is run. The results quickly show there are five variables (out of many more) that have the most impact on profits: price per unit, marketing costs, build time, price of memory, and price of CPU chips. Excelsior decides to concentrate on these variables.

Next, Assess Probabilities

Distribution functions are needed to replace the five variables in the spreadsheet model. Normal distributions are used for price per unit and build time, based on internal decisions and information from Excelsior's manufacturing division.

Add Distribution Fitting

Research is done to get weekly price quotes for memory and CPU's over the past two years. This data is fed into @RISK's distribution fitting and distributions are fitted to the data. Confidence level information confirms that the distributions are good fits, and the resulting @RISK distribution functions are pasted into the model.

Simulate with @RISK

Once all the @RISK functions are in place, the "Profit" cells are selected as outputs and a simulation is run. Overall, the results look promising. Although there will be losses initially, there is an 85% chance they will make an acceptable profit, and a 25% chance the venture will generate more revenue than they had initially assumed! The Excelsior 5000 project is given the go-ahead.

Decide with PrecisionTree

Excelsior Electronics had assumed they would sell and distribute the Excelsior 5000 themselves. However they could use various catalogs and computer warehouses to distribute their product. A decision tree model is built using PrecisionTree, taking into account unit prices, sales volume, and other critical factors for direct sales versus catalog sales. A Decision Analysis is run and PrecisionTree suggests using catalogs and warehouses. Excelsior Electronics puts that plan into full motion.

Introduction to @RISK

The techniques of Risk Analysis have long been recognized as powerful tools to help decision-makers successfully manage situations subject to uncertainty. Their use has been limited because they have been expensive, cumbersome to use, and have substantial computational requirements. The growing use of computers in business and science has offered the promise that these techniques can be used by all decision-makers.

That promise has been finally realized with @RISK (pronounced "at risk"), a system which brings these techniques to the industry standard modeling package, Microsoft Excel. With @RISK and Excel any risky situation can be modeled, from business to science and engineering. You are the best judge of what your analysis needs require, and @RISK, combined with the modeling capabilities of Excel, lets you design a model which best satisfies those needs. Anytime you face a decision or analysis under uncertainty, use @RISK to improve your picture of what the future could hold.

Why You Need Risk Analysis and @RISK

Traditionally, analyses combine single point estimates of a model's variables to predict a single result. This is the standard Excel model, a spreadsheet with a single estimate of results. Estimates of model variables must be used because the values which actually occur are not known with certainty. In reality, however, many things just don't turn out the way that you have planned. Maybe you were too conservative with some estimates and too optimistic with others. The combined errors in each estimate often lead to a real-life result that is significantly different from the estimated result. The decision you made based on your expected result might be the wrong decision, and a decision you never would have made if you had a more complete picture of all possible outcomes. Business decisions, technical decisions, and scientific decisions all use estimates and assumptions. With @RISK, you can explicitly include the uncertainty present in your estimates to generate results that show all possible outcomes.

Monte Carlo Simulation @RISK uses a technique called Monte Carlo simulation to combine all the uncertainties you identify in your modeling situation. You no longer are forced to reduce what you know about a variable to a single number. Instead, you include all you know about the variable, including its full range of possible values and some measure of likelihood of occurrence for each possible value. @RISK uses all this information, along with your Excel model, to analyze every possible outcome. It's just as if you ran hundreds or thousands of What-if

scenarios all at once! In effect, @RISK lets you see the full range of what could happen in your situation. It's as if you could live through your situation over and over again, each time under a different set of conditions, with a different set of results occurring.

All this added information sounds like it might complicate your decisions, but one of simulation's greatest strengths is its power of communication. @RISK gives you results that graphically illustrate the risks you face. This graphical presentation is easily understood by you, and easily explained to others.

When Should You Use @RISK?

Anytime you make an analysis in Excel that could be affected by uncertainty, you can and should use @RISK. The applications in business, science and engineering are practically unlimited and you can use your existing base of spreadsheet models. An @RISK analysis can stand alone, or be used to supply results to other analyses. Consider the decisions and analyses you make every day. If you've ever been concerned with the impact of risk in these situations, you've just found a good use for @RISK!

@RISK and Microsoft Excel

As an add-in to Microsoft Excel, @RISK links directly to Excel to add Risk Analysis capabilities. The @RISK system provides all the necessary tools for setting up, executing and viewing the results of Risk Analyses. And @RISK works in a style you are familiar with, Excel style menus and functions.

@RISK Functions

Uncertain cell values in @RISK for Excel are defined as probability distributions using functions. @RISK adds over thirty new functions to the Excel function set, each of which specifies a different distribution type for cell values. Distribution functions can be added to any number of cells and formulas throughout your worksheets and can include arguments which are cell references and expressions, allowing extremely sophisticated specification of uncertainty.

Available Distribution Types

The probability distributions provided by @RISK specify nearly any type of uncertainty in cell values in your spreadsheet. A cell containing the distribution function =RISKNORMAL(10,10), for example, returns samples during a simulation drawn from a normal distribution (mean = 10, standard deviation = 10). Distribution functions are only invoked during a simulation — in normal Excel operations, they show a single cell value — just the same as Excel before @RISK.

Using PrecisionTree with @RISK

@RISK is a perfect companion to PrecisionTree. @RISK allows you to 1) quantify the uncertainty that exists in the values and probabilities which define your decision trees, and 2) more accurately describe chance events as a continuous range of possible outcomes. Using this information, @RISK performs a Monte-Carlo simulation on your decision tree, analyzing every possible outcome and graphically illustrating the risks you face.

Using @RISK to Quantify Uncertainty

With @RISK, all uncertain values and probabilities for branches in your decision trees and supporting spreadsheet models can be defined with distribution functions. When a branch from a decision or chance node has an uncertain value, for example, this value can be described by an @RISK distribution function. During a normal decision analysis, the expected value of the distribution function will be used as the value for the branch. The expected value for a path in the tree will be calculated using this value.

However, when a simulation is run using @RISK, a sample will be drawn from each distribution function during each iteration of the simulation. The value of the decision tree and its nodes will then be recalculated using the new set of samples and the results recorded by @RISK. A range of possible values will then be displayed for the decision tree. Instead of seeing a risk profile with a discrete set of possible outcomes and probabilities, a continuous distribution of possible outcomes is generated by @RISK. You can see the chance of any result occurring.

Describing Chance Events as a Continuous Range of Possible Outcomes

In decision trees, chance events must be described in terms of discrete outcomes (a chance node with a finite number of outcome branches). But, in real life, many uncertain events are continuous, meaning that any value between a minima and maxima can occur.

Using @RISK with PrecisionTree makes modeling continuous events easier using distribution functions. And, @RISK functions can make your decision tree smaller and easier to understand!

Methods of Recalculation During a Simulation

Two options are available for recalculation of a decision model during a simulation performed with @RISK. These are set using the @RISK command in the Decision Tree or Influence Diagram settings dialog box. The first option, *Expected Values of the Model*, causes @RISK to first sample all distribution functions in the model and supporting spreadsheets with each iteration, then recalculate the model using the new values to generate a new expected value. Typically the output from the simulation is the cell containing the expected value of the model. At the end of the run an output distribution reflecting the possible range of expected values for the model and their relative likelihood of occurrence is generated.

The second option, *Values of One Sampled Path through the Model*, causes @RISK to randomly sample a path through the model with each iteration of a simulation. The branch to follow from each chance node is randomly selected based on the branch probabilities entered. This method does not require that distribution functions be present in the model; however if they are used, a new sample is generated with each iteration and used in path value calculations. The output from the simulation is the cell containing the value of the model, such as the value of the root node of the tree. At the end of the run an output distribution reflecting the possible range of out values for the model and their relative likelihood of occurrence is generated.

Using Probability Distributions in Nodes

Remember the Oil Drilling model *in Chapter 3: Overview of PrecisionTree*? Let's take another look at one of the chance nodes in the model:

Drilling Decision for Open Test Results
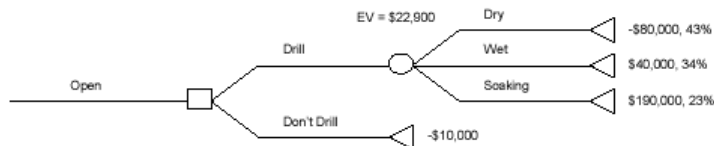

The results of drilling are divided into three discrete outcomes (Dry, Wet and Soaking). But, in reality, the amount of oil found should be described with a continuous distribution. Suppose the amount of money made from drilling follows a lognormal distribution with a mean of $22900 and a standard deviation of $50000, or the @RISK distribution =RiskLognorm(22900, 50000).

To use this function in the oil drilling model, change the chance node to have only one branch, and the value of the branch is defined by the @RISK function. Here's how the new model should look:

Drilling Decision With a Probability Distribution
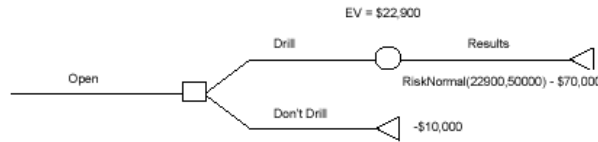
During an @RISK simulation, the RiskLognorm function will return random values for the payoff value of the Results node and PrecisionTree will calculate a new expected value for the tree.

Decision Forcing During Simulation

But, what about the decision to Drill or Don't Drill? If the expected value of the Drill node changes, the optimum decision could change from iteration to iteration. That would imply that we know the outcome of drilling before the decision is made. To avoid this situation, click *Decisions Follow Current Optimal Path* option in the *@RISK* dialog before running an @RISK simulation. Every decision node in the tree will be changed to a forced decision node, which causes each decision node to select the decision that's optimal when the command is used. This avoids changes in a decision due to changing a decision tree's values and probabilities during a risk analysis.

Using @RISK to Analyze Decision Options

Value of Perfect Information

There may be times when you want to know the outcome of a chance event before making a decision. You want to know the value of perfect information.

Before running a risk analysis, you know the expected value of the Drill or Don't Drill decision from the value of the Drill Decision node. If you ran a risk analysis on the model without forcing decisions (i.e., the Decisions May Change Each Iteration option is selected), the return value of the Drill Decision node would reflect the expected value of the decision if you could perfectly predict the future. The difference between the two values is the highest price you should pay (perhaps by running more tests) to find out more information before making the decision.

Selecting @RISK Outputs

Running a risk analysis on a decision tree can produce many types of results, depending on the cells in your model you select as outputs. True expected value, the value of perfect information, and path probabilities can be determined.

Start Node Select the value of a start node of a tree (or the beginning of any sub-tree) to generate a risk profile from an @RISK simulation. Since @RISK distributions generate a wider range of random variables, the resulting graph will be smoother and more complete than the traditional discrete risk profile.

Decision Node If you want to calculate the value of perfect information for a decision, don't select Decisions Follow Current Optimal Path - select Decisions May Change Each Iteration instead. Select the decision node you are interested in as an @RISK output and run a simulation. After the simulation, find the expected value of the output (from the @RISK window) and subtract the node's original expected value from it. The result is the value of perfect information.

Introduction to TopRank

TopRank is the ultimate What-if tool for spreadsheets from Palisade Corporation. TopRank greatly enhances the standard What-if and data table capabilities found in your spreadsheet. In addition, you can easily step up to powerful risk analysis with its companion package, @RISK.

TopRank and What-if Analysis

TopRank helps you find out which spreadsheet value(s) or variable(s) affects your results the most — an automated What-if or sensitivity analysis. You also can have TopRank automatically try any number of values for a variable — a data table — and tell you the results calculated at each value. TopRank also tries all possible combinations of values for a set of variables (a Multi-Way What-if analysis), giving you the results calculated for each combination.

Running a What-if or sensitivity analysis is a key component of making any decision based on a spreadsheet. This analysis identifies which variables affect your results the most. This shows you those factors you should be most concerned with as you 1) gather more data and refine your model and 2) manage and implement the situation described by the model.

TopRank is a spreadsheet add-in for Microsoft Excel. It can be used with any pre-existing or new spreadsheet. To set up your What-if analyses, TopRank adds new custom "Vary" functions to the spreadsheet function set. These functions specify how the values in your spreadsheet can be varied in a What-if analysis; for example, +10% and -10%, +1000 and -500, or according to a table of values you've entered.

TopRank can also run a fully automatic What-if analysis. It uses powerful auditing technology to find all possible values in your spreadsheet which could affect your results. It can then change all these possible values automatically and find out which is most significant in determining your results.

TopRank Applications

TopRank applications are the same as spreadsheet applications. If you can build your model in a spreadsheet, you can use TopRank to analyze it. Businesses use TopRank to identify the critical factors — price, up front investment amount, sales volume or overhead — that most affect the success of their new product. Engineers use TopRank to show them the individual product components whose quality most affects final product production rates. A loan officer can have TopRank quickly run her model at all possible interest rate, loan principle amount and down payment combinations and then review results for each possible scenario. Whether your application is in business, science, engineering,

accounting or another field, TopRank can work for you to identify the critical variables which affect your results.

Modeling Features

Why TopRank?　As an add-in to Microsoft Excel, TopRank links directly to Excel to add What-if analysis capabilities. The TopRank system provides all the necessary tools for conducting a What-if analysis on any spreadsheet model. And TopRank works in a style you are familiar with — Excel style menus and functions.

What-if analysis and Data Tables are functions that can be performed directly in your spreadsheet, but only in a manual, unstructured format. Simply changing a cell value in your spreadsheet and calculating a new result is a basic What-if analysis. And a Data Table which gives a result for each combination of two values can also be built in your spreadsheet. TopRank, however, performs these tasks automatically and analyzes their results for you. It instantly performs What-if's on all possible values in your spreadsheet which could affect your result, instead of requiring you to change values individually and recalculate results. It then tells you what spreadsheet value is most significant in determining your result.

*Multi-Way
What-if Analysis*　TopRank also runs data table combinations automatically, without requiring you to set up tables in your spreadsheet. Combine more than two variables in its Multi-Way What-if analysis — you can generate combinations of any number of variables — and rank your combinations by their affect on your results. You can perform these sophisticated and automated analyses quickly, as TopRank keeps track of all the values and combinations it tries, and their results, separate from your spreadsheet. By taking an automated approach, TopRank gives you What-if and Multi-Way What-if results almost instantly. Even the least experienced modeler can get powerful analysis results.

*TopRank
Functions*　TopRank defines variations in spreadsheet values using functions. To do this, TopRank has added a set of new functions to the Excel function set, each of which specifies a type of variation for your values. These functions include:

- **Vary** and **AutoVary** functions which, during a What-if analysis, change a spreadsheet value across a + and - range you define.

- **VaryTable** functions which, during a What-if analysis, substitute each of a table of values for a spreadsheet value.

TopRank uses functions to change spreadsheet values during a What-if analysis and keeps track of the results calculated for each value change. These results are then ranked by the amount of change from the original

expected results. Then, functions which caused the greatest change are identified as the most critical to the model.

TopRank Pro also includes over 30 probability distribution functions found in @RISK. These functions can be used along with Vary functions to describe variation in spreadsheet values.

How are TopRank Functions Entered?

TopRank functions are entered wherever you want to try different values in a What-if analysis. The functions can be added to any number of cells in a spreadsheet and can include arguments which are cell references and expressions — providing extreme flexibility for defining the possible variation of values in your spreadsheet models.

In addition to adding Vary functions yourself, TopRank can automatically enter Vary functions for you. Use this powerful feature to quickly analyze your spreadsheets without manually identifying values to vary and typing in functions.

Automated What-if's	When automatically entering Vary functions, TopRank traces back through your spreadsheet and finds all possible values which could affect the result cell you identify. As it finds a possible value, it substitutes in an "AutoVary" function with the default variation parameters (such as +10% and -10%) you've selected. With a set of AutoVary functions inserted, TopRank can then run its What-if analysis and rank the values which could affect your results in order of their importance.

With TopRank, you can step through your Vary and AutoVary functions and change the variation each function specifies. As a default you can use a -10% and +10% variation, but for a certain value you may feel that a -20% and +30% change is possible. You can also select to not have a value varied — as in some cases a spreadsheet value is fixed and could never be changed.

Running a What-if Analysis	During its analysis, TopRank individually changes values for each Vary function and recalculates your spreadsheet using each new value. Each time it recalculates, it collects the new value calculated in each result cell. This process of changing value and recalculating is repeated for each Vary and VaryTable function. The number of recalculations performed depends on the number of Vary functions entered, the number of steps (i.e., values across the min-max range) you want TopRank to try for each function, the number of VaryTable functions entered, and the values in each table used.

TopRank Results	TopRank ranks all varied values by their impact on each result cell or output you've selected. Impact is defined as the amount of change in the output value that was calculated when the input value was changed. If, for example, the result of your spreadsheet model was 100 prior to changing values, and the result was 150 when an input changed, there is a +50% change in results caused by changing the input.

TopRank results can be viewed graphically in Tornado, Spider or Sensitivity graph. These graphs summarize your results to easily show the most important inputs for your results.

Using PrecisionTree with TopRank

PrecisionTree offers one and two-way sensitivity analyses. But what if you want to look at larger combinations of variables, or vary values using more sophisticated methods? TopRank has the capabilities to handle more sophisticated and thorough sensitivity analyses of a decision tree with it's built in automatic sensitivity analysis, support for what-if tables and multi-way what-if capabilities.

Using TopRank to Run Sensitivity Analyses

Defining Outputs

When using TopRank with PrecisionTree, you use the TopRank Add Output command to define the start node of a tree (or any sub-tree) as a TopRank output. TopRank will then automatically identify the values in your decision tree and supporting spreadsheet models which affect the tree's expected value. It then varies these values to determine how changes in them affect your results.

Identifying Inputs

When a TopRank output is selected, all values affecting that output are identified and Vary functions are substituted for these values. For example, if you select the value of a Start node of a tree as an output, TopRank traces thorough all the relationships in your tree and finds all values, such as branch probabilities and branch values, which could affect your output. In addition to identifying values located in the tree itself, TopRank scans supporting spreadsheet models to identify inputs in those models that are referenced in the decision tree. For all identified inputs, TopRank substitutes Vary functions that will be used in a what-if analysis.

Running a What-if Analysis on a Decision Tree

During its analysis, TopRank individually changes values for each Vary function and recalculates your decision tree using each new value. Each time it recalculates, it collects the new value calculated for each output, such as a new expected value for the tree. This process of changing values and recalculating is repeated for each Vary and VaryTable function. The number of recalculations performed depends on the number of Vary functions entered, the number of steps (i.e., values across the min-max range) you want TopRank to try for each function, the number of VaryTable functions entered, and the values in each table used.

TopRank ranks all varied values by their impact on the expected value of the tree or the expected value of other nodes you've selected as outputs. Impact is defined as the amount of change in the output value that was calculated when the input value was changed. Your Tornado graph summarizes this ranking, showing which inputs were most critical in determining your decision analysis results.

Using Tables of Values in a Sensitivity Analysis of Your Decision Tree

TopRank includes a powerful function – VaryTable -- that allows you to calculate your decision tree's results for each value in a table of values. Examples of VaryTable functions are:

- *=RiskVaryTable(100,{50,80,120,150,175})*

- *=RiskVaryTable(100,A1:A10)*

During a what-if analysis, TopRank will return each value from the entered or referenced table and calculate your decision tree's result using that value. If, for example, the first VaryTable function above was used in place of a branch value of 100 in your decision tree, TopRank would recalculate the decision tree using the values 50, 80, 120, 150 and 175 as the branch value. TopRank would keep track of how each of these changes in branch value affected the expected value of the tree.

Appendix F: Glossary of Terms

@RISK　　　　　Pronounced "at risk," a risk analysis add-in for Microsoft Excel from Palisade Corporation.

Arc　　　　　An arrow connecting nodes in an influence diagram indicating a dependency between the two nodes. Arcs to chance nodes represent relevance while arcs to decision nodes represent the flow of information.

Barren Node　　　　　A node which has no effect on the decision to be made. In an influence diagram the node has predecessors but no successors.

Base Case　　　　　The state of a decision model before a sensitivity analysis is run, when all variables are set to their most likely value.

Bayes' Theorem　　　　　An algebraic formula that describes the relationship among the probabilities of dependent events. In decision analysis, Bayes' theorem is used to reorder (or "flip") two chance nodes in a decision model.

Branch　　　　　In a decision tree, a branch is drawn for each possible outcome of a decision or chance event.

Chance Node　　　　　A circle in a decision tree or influence diagram representing an event over which the decision maker has no control. Each outcome of the event has a corresponding value and probability.

Certainty Equivalent　　　　　The value you place on an uncertain situation, or the amount of money that you would accept to avoid a risky situation. In a decision tree, the certainty equivalent is calculated from the expected utility using the inverse of the utility function.
See Utility Function, Expected Utility.

Collectively Exhaustive　　　　　No other possibilities exist for a node.
See Mutually Exclusive.

Conditional Independence　　　　　Two nodes are conditionally independent given a third node if and only if the outcomes of the two nodes depend only the outcome of the third node and not on each other.

Constant Risk Aversion　　　　　A situation where the decision maker views a risky situation the same way no matter how much money he has.
See Decreasing Risk Aversion, Utility Function.

Cycle　　　　　In an influence diagram, a "loop" of arcs in which there is no clear endpoint. Cycles should be avoided in your decision models.

Decision Analysis	The process of modeling a problem situation, taking into account the decision maker's preferences and beliefs regarding uncertainty, in order to gain insight and understanding. Decision Analysis provides a systematic method for describing problems.
Decision Node	A square in a decision tree or influence diagram representing an event where the decision maker must choose one of a number of options. Each option has a value associated with it.
Decision Tree	A graphical representation of a problem describing chance events and decisions in chronological order. Events "branch" from their successors, making the final model look like a tree. Traditionally, decision trees begin with a decision node.
Decreasing Risk Aversion	A situation where risk becomes more attractive when the decision maker has more money. *See Constant Risk Aversion, Utility Function.*
Deterministic	A value or variable with no associated uncertainty. *See Stochastic, Risk.*
Deterministic Dominance	A situation where the dominating alternative pays off at least as much as the one that is dominated.
Deterministic Sensitivity Analysis	A sensitivity analysis where the variable is a payoff related to an event or events. *See Probabilistic Sensitivity Analysis.*
End Node	A triangle in a decision tree which represents the termination point of a branch.
Event	An outcome or group of outcomes that might result from a given action. Usually refers to the possible outcomes of a chance node.
Event Tree	A tree which begins with a chance node.
Expected Utility	The weighted average of the utility units for each outcome in a chance node. *See Utility Function.*
Expected Value (EV)	Weighted average of possible outcomes for a chance node or for an entire decision model.
Fault Tree	An event tree showing the relationship of prior events to an event in question, often the failure of some complicated system. Typically, fault trees contain only chance nodes.
Independent Nodes	In an influence diagram, if there are no arrows connecting two nodes, the nodes are independent if and only if the outcome of each node does not affect the outcome of the other.

Influence Diagram	A simple graphical representation of a problem which emphasizes the relationship between events. Although influence diagrams are less detailed than decision trees, they can show the "whole picture" in a way that is easy to explain to others
Kurtosis	A measure of the shape of a distribution indicating how flat or peaked the distribution is. The higher the kurtosis, the more peaked the distribution.
Logic Node	Similar to a decision node. Allows the decision maker to select the optimum choice by evaluating the logical expression of each child branch. Expressions at the nodes are usually logical formulas such as =x>5, =x=2, etc., which return either the value TRUE or FALSE.
Minimum	The lowest possible value that a variable can reasonably have.
Most Likely Value	The outcome with the highest probability of occurrence. In a Risk Profile, the most likely value is the value corresponding to the highest bar in the graph.
Mutually Exclusive	Only one outcome can occur at a node. *See Collectively Exhaustive.*
Objective Risk	A probability value or distribution that is determined by "objective" evidence or accepted theory. The probabilities associated with an objective risk are known with certainty. *See Subjective Risk.*
One-Way Sensitivity Analysis	An analysis of the effect of a single variable on the outcome of a model. Results are typically displayed in a One-Way Sensitivity Graph. *See Sensitivity Analysis.*
One-Way Sensitivity Graph	A graph comparing a variable against the expected value of a model as the value of the variable ranges from its lower to upper bound. *See Sensitivity Analysis, One-Way Sensitivity Analysis.*
Oriented Diagram	An influence diagram that contains a payoff node. *See Influence Diagram.*
Payoff Node	A rectangle with rounded corners in an influence diagram which represents the payoff of a decision.
Policy Suggestion	An outline of the optimum decision path in a model, the results of a decision analysis.
Predecessor Node	The node directly before the selected node. *See Successor Node.*
Probabilistic Dominance	Occurs when the preferred alternative pays the same as the other with a greater probability of payoff. *See Stochastic Dominance.*

Probabilistic Sensitivity Analysis	A sensitivity analysis where the variable is the probability of a chance occurrence or occurrences. *See Deterministic Sensitivity Analysis.*
PrecisionTree	The decision analysis add-in for Microsoft Excel described in this User's Guide.
Probability	A measure of how likely a value or event is to occur.
Proper Diagram	An influence diagram that is an unambiguous representation of a single decision maker's view of the world.
Reduction	The act of representing the probability distribution for the objective function of an entire model as a single chance variable.
Reference Node	A diamond in a decision tree representing an event described by a separate decision tree.
Risk	Uncertainty or variability in the outcome of some event or decision. In many cases the range of possible outcomes can include some that are perceived of as undesirable along with others that are perceived as desirable. The range of outcomes is often associated with levels of probability of occurrence.
Risk Analysis	Any method used to study and understand the risk inherent to a situation of interest. Methods can be quantitative and/or qualitative in nature.
Risk Averse	An attitude toward risky situations where a decision maker is less likely to chose a situation with a higher payoff if it includes a proportionately higher risk. There are situations where individuals may display the opposite behavior; they are risk takers. *See Risk Neutral.*
Risk Neutral	A decision maker who always selected the alternative with a higher payoff, regardless of risk. *See Risk Averse, Bayesian.*
Risk Premium	The difference between the expected value and the certainty equivalent of an uncertain event, or the amount of money you are willing to give up to avoid risk. *See Expected Value, Certainty Equivalent.*
Risk Profile Cumulative Chart	A distribution function that shows the probability that the outcome of the model is less than or equal to a specified value. *See Risk Profile Probability Chart.*
Risk Profile Probability Chart	A distribution function that shows the probability that an outcome may occur. *See Risk Profile Cumulative Chart.*

Risk Tolerance	A constant measuring the decision maker's attitude towards risk, is a parameter in the utility function. *See Utility Function.*
Sensitivity Analysis	A determination of which variables matter most in a decision (are most critical) by examining the impact of reasonable changes in base-case assumptions. Sensitivity analysis is useful for finding variable that have little impact on the final decision so that they may be treated deterministically. *See TopRank.*
Skewness	A measure of the shape of a distribution indicating the degrees of asymmetry in a distribution. Skewed distributions have more values on one side of a peak or most likely value - one tail is much longer than the other. A skewness of zero indicates a symmetric distribution, negative and positive skewness values indicate distributions that are skewed to the left and right, respectively. *See Kurtosis.*
Spider Graph	A graph showing the reasonable limits of change for each independent variable and the unit impact of these changes on the expected value of a model.
Standard Deviation	The square root of the variance. *See Variance.*
Stochastic	Uncertain or risky. *See Risk, Deterministic.*
Stochastic Dominance (First Order)	Occurs when two profiles on a cumulative risk profile do not cross and there is space between them. There a two forms of stochastic dominance. The first, called payoff, occurs when the preferred alternative pays more than the other with an equal probability of payoff. The second, called probability, occurs when the preferred alternative pays the same as the other with a greater probability of payoff. Stochastic dominance can contain a combination of both forms, but the dominant alternative always has a higher expected value.
Strategy Region Graph	Created after a two-way sensitivity analysis, a strategy region graph shows regions for which different strategies are optimal and provides guidance in determining how much effort is needed to model uncertainty in a decision problem. Demonstrates the extent to which the decision is sensitive to uncertainty.
Subjective Risk	A probability value or distribution determines by an individual's best estimate based on personal knowledge, expertise, and experience. New information often causes changes in such estimates and reasonable individuals may disagree on such estimates. *See Objective Risk.*

Successor Node	The node directly after the selected node. *See Predecessor Node.*
TopRank	Sensitivity analysis add-in for Microsoft Excel by Palisade Corporation.
Tornado Graph	Created after a one-way sensitivity analysis, a Tornado Graph shows how much the value of an alternative can vary with changes in a specific quantity when all other variables remain at their base values.
Two-Way Sensitivity Analysis	An analysis of the impact of two simultaneously changing variables on the outcome of a model. *See Sensitivity Analysis.*
Two-Way Sensitivity Graph	Created after a two-way sensitivity analysis, a two-way Sensitivity Graph shows regions where the expected value of the model is greater than a specified target value.
Uncertainty	*See Risk.*
Uncertainty Node	Node representing an event with an uncertain outcome. *See Chance Node.*
Utility Function	An expression that measures risk by converting the payoffs related to an outcome to utility units. The utility of one decision is then compared to that of another decision to select the optimum decision.
Value Sensitivity Analysis	Measuring the effects of model inputs on the decision policy by varying any value in the model and examining the effects on the optimal policy and expected value.
Variable	A basic model component that can take on more than one value. If the value that actually occurs is not known with certainty, the variable is considered uncertain. Usually a variable is found in a cell or named range in your model.
Variance	A measure of how widely dispersed the values are in a distribution, and thus is an indication of the "risk" of the distribution. It is calculated as the average of the squared deviations about the mean. The variance gives disproportionate weight to "outliers," values that are far away from the mean. *See Standard Deviation.*

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