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Using PrecisionTree with @RISK ........................................... 157
Welcome to PrecisionTree, the decision analysis add-in to Microsoft Excel. Now you can do something you have 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 trying 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. PrecisionTree 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 ribbons and menus.

With PrecisionTree, there is no limit to the size of the tree you can define. PrecisionTree reduces the tree to an easy-to-understand report right in your current workbook.
**PrecisionTree Nodes**

PrecisionTree allows you to define decision tree and influence diagram 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. Decision trees outline the chronological and numerical details of the decision, while influence diagrams are useful for showing the relationship between events and the general structure of a decision clearly and concisely.

**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. As you edit your tree, all payoffs and node values are automatically recalculated.

**Decision Analysis**

PrecisionTree's decision analyses provide 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 is no need to learn a whole new set of formatting commands because all PrecisionTree reports can be modified like any other Excel worksheet or chart.
If you ever wondered which variables are the most important drivers of your decisions, you need PrecisionTree’s sensitivity analysis options. You can perform both one and two-way sensitivity analyses and generate tornado graphs, spider graphs, strategy region graphs, and more.

If you need more sophisticated sensitivity analyses, PrecisionTree links directly to TopRank, Palisade Corporation’s sensitivity analysis add-in.

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 that follow the node. A single subtree can be referenced from multiple nodes in other trees, saving the re-entry of the same tree over and over.

@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 by using distribution functions. Then with 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.

You can 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.

PrecisionTree offers many advanced analysis options including:

- Utility functions
- Use of multiple worksheets to define trees
- Logic nodes
- Bayesian revision
- Sensitivity analysis
Chapter 2: 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 2007 or higher.

About This Version

This version of PrecisionTree can be used with Microsoft Excel 2007 or higher.

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. There is no such limit in the Industrial version.

Working with your Operating Environment

This manual 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, ribbon, and window.
- You understand basic concepts such as directory (folder) 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 consulted the relevant sections of this online manual?
• Have you watched the online Quick Start videos available from the NeuralTools Welcome screen?
• Have you read the README file? It contains current information on PrecisionTree that might 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 consulted our Web site, www.palisade.com? This Web site contains the latest FAQ (a searchable database of tech support questions and answers). 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
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- Fax us at +44 1895 425051 (UK).
- Mail us a letter to:
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  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.

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.
- Go to [www.palisade.com](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 for Microsoft Excel or higher for Windows include:

- Microsoft Windows XP or higher.
- Microsoft Excel 2007 or higher.
Installation Instructions

General Installation Instructions

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

- Double-click the PrecisionTree Setup.exe (or the DTSuite Setup.exe) from your download or installation CD.
- 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.

If you wish to remove PrecisionTree from your computer, use the Control Panel’s Add/Remove Programs utility and select the entry for PrecisionTree (or the DecisionTools Suite).

The DecisionTools Suite

PrecisionTree for Excel is a member of the DecisionTools Suite, a set of products for risk and decision analysis. The default installation procedure of NeuralTools puts PrecisionTree in a subfolder of a main Program Files\Palisade (or Program Files (x86)\Palisade) folder.

One subfolder of this Palisade folder will be the PrecisionTree folder (by default called PrecisionTree7). This folder contains the program files plus example models and other files necessary for TopRank to run. Another subfolder of the Palisade folder is the SYSTEM folder. This contains files required by every add-in in the DecisionTools Suite, including common help files and program libraries.
Software Activation

Activation is a one-time license verification process that is required for your Palisade software to run as a fully licensed product. An activation ID is on your printed/emailed invoice and is a dash separated sequence like "DNA-6438907-651282-CDM". If you enter your Activation ID during installation, your software is activated at the end of the installation process and no further user action is required. If you need to activate your software after installation, select the License Manager command from the PrecisionTree Help menu.

The License Manager can be used to activate, deactivate, and move software licenses. It is also used to manage licenses for network installations. Follow the prompts and dialogs in the License Manager to perform the desired licensing operation.
Instructional Materials

The PrecisionTree package includes a number of instructional materials to help you learn PrecisionTree features and how to model with PrecisionTree.

Example Spreadsheets

PrecisionTree includes about 20 example spreadsheets. Some of these examples illustrate specific features of PrecisionTree, whereas many others illustrate potential uses of PrecisionTree in various fields. These examples not only help you learn how to use PrecisionTree, but they illustrate how extensively PrecisionTree can be applied.

You can find these example spreadsheets from the PrecisionTree Help menu. When you click its Example Spreadsheets command, an “example file list” file opens in Excel. This file contains links to all of the example files.

Quick Start Tutorials

From the PrecisionTree Welcome screen, which you see when you launch PrecisionTree or can access at any time from the PrecisionTree Help menu, you can click the Quick Start link to see a series of short videos that lead you through the basic features of PrecisionTree. These Quick Start videos are intended for beginners, but they are sufficient to get you started creating your own PrecisionTree models.

Guided Tour Videos

A series of Guided Tour videos is also available from the PrecisionTree Welcome Screen. These are more in-depth videos, and they lead you through practically all of the PrecisionTree features, from simple to more complex.

Examples and Videos for the XDK

Once you are comfortable using PrecisionTree, you might want to learn how to use the macro language of Excel, Visual Basic for Applications (VBA), to automate PrecisionTree procedures. PrecisionTree provides an Excel Developer Kit (XDK) for doing this. You can learn about the XDK from the Developer Kit (XDK) command on the PrecisionTree Help menu. There you will see links to example spreadsheet models of PrecisionTree automation, as well as additional instructional videos on using the XDK.
Chapter 3: Overview of Decision Analysis

Introduction

Decision analysis provides a systematic method for describing problems where you have to make one or more sequential decisions, usually in the face of uncertainty. It is the process of modeling a problem situation, taking into account the decision maker’s preferences and beliefs regarding uncertainty. The goal is to identify the “best” decisions.

The term “decision strategy” (or simply “strategy”) is sometimes used instead of the term “decision.” A decision is a choice of an alternative at one point in time. Many problems involve only a single decision. However, other problems involve a sequence of decisions. For example, in a medical situation, the first decision might be whether to perform an expensive test on a patient. Then, if the test is performed and after its results are known, a second decision might be whether to operate on the patient. In this case, the goal of the decision problem is to find the best strategy, or sequence of decisions. Of course, the best second decision can depend on previous results, such as “operate if the test shows malignancy, and don’t operate otherwise.”

A decision analysis provides a straightforward report consisting of the preferred decision strategy and the consequences of following it. Decision analysis can also produce more qualitative results by helping decision makers understand trade-offs, conflicts of interest, and important objectives.
Decision Trees, Influence Diagrams, and BigPicture

Decisions can be modeled in two forms, decision trees and influence diagrams. PrecisionTree provides full support for both of these. Decision trees are best for actually “solving” a decision problem. They show all of the elements of the problem—the timing, the possible decisions, the uncertain outcomes, the payoffs and costs, and the probabilities—in a form that is straightforward and easy to understand. In the “folding back” process, which is automated by PrecisionTree, you can see directly in the worksheet how the tree is used to identify the best decisions.

In contrast, influence diagrams are best for showing decision problems from a “high-level” view, not for showing the numerical details. Influence diagrams in PrecisionTree can indeed capture the numerical details and perform calculations in a decision problem, but they do so in a much less straightforward manner than decision trees. In essence, influence diagrams show the “big picture” and mask the details, although the details are there.

The BigPicture add-in introduced in version 7 of the Palisade DecisionTools Suite provides a potential substitute for influence diagrams. Indeed, as its name implies, the whole purpose of BigPicture, a drawing add-in for Excel, is to display a “big picture” for various types of problems, including decision problems. It makes no attempt to perform numerical calculations for solving decision problems. Its much more modest goal is to show how different elements of a decision problem are related. In short, BigPicture fills the role of influence diagrams but is much easier to use and understand.
Decision Trees

Decision trees describe events in chronological order and show all of the quantitative data relevant to the problem. They use nodes and branches connecting the nodes to show graphically how decisions unfold through time (from left to right in the tree).

- **Nodes.** Each node represents a point in time. A decision node (shown as a green square) is a time when a decision must be made. A chance node (shown as a red circle) is a time when an uncertain outcome is revealed. An end node (shown as a blue triangle) indicates that the problem is over—all decisions have been made and all uncertainty has been resolved. Two additional nodes (logic and reference) are available for advanced modeling.

- **Branches.** Decision trees use branches to connect nodes. The following types of branches extend (to the right) from the three main node types in a decision tree:
  - A decision node has a branch extending from it for every possible decision at that point in time.
  - A chance node has a branch for each possible outcome.
  - An end node has no branches extending from it. It simply returns the payoff and probability for the associated sequence of decisions and outcomes that lead to it.

**Sports Wager Example**

A simple decision to model is one where there is one decision and one chance event following the decision. For example, suppose you have an opportunity to bet on a sports game. Your decision is whether to bet on team A or team B. The chance event is the outcome of the game. The payoff node represents the monetary payoff (or loss) of the wager.

The time sequence is that you first decide which team to bet on, then you observe which team wins, and finally you receive a payoff.

Suppose you must pay $1 to place a bet, there is 37.5% chance that team A will win and a 62.5% chance that team B will win, and your payoff is $5 if you bet on team A and it wins, or $3 if you bet on team B and it wins. If you bet on the losing team, your payoff is $0.
The resulting decision tree is as follows. (This isn’t exactly PrecisionTree’s format; it is the format you might use if you drew the tree by hand. However, it is similar to PrecisionTree’s format.)

In this tree, the possible decisions, payoffs (or losses), and probabilities are visible right on the diagram. However, even with this very simple problem, you can begin to see a drawback of decision trees—they can be large and “bushy.” You can imagine how large a tree can be when there are many possible decisions and many uncertain outcomes.

**Guidelines for Designing Trees**

A decision tree should represent all possible events as accurately as possible. You should follow these guidelines when designing a decision tree.

- **Define decision nodes so that only one option can be chosen at each node and every possible option is included.** The following 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, the tree should have more (and different) options.
• Define chance nodes so they are mutually exclusive and collectively exhaustive. That is, only one of the branches can occur, and one of them must occur. In the following, the branches from the node on the left are not mutually exclusive, as it can snow on Monday and be sunny on Tuesday. The branches from the node on the right are not collectively exhaustive, as it could rain on Monday.

\[
\begin{align*}
\text{Snow on Monday} & \quad \text{Snow on Monday} \\
\text{Sunny on Tuesday} & \quad \text{Sunny on Monday}
\end{align*}
\]

• The tree should proceed chronologically from left to right. Putting the chance node first, as in the following 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, to the left of the chance nodes.

\[
\begin{align*}
\text{Wager on Team A} & \quad \text{Wager on Team B} \\
37.5\% & \quad 62.5\% \\
\text{Wager on Team A} & \quad \text{Wager on Team B} \\
62.5\% & \quad \text{Wager on Team B}
\end{align*}
\]

Solving Decision Trees

The method for calculating the optimum path in a decision tree is called “folding back.” Briefly, the folding back process consists of the following steps:

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 optimal 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.

Fortunately, this process is automated by PrecisionTree. Once you have built the “skeleton” of the tree and have entered the payoff/cost and probability data, PrecisionTree performs the folding back calculations automatically. If the data is then changed, the tree recalculates automatically to show new results of the folding back process.
Although you don’t need to perform the folding back process with Excel formulas, you do need to understand and be able to interpret the results. The example file Bidding Decision 1a – PrecisionTree Calculations.xlsx is very useful in this regard.

**Risk Profiles**

The above steps describe how to determine the optimal path in a decision tree. But you also need to know the consequences of following the suggested path. This can be shown compactly with a risk profile.

A risk profile is a probability distribution showing the possible payoffs (or losses) and the associated probabilities for any decision strategy. A risk profile is graphed as a discrete distribution in a probability chart, or it can be shown as a cumulative distribution in a cumulative chart. The discrete distribution shows the probability that the outcome equals any value $X$. The cumulative distribution shows the probability that the outcome is less than or equal to any value $X$.

**Policy Suggestion**

A policy suggestion report is a subtree of the full decision tree. This subtree shows only the nodes and branches that are relevant when following the optimal strategy. It lets you focus on the part of the tree could occur, assuming that you follow the optimal strategy.

**Sensitivity Analysis**

Sensitivity analysis is an important component of any decision analysis. It lets you discover the key drivers of the decisions you make, and it shows how changes in various inputs can change the optimal decision strategy. PrecisionTree makes it easy to perform one or more sensitivity analyses, and its results are easy to understand.

Before getting into the details of sensitivity analysis, the following terms are used:

- 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** and **maximum** values of an input are the lowest and highest possible values you think this input can reasonably have.
One-Way and Two-Way Sensitivity Analysis

One-way sensitivity analysis studies the effect of a single input on the expected value of a model. This expected value corresponds to the expected payoff from a designated time (that is, a node) to the end of the problem.

Before running a one-way sensitivity analysis, you must decide which input you want to study, and you must define the upper and lower limits on 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 entered in the model and the expected value is calculated. This expected value is referred to as the base case of the model; it is the value that all subsequent results are compared to.

During the sensitivity analysis, the input value is varied from its minimum value to its maximum value in a sequence of equally-spaced steps, and a new expected value is calculated at each step. Finally, the input is returned to its original value so that another input can be analyzed.

Two-way sensitivity analysis is similar, except that it varies two inputs simultaneously over their min-max ranges, keeping all other inputs at their base values.

PrecisionTree shows the sensitivity results in several types of graphs, including tornado graphs, spider graphs, and strategy region graphs. These graphs are discussed in detail later in this manual.
Influence Diagrams

Influence diagrams present a decision in a simple, graphical form. Decisions, chance events, and payoffs (values) are drawn as shapes (again called nodes) and are connected by arrows (called arcs) which define their relationship to each other. In this way, a complex decision can 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 can contain different forms of influence: value, timing, or structural (or a combination of the three).

**Sports Wager Example**

The influence diagram for the same betting decision discussed in the previous section appears as follows.

Because the wager and the game outcome both 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, whereas 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 can 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 of 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

You should follow these additional guidelines when designing your influence diagram.

- **An influence diagram should have only one payoff node.** There should only be one endpoint of the analysis, as described by the payoff node. The following example contains two payoff nodes. The cost of the speeding fine and the increase in the insurance premium should be combined into one payoff node.

![Influence Diagram with Two Payoff nodes](image)

- **An 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, you can trace back from the payoff node. If you see 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?

- **An 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 because it has no successors. The Team Standings node does have one successor, but because the successor is a barren node, the Team Standings node is also barren.
### Influence Diagrams versus Decision Trees

As described here, PrecisionTree allows you to create an accurate and understandable model of your decision problem with a decision tree or an influence diagram. Each form of a decision model has both advantages and drawbacks, as discussed briefly here.

**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 an influence diagram very compact, helping everyone to understand the key aspects of the decision problem without getting bogged down in numerical details. You will 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.

**Drawbacks to Influence Diagrams**

The drawback to influence diagrams is their abstraction. As implemented in PrecisionTree, the numerical details are there, but they aren’t visible on the worksheet.

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 accurately depicts the timing present in your decision problem.

**Benefits of Decision Trees**

Decision trees 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 worksheet. There is very little ambiguity as to the possible outcomes and decisions the tree represents. You can look at any node and see all possible outcomes resulting from the node and the events and decisions that follow.

**Drawbacks to Decision Trees**

Decision trees can become very “bushy,” even for moderate-sized problems. They can easily become too large to fit on a screen (unless you zoom out so much that the text and numbers are no longer readable). This is an inherent problem with decision trees and has nothing to do with PrecisionTree’s implementation. However, PrecisionTree tools can help to alleviate this problem by hiding parts of the tree and letting you focus on one section at a time.
If you find that influence diagrams are difficult to master, but you still want to be able to see a compact display of a decision problem, you can instead use BigPicture, Palisade’s newest add-in in the DecisionTools Suite. BigPicture allows you to create a diagram of the decision problem, with virtually no rules imposed. Unlike influence diagrams in PrecisionTree, a diagram in BigPicture does not have to “embed” all of the quantitative information (payoffs and probabilities) or follow tricky guidelines. It is simply a picture that allows you and your colleagues to discuss a decision problem from a top-level view. Then you can use a decision tree to show all the details and eventually find a best decision strategy.

PrecisionTree even lets you go the other direction. If you first create a decision tree, you can click a button on the PrecisionTree ribbon to produce a BigPicture diagram implied by the decision tree. This allows you and your colleagues to discuss the details in the tree or discuss the “big picture” in the diagram.
Chapter 4: Overview of PrecisionTree

Introduction

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

PrecisionTree Ribbon

PrecisionTree extends the analytical capabilities of Excel to include decision analysis with decision trees and influence diagrams. To add decision analysis capabilities to your spreadsheet, PrecisionTree uses commands on the following ribbon.

Decision trees and influence diagrams are created directly in Excel, and all PrecisionTree results and graphs are generated as Excel charts or worksheets for further customization and presentation.

Defining Nodes

In PrecisionTree, nodes of a decision tree or influence diagram 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 that node. For an influence diagram, the probabilities and values associated with the possible outcomes for a node are entered in a value table. This value table is displayed when you right-click a node. The table is a standard Excel worksheet with cells, rows, and columns.

PrecisionTree provides an easy-to-use interface, where nodes are entered in your spreadsheet automatically. Once a tree is started, nodes can be edited or added by clicking node in your worksheet. Left-
clicking a node displays its settings. Right-clicking a node displays a PrecisionTree menu with additional commands. Influence diagram nodes are added by clicking the **Influence Diagram/Node** icon on the ribbon.

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 to the right of each node. Each branch has a label and two values in cells above and below the branch. For a chance node, the two values are the branch probability and the branch payoff value. For a decision node, the top cell for each branch has a TRUE or FALSE, indicating whether the branch is part of the optimal strategy, and the bottom cell contains the branch payoff value. For an end node, two values are shown: the probability that the path through the tree will occur when the optimal strategy is used, and the combined payoff value of the path.

PrecisionTree uses a color-coding system for node and branch values in a decision tree. This will be explained in more detail later in this manual, but for now, you will notice that numbers on the tree are either red, green, blue, or black. The values in red, green, and blue use special PrecisionTree formulas, and you should not change them. The numbers in black are for user inputs. These are the cells you can change by entering monetary values or probabilities. You can enter values directly in the black cells, or you can cell reference values elsewhere in the workbook.

You will occasionally see errors in decision tree cells. The most likely cause is that the probabilities of branches emanating from a node do not sum to 1. If this occurs, you need to make the probabilities sum to 1.
The following decision tree is taken from the Basic Tree Terminology.xlsx example file. It is annotated with text boxes to explain the various parts of the tree.

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. Clicking the node 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 can be entered by clicking an arc.
The following influence diagram is taken from the **Oil Drilling 7 - Influence Diagram.xlsx** example file. It is annotated with text boxes to explain the various parts of the diagram.

**PrecisionTree**

### Influence Diagram Defined in PrecisionTree

**Drill Decision:**
- This is where the decision is made whether to drill. Drilling costs $500,000, not drilling costs nothing.

**Amount of Oil:**
- This indicates the amount of oil found and the cost of drilling and testing.

**Test Results:**
- This indicates the amount of oil found and the cost of drilling and testing.

**Influence Arc from Test Results to Drill Decision:**
- This arc indicates timing influence. The decision to drill must come after the test results are determined.

**Influence Arc from Amount of Oil to Test Results:**
- This arc indicates influence, but no timing influence. Amount of oil influences the results of the test, but the amount of oil is not known until after the test results.

**Influence Arc from Drill Decision to Amount of Oil:**
- This arc indicates structural influence. If the decision is made not to drill, the amount of oil is treated as unknown.

### Results Shown in a Decision Tree or Influence Diagram

PrecisionTree displays a set of results for your decision model in real time, so that your results change 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. 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, much of the decision analysis is already complete. Specifically, if you have created a decision tree, together with all the payoffs/costs and probabilities, PrecisionTree does the folding back process automatically (using its special formulas in the red, green, and blue cells). This identifies the optimal strategy and its consequences as follows:

- Starting at the left, you can follow the branches with TRUE labels to identify the optimal strategy.
- The number to the right of any node represents the expected payoff (or cost) from that time point onward, assuming that an optimal strategy is used from then on.

In other words, much of the information you need is automatically available in the tree as soon as it has been created. However, more information is available through PrecisionTree’s tools, discussed next.

Risk Profile and Policy Suggestion

In a complex decision problem, it can be difficult to follow all the paths and payoffs that correspond to an optimal strategy. Therefore, PrecisionTree offers two tools, risk profile and policy suggestion, to help you understand decision strategies better. Both of these tools are available from the Decision Analysis menu on the PrecisionTree ribbon.

A risk profile is the probability distribution of payoffs/costs corresponding to a given strategy, usually the optimal strategy. It can be shown as a probability chart or a cumulative probability chart, along with a table of values and probabilities and an optional statistical summary table.

The following risk profile, taken from one of the oil drilling example files, is typical. It shows that if the optimal strategy is used, there are four possible payoffs (two of which are actually losses), with probabilities listed in the table and reflected in the graph.
A policy suggestion is a subtree of the full decision tree. If you start from the left and follow only decision branches with TRUE labels—that is, you follow the optimal strategy—the policy suggestion subtree shows only the branches you would ever visit. In other words, if you follow the optimal strategy, the rest of the original decision tree is irrelevant.

Here is the policy suggestion for the same oil drilling problem. Note that at each decision node, this subtree indicates with certainty which branch will follow next. However, it can’t indicate with certainty which branch will be followed from chance nodes. Therefore, any of the 7 paths from left to right could occur. The blue probabilities to the right of the end nodes are the probabilities of these 7 paths, and they sum to 1.
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, you click the Sensitivity Analysis icon on the PrecisionTree ribbon. PrecisionTree prompts you for the output and the cell(s) to vary. This is explained in more detail later in this manual.

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. For example, the following graph shows how the expected payoff from the tree varies as the “large payoff” input in cell C7 varies over a range.
The following “strategy region” graph is even more useful. It shows how the expected payoffs from two possible decisions vary as the “drilling cost” input in cell C4 varies over a range. The interest here is in the point where the two lines cross. To the left of this point, the Don’t Test decision provides the larger expected cost, so it is the best decision; to the right of this point, the Test decision is best.
You can also run a “one-way” sensitivity analysis for multiple inputs. In this case, PrecisionTree creates graphs like the ones above for each selected input, and it also provides the option of Tornado and/or Spider graphs. These graphs let you see how sensitive an expected value from the tree is to each input.

With a Tornado graph, there is a bar for each input showing much the expected value varies as the input varies over its range. The most influential inputs, those with the longest bars, are shown at the top.

A spider graph is similar. It has a line (or curve) for each input, showing how the expected value varies as the input varies over its range. The inputs with the steepest slopes are the most influential.
In a two-way sensitivity analysis, you designate two inputs, one for the X-axis and one for the Y-axis. These two inputs are then varied over combinations of their values. The most useful graph in this case is another type of “strategy region” graph, where each point corresponds to a combination of input values and their shapes indicate the best decision for the combination.
Developing a Decision Tree

This section provides a more in-depth look at the process of developing a decision tree in Excel with PrecisionTree. You will learn how to create a decision tree by defining nodes and branches.

Defining the Decision

To design a decision tree, you must define the events involved in your decision. Always remember that events in a decision tree progress in chronological order from left to right.

For example, here is the classic oil-drilling example.
The 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. In particular, the decision to test is made before the decision to drill.

Creating a New Tree

To create a decision tree using PrecisionTree, select a blank cell. (It helps if there is plenty of blank space below and to the right of this cell. PrecisionTree won’t overwrite cell contents, but it will move them to make way for the tree.) Then click the Decision Tree icon on the PrecisionTree ribbon. This opens the Model Settings dialog, with the General tab selected. This tab lets you give a descriptive name, such as “Oil Drilling” to the tree. The other tabs, discussed later in this manual, provide a number of other useful options for the tree.

When you click OK, the following tree is created. If you need to open the Model Settings dialog again, you can click the Oil Drilling “name” box, or you can choose Model Settings from the Settings menu.
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). This opens the following dialog, where you can choose the type of node. In this case, you should click the Decision option.

This leads to the following Node Settings dialog, where you can give a descriptive name like “Test Decision” to the decision node, and you can specify information about the branches emanating from this node.
Specifically, 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 can be entered directly in your Excel worksheet or through the Node Settings dialog. In this example, you can replace the generic branch labels, Branch #1 and Branch #2, with the more descriptive labels Test and Don’t Test. Again, you can type these labels directly in the worksheet, or you can enter the names in the Node Settings dialog.

A branch value is also needed for each branch from the decision node. Because testing costs $55,000, the value for the Test branch is -55000. The value for the Don’t Test branch is 0 because there are no costs associated with that option. You can type these values directly in the worksheet, in the cell below the branch name. This is where the default branch value of 0 is located. Alternatively, you can enter the values for each branch in the Node Settings dialog.

Note the buttons at the right in the Node Settings dialog. These allow you to add, delete, or rearrange branches from that node.

Here is the resulting tree. Note that each end node (a blue triangle) shows the value (bottom) and probability (top) of the path through the tree that terminates at that end node.

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. In this simple example, the value (so far) is 0, because not testing is less expensive than testing.

Each branch from a decision node has a TRUE or FALSE decision indicator. If a branch is selected as the best decision, 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 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 is placed to the right of the Test outcome, replacing the existing end node.

To replace an end node with a chance node, click the end node to be replaced, select Chance as the node type, and fill in the Node Settings dialog. This is the same dialog as for a decision node, except that the branches now have probabilities, as well as monetary values. As always, you can enter these probabilities directly in the worksheet, or you can specify them in the Node Settings dialog. Note that for this example, there are three possible outcomes of the test, so the “plus” icon was used to create a third branch.
After you provide labels and probabilities (38%, 39%, and 23%) for the three branches, the following tree results.

Note the layout of the decision tree PrecisionTree has drawn for you. In the cells to the right of each node are the name of the node and its expected value. (These expected values aren’t very interesting yet, but they will be shortly.) You can see the names, values, and probabilities for each node’s branches next to the branches themselves. The probabilities are above the branches and the monetary values are below the branches. You can edit these values and labels directly in your worksheet if necessary. (Remember, they are in black font, so you are allowed to change them.)
Completing the Tree

The entire decision can be completed 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.

As always, the payoff and probability for each path through the tree are shown to the right of 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. (You can find this tree in the example file Oil Drilling 1 – Basic PrecisionTree Model.xlsx.)
Developing an Influence Diagram

This section provides a more in-depth look at the process of developing an influence diagram in Excel with PrecisionTree. (You can skip this section if you plan to use decision trees only.) You will learn how to create an influence diagram by defining nodes and arcs. In addition, you will learn how to 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 that was modeled with a decision tree in the previous section. (You can find the completed influence diagram in the example file Oil Drilling 7 - Influence Diagram.xlsx.)

Creating a New Influence Diagram

To create an influence diagram with PrecisionTree, select a blank cell. (It helps if there is plenty of blank space below and to the right of this cell. PrecisionTree won’t overwrite cell contents, but it will move them to make way for the tree.) Then click the Influence Diagram/Node icon on the PrecisionTree ribbon. This opens the Model Settings dialog, with the General tab selected. This tab lets you give a descriptive name, such as “Oil Diagram” to the influence diagram. The other tabs, discussed later in this manual, provide a number of other useful options.
When you click OK, the following influence diagram and accompanying statistical table are created.

<table>
<thead>
<tr>
<th>Oil Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Value</td>
</tr>
<tr>
<td>Std. Deviation</td>
</tr>
<tr>
<td>Minimum</td>
</tr>
<tr>
<td>Maximum</td>
</tr>
</tbody>
</table>

### 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.
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 the model. To create this node, click the Influence Diagram/Node icon on the ribbon and select the cell where you want to place the node. In the Influence Node Settings dialog, first change the name to Amount of Oil.

There are three possible outcomes for Amount of Oil: Large well, Small well, and Dry well. These are specified in the Outcomes tab. By clicking the Add button, you can add a third outcome to the default Outcome #1 and Outcome #2.
Adding Other Nodes

Now, you can add the remaining nodes and their possible outcome names to the diagram. Specifically, click the Influence Diagram/Node icon and select the cell where you want each node positioned to 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, Large well, Small well and Dry well.

This will lead to a diagram that looks something like the following. (You can drag any of the nodes to a new position to get the layout you prefer.)

The next step is to connect the nodes with arcs that indicate the relationships among the elements of the model.
Entering Arcs

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

In the current example, the Amount of Oil chance node influences two other nodes: the Test Results and Payoff nodes. The values for Payoff and Test Results (and the probabilities for Test Results) are influenced by the Amount of Oil outcome. That is, different values for Payoff and Test Results will be specified for each possible Amount of Oil outcome. This influence is shown in the diagram by drawing arcs from the Amount of Oil node to the Payoff and Test Results nodes. You create an arc by clicking the Influence Arc icon and specifying the source and destination nodes.

![Influence Arc Settings Dialog](image)

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. Depending on which node types are being connected, some options will be checked and/or disabled.
Some influence arcs specify a value influence, as described here between Amount of Oil and Payoff. Other arcs only indicate timing (where one event must occur prior to another) or structure (where an outcome for one event affects the outcomes that occur for another event, or whether the event takes place at all). An arc can specify multiple types of influence. For example, the 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 critical 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 create an “asymmetric” tree. The decision tree that 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 – Indicates small - Drill – Large well).

To define all relationships for the Oil Drilling model, you can add the following influence arcs with specified influence types 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 (you won’t 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 (you won't 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. When a structure influence is desired, it is necessary to specify how the predecessor node affects the structure of the outcomes for the successor node. When you select structure influence in the Influence Arc Settings dialog, you can describe the type of structure in the Structural Influence Table.

![Influence Arc Settings](image)

Each of the outcomes from the predecessor node (in this case, Drill Decision outcomes) can have a structural influence on the outcomes from the Amount of Oil successor node. 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 a node and selecting *Influence Value Table* displays the Value Table (in a new Excel worksheet) for the node. This is where you can 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 worksheet with values of influencing nodes shown. In the Value Table, values and probabilities are entered in the white columns. For example, the following Value Table shows the possible values for Amount of Oil and their probabilities.

<table>
<thead>
<tr>
<th>Amount of Oil</th>
<th>Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value when skipped</td>
<td>0.00000</td>
<td></td>
</tr>
<tr>
<td>Large well</td>
<td>3400000</td>
<td>0.2</td>
</tr>
<tr>
<td>Small well</td>
<td>1500000</td>
<td>0.3</td>
</tr>
<tr>
<td>Dry well</td>
<td>0</td>
<td>0.5</td>
</tr>
</tbody>
</table>
As another example, the Amount of Oil chance node influences the probabilities of the Test Results chance node. There are three different possible outcomes for Test Results: Indicates dry, Indicates small, and Indicates large. (There are no values associated with these results, only probabilities.) For each possible outcome for Amount of Oil, a different probability is entered for each Test Result.

<table>
<thead>
<tr>
<th>Test Results</th>
<th>Value</th>
<th>Probability</th>
<th>Amount of Oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicates dry</td>
<td></td>
<td>0.1</td>
<td>Large well</td>
</tr>
<tr>
<td>Indicates small</td>
<td></td>
<td>0.3</td>
<td>Large well</td>
</tr>
<tr>
<td>Indicates large</td>
<td></td>
<td>0.6</td>
<td>Large well</td>
</tr>
</tbody>
</table>

In the influence diagram, probability information is entered for Test Results at each possible outcome for Amount of Oil. These events, however, occur in the opposite sequence chronologically—you learn the Test Results prior to learning 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.

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.
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.

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 to the left of the Excel formula bar 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.

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 in real time, just like other other spreadsheet results. If you change a value or probability in your diagram, you will immediately see the impact on the results of your model.

### Model Statistics

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Value</td>
<td>$543,000</td>
</tr>
<tr>
<td>Std. Deviation</td>
<td>$1,347,868</td>
</tr>
<tr>
<td>Minimum</td>
<td>-$653,000</td>
</tr>
<tr>
<td>Maximum</td>
<td>$2,743,000</td>
</tr>
</tbody>
</table>
Advanced Features

PrecisionTree offers many advanced features that can greatly enhance your decision models. This section provides an overview of many of these features. For additional information on using the features described here, see the following Reference chapters.

Formulas for Branch Values, Probabilities

Branch values and probabilities entered in the tree (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. This formula could be a simple link to another cell, or it could involve more complex logic. For branch probabilities, entered values should be normalized so that the sum of all branch probabilities from the node equals 1.

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 to determine 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 file Simple Linked Tree.xlsx for additional information on working with linked trees. This method is also illustrated in the example file Oil Drilling 3 – Linked Spreadsheet Method.xlsx.

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 file Oil Drilling 4 – Payoff Formula Method.xlsx 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 file Oil Drilling 5 – VBA Macro Method.xlsm for an example of this method.
Collapsing and Expanding 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.

Here is an example, where all of the “Oil Amount” chance nodes have been collapsed. The + sign next to the collapsed nodes indicate that hidden subtrees follow them.

To collapse a section of a tree, right-click the desired node, and choose **Collapse Child Branches**. To expand, click the small + symbol next to a collapsed node. This 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 optimal path through the node. Use the Force option when a specific (and not necessarily optimal) decision is made, or after the uncertainty about a specific chance node outcome has been resolved.

To force a branch, left-click a node to open the Node Settings dialog. Then check one of the Force boxes.

**Logic Nodes**

Logic nodes are a special type of node where the optimal branch is not selected using the PrecisionTree settings for path selection. Instead, decisions are made according to user-defined conditions. In this case, 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 TRUE or FALSE. A logic node is designated by a purple square. A logic node is like a decision node, but it selects the branch whose branch logic formula evaluates to TRUE.

In the example file **Logic Nodes.xlsx**, the basic decision is whether to submit a proposal. If you submit it (cost $8000), you then learn how many man-hours it requires. From company policy, you will then go with contractor A if no more than 1500 man-hours are required, and you will go with contractor B otherwise. (Perhaps contractor B has more capacity.) This is implemented with logic nodes.
The formulas for the top logic node are =$D6<=1500$ for contractor A and
$=D6>1500$ for contractor B. PrecisionTree selects the first option as the
optimum path whenever less than 1500 manhours are required and the
second option otherwise.

If two or more branches of a logic node evaluate to TRUE, all TRUE
branches are followed and are equally likely to occur. In this case, 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.
Reference Nodes

Reference nodes can be used to reference a separate tree or a subtree of the current tree. The referenced tree can be present in the same worksheet or on a different worksheet in the same workbook. You typically use reference nodes to simplify a tree, to reference the same subtree 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.

The idea of using reference nodes to decrease the size of a bushy tree is attractive, but you have to be careful. When you use a reference node to reference a similar-looking subtree, you get an exact copy of that subtree. Not only will it have the same node/branch structure, but it will have exactly the same values and probabilities. This is often not what you need, as the probabilities or values should not be the same.

Using @RISK with PrecisionTree

@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, @RISK distribution functions can 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 is drawn from each distribution on 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.
Chapter 5: PrecisionTree
Command Reference

PrecisionTree Icons

The following table provides brief descriptions of the individual icons on the PrecisionTree ribbon. The rest of this chapter discusses the corresponding commands in detail.

<table>
<thead>
<tr>
<th>Icon</th>
<th>FunctionPerformed</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="DecisionTree" /></td>
<td>Creates a new tree</td>
</tr>
<tr>
<td><img src="image" alt="InfluenceDiagram/Node" /></td>
<td>Creates a new influence diagram or node</td>
</tr>
<tr>
<td><img src="image" alt="InfluenceArc" /></td>
<td>Creates a new influence diagram arc</td>
</tr>
<tr>
<td><img src="image" alt="Settings" /></td>
<td>Lets you edit model, node, or arc settings</td>
</tr>
<tr>
<td><img src="image" alt="DecisionAnalysis" /></td>
<td>Creates a risk profile or policy suggestion on an existing tree</td>
</tr>
<tr>
<td>Command</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Sensitivity Analysis</td>
<td>Performs a one-way or two-way sensitivity analysis on a given tree</td>
</tr>
<tr>
<td>Bayesian Revision</td>
<td>Automatically “flips” a probability tree to implement Bayes’ rule</td>
</tr>
<tr>
<td>Append Tree</td>
<td>Appends a symmetric subtree to an end node</td>
</tr>
<tr>
<td>Find</td>
<td>Displays a table with all nodes and branches (or arcs) in a model</td>
</tr>
<tr>
<td>Model Errors</td>
<td>Displays a table with all errors found in open models</td>
</tr>
<tr>
<td>Update Links</td>
<td>Updates all payoff values for a linked decision tree or influence diagram</td>
</tr>
<tr>
<td>View in BigPicture</td>
<td>Creates a BigPicture diagram that corresponds to an existing tree</td>
</tr>
<tr>
<td>Utilities</td>
<td>Opens the Application Settings dialog, and lets you load or unload DecisionTools add-ins</td>
</tr>
<tr>
<td>Help</td>
<td>Displays PrecisionTree Help options</td>
</tr>
</tbody>
</table>
PrecisionTree Commands

The PrecisionTree commands discussed in depth in this section fall into five groups, as indicated in the PrecisionTree ribbon.

Create New Group

The commands in this group let you create a new decision tree, a new influence diagram, or new nodes and arcs in an influence diagram.

Edit Group

The single menu in this group lets you view or edit a number of model, node, and branch/arc settings for a decision tree or influence diagram.

Analysis Group

The commands in this group let you create a risk profile, a policy suggestion, or run a sensitivity analysis for an existing model.
Tools Group

The commands in this group let you perform Bayesian revision on a probability tree, append a symmetric subtree to an end node, and examine your model in several ways.

Help Group

The two menus in this group let you open the Application Settings dialog, load other DecisionTools add-ins (or close PrecisionTree), and access a number of help files.
Decision Tree Command

Creates a new decision tree on the active worksheet

The Decision Tree command creates a new decision tree in a selected cell. The new tree has a generic default name and a single branch terminating in an end node.

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

If necessary, you can open the Model Settings dialog at a later time by either of the following methods:

- Click the box showing the tree name in your worksheet, or
- Choose Model Settings from the Settings menu.
Influence Diagram / Node Command

Creates a new influence diagram or node on the active worksheet

This 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 generic default name and a single Payoff node.

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

If necessary, you can open the Model Settings dialog at a later time by either of the following methods:

- Click the box showing the influence diagram name in your worksheet, or
- Choose Model Settings from the Settings menu.
Influence Diagram Arc Command

Creates a new influence diagram arc on the active worksheet

This command creates a new influence diagram arc between two nodes in the current influence diagram. It opens the Create New Influence Arc dialog, where you can select the source and destination nodes that the arc will connect.

Once you select the Source and Destination nodes and click OK, the Influence Arc Settings dialog is displayed. This allows you to specify the type of influence between the two nodes. More detailed information on the types of influence is provided later in this chapter.
The commands in the Settings menu let you view or change the current settings for a model (decision tree or influence diagram), a decision tree or influence diagram node, or an influence diagram arc.

You can access these commands directly from the worksheet model. Here are the possibilities:

- For settings on a decision tree, click the decision tree name shown at the root of the tree.
- For settings on an influence diagram, click the influence diagram name shown at the top left of the worksheet that contains the diagram.
- For settings on a decision tree or influence diagram node, click the name of the node in the decision tree or influence diagram.
- For settings on a decision tree branch or influence diagram arc, click the branch or arc in the worksheet.
Model Settings Command

Displays the settings for the selected decision tree or influence diagram model

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.

Note: To quickly access the Model Settings dialog box, you can 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 worksheet).

The General tab of the Model Settings dialog shows you the location of the current model and its type (decision tree or influence diagram), but the only setting you can edit is the model name.
The **Calculation** tab of the Model Settings dialog lets you change the method for calculating the path payoffs (the four options are shown below), select whether to maximize or minimize, and a couple other options described below.

![PrecisionTree - Model Settings](image)

The **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. For an influence diagram, only the default **Influence Diagram** calculation method is available.

The Path Payoff Methods for decision trees are:

- **Cumulative Payoff**. This is the simplest (and the default) 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 to calculate the payoff value shown at the end node of that path. You must be careful not to “double count.” For example, if there is a cost for conducting a preliminary test, it can be included on the decision branch where the Test decision is made, or it can be included in payoffs in later outcome branches, but it shouldn’t be included in both.
- **Payoff Formula.** This method for payoff calculation allows end node payoff values to be calculated with a formula. (See the example file Oil Drilling 4 – Payoff Formula Method.xlsx for an illustration.) This formula can reference the values and probabilities for branches on the path whose payoff is being calculated. A typical payoff formula is:

\[ \text{=BranchVal("Price", 0)*BranchVal("Sales Volume", 0)-BranchVal("Costs", 0)} \]

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

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

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

- **BranchVal("node name", missing value).** This returns the value of the branch of “node name” that 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.
- **BranchProb("node name", missing value).** This returns the probability of the branch of "node name" that 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.** This 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. (See the example files Simple Linked Tree.xlsx and Oil Drilling 3 – Linked Spreadsheet Method.xlsx for illustrations).

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.

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

- **Link Updating.** This specifies whether PrecisionTree will automatically update end node payoffs in a linked tree each time the tree or linked model is edited. This option can 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, you can click the Update Model Links command on the PrecisionTree ribbon to force all end node payoffs to be updated.

- **Default Cell.** This 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 can be changed on an end node-specific basis when payoffs should be read in from a different cell for the linked tree.

- **VBA Macro.** This 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. (See the example model Oil Drilling 5 – VBA Macro Method.xlsx for an illustration.)
Your own macros can use the PrecisionTree object model. This manual does not cover the PrecisionTree object model, but it is covered in depth in the items listed in the Developer Kit (XDK) menu item under PrecisionTree Help.

**Other Options**

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

- **Optimal Path.** This specifies the criteria PrecisionTree will use for selecting the optimal path at each node in the model. Two options are available. If Maximum Payoff is selected, PrecisionTree will follow the path that has the highest expected value at a decision node. If Minimum Payoff is selected, PrecisionTree will follow the path that has the lowest expected value from a decision node. The Maximum Payoff option is the default, but if your model is expressed entirely in terms of costs, you should remember to switch to the Minimum Payoff option.

- **Chance Probabilities.** This specifies how chance node probabilities are entered. Two options are available:
  - **Must Total 100%.** This option specifies that unless the probabilities for a chance node sum to 100% (within the entered Within Tolerance of amount), errors will displayed.
  - **Automatically Normalized.** This option indicates that PrecisionTree will normalize entered probability values for a chance node so that they sum to 100%. This prevents errors from showing if the “probabilities” you enter don’t sum to 100%.
The **Format** tab of the Model Settings dialog is a gem many users are unaware of. It lets you format all monetary values and probabilities in a decision tree once and for all through a single dialog. If you have ever formatted each value individually in a complex tree, you will love it!

![Format Tab - Model Settings Command](image)

The **Number Formats** options on the Format tab include the following. Here it is helpful to remember that “Calculated” refers to green, red, and blue cells, those with special PrecisionTree formulas, whereas “Input” refers to black cells where you enter values and probabilities.

- **Calculated Values.** This 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.** This 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.** This specifies the number formatting to be applied to input values (those you enter) in a model.

- **Input Probabilities.** Specifies the number formatting to be applied to input probabilities in a model.
The **Calculated Values** option specifies the label that will be applied to calculated values 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, you can enter the desired text in the Calculated Values box.

The **Utility Function** tab in the Model Settings dialog is useful if you are risk averse and want to base decisions on expected utility instead of expected monetary value.

![Utility Function Tab - Model Settings Command](image)

A utility function converts a model’s monetary payoffs into a different measure: utilities. For risk averse decision makers—most of us, especially when large amounts of money (relative to our wealth) are at stake—a utility function is increasing and concave. The increasing part means that we prefer more money to less money. The concave part implies risk averseness, where every extra payoff dollar is valued less than the previous dollar, and every extra cost dollar is disliked more than the previous cost dollar.

Many utility functions are available, but PrecisionTree provides two of the most popular types, exponential and logarithmic. Each of these is defined by a single “R” parameter called the “risk tolerance.” Essentially, the larger the “R” value, the less risk averse the decision maker is. (When the “R” value is really large, the decision maker behaves like an expected monetary value maximizer.)

When a utility function is used, the monetary values on the tree are first converted to utilities, and then the folding back process maximizes
expected utility, not expected monetary value. This can often change the optimal strategy. Specifically, if a risky strategy optimizes expected monetary value, a less risky strategy could maximize expected utility.

Options in the Utility Function tab include:

- **Use Utility Function.** If this is checked, a utility function will be used (and the other options below will be enabled). If this option is not checked, the usual expected value criterion will be used.

- **Function.** This specifies the utility function to use. The two built-in options are *Exponential* and *Logarithmic*. However, you can also enter the name of a custom utility function you have defined in VBA. This name of this custom function must start with `UTILITY_`.

- **“R” Value.** This is the parameter that defines the level of risk averseness (lower for more risk averse, higher for less risk averse) for the selected utility function. Note that the R value can be an Excel cell reference.

- **Display.** This option specifies the type of calculated values to be displayed in the tree and in reports for models that are using a utility function:
  - **Expected Value.** This option displays calculated values in the tree as is normally done, even if expected utility is the criterion used for making decisions.
  - **Expected Utility.** This option uses the specified utility function to calculate expected utilities and displays these expected utility values in the tree.
  - **Certainty Equivalent.** This option calculates expected utilities and then converts them into monetary amounts that you would accept to avoid a risky decision. For example, in a choice between winning or losing $1 million, based on a flip of a fair coin, the certainty equivalent might be a negative $20,000. The implication is that you would be willing to pay $20,000 to avoid the risky gamble, even though the expected value of the gamble is $0.

**Using Utility Functions**

The utility function used, together with the “R” value, describes the decision maker’s attitude toward risk. In PrecisionTree, a utility function is selected on a tree-specific basis. For each tree, you can select a different utility function and R coefficient.
Defining Your Own Utility Function

PrecisionTree will recognize any public VBA function present in an open Excel file as a valid user-defined utility function if its name starts with UTILITY_. For example, the function UTILITY_SQUAREROOT is a valid utility function name. However, a second function whose name starts with INVERSE_, such as INVERSE_SQUAREROOT, must also be supplied. If you have defined a custom utility function, you can enter its name in the Function box. For more information on defining your own utility functions, see the Appendix C: Utility Functions.

@RISK Tab - Model Settings Command

@RISK (pronounced “at risk”) is a Monte Carlo simulation add-in to Excel, available separately from Palisade or as part of the DecisionTools Suite. The @RISK tab options in the Model Settings dialog control how @RISK will recalculate during a Monte Carlo simulation of a decision tree or influence diagram. Two sets of options are available. The first set determines the type of recalculation that is performed during each iteration of the simulation. The second set determines how decisions can change during a simulation. These options are explained here, but for more clarification, you should consult the example file Using @Risk with PrecisionTree.xlsx.
Two options are available for recalculation during a simulation performed with @RISK:

- **Expected Values of the Model.** This 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 that 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.** This option 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.

Note: The calculation of path probabilities and node expected values is somewhat odd in this mode. Only the values and probabilities for the path that was actually sampled on that iteration will be calculated; the others will (intentionally) all be error values.

The **Decision Forcing During Simulation** options force PrecisionTree to select a specific branch from a decision node in 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. You could do this 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.** This option 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).** This option 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).** This option allows all decision nodes in the simulated tree to follow, with each iteration, the currently identified optimal 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—before making decisions.

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

The Decision Tree Node Settings command from the Settings menu displays the current settings for the selected decision tree node. The available settings include node name, number of branches, branch values (and probabilities for chance nodes), access to advanced branch options, and a few others. Some of the options for Node Settings change depending on the type of node being defined.

There are two ways to open this dialog for a given node:

- The quickest way is to click the desired decision tree node.
- Alternatively, you can select either cell just to the right of the node—that is, the cell containing the name of the node or the cell containing the expected value of the node—and then select Decision Tree Node Settings from the Settings menu.

Options in 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.

- **Force.** This checkbox is used to force this branch to be followed regardless of what PrecisionTree has determined would be the optimal 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.
• **Values, Probabilities.** You can enter monetary values and (for chance nodes) probabilities in this dialog, or you can enter them directly in the tree.

• **Branch Options.** You can use the four buttons at the right to add, delete, or rearrange branches from this node.

• **Node Type.** You can use the buttons on the left to change the node type. (Note that these changes can’t be undone with Ctrl+z, so be careful.) 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 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 of the current tree.

  - **End.** A blue triangle that represents the end point of a path through a decision tree.
Other options in the Node Settings dialog change depending on the node type selected and also the calculation method specified under Model Settings. These variations are discussed next.

For decision, chance, and logic nodes, if the Linked Spreadsheet payoff calculation method is used, the Node Settings dialog has a **Linked to Cell** option. This specifies the cell reference to be linked with the current node in a linked decision tree.

For end nodes, the Node Settings dialog box also displays the **Default Cell** option, showing the default linked cell that is used to return values to an end node payoff option. You can specify another cell to use instead in the **Cell** box.
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 entered in the cell specified with the Linked to Cell option. For end nodes, the value calculated in the cell specified in the Cell or Default Cell option 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 and returned to the end node for the path. (See the example files Simple Linked Tree.xlsx and Oil Drilling 3 – Linked Spreadsheet Method.xlsx for illustrations of linked trees.)

For reference nodes, the Reference Options in the Node Settings dialog specify the location of the tree or subtree that the node references.

Two options are available for referencing trees: Node of this Tree or Other Tree. Node of this Tree is a subtree that begins at another node in the tree where the reference node is located. Other Tree refers to a separate decision tree with its own start node. You can enter a cell reference by clicking 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).
For end nodes in a model where the Payoff Formula calculation method is used, the Node Settings dialog has **Path Payoff Calculation** options. They specify whether to use the default payoff formula or an alternate formula when calculating payoff values in a formula tree.

Finally, you can click the Advanced Branch Options in the Node Settings dialog to display the two-tab **Advanced Branch Options** dialog. Its options also depend (to a lesser extent) on the node type and calculation method.

The **Automatic Definitions** tab of the Advanced Branch Options dialog lets you provide an alternative definition of branch values or probabilities, as explained below.
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.

You first select the desired probability distribution from the Definition Type menu in the Automatic Definitions tab. 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 syntax as Palisade’s @RISK add-in.

Options for a distributed chance node include:

- **Distribution Approximation (Equal Intervals)**. This option creates equally spaced “bins” across the min-max 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 so that they sum to 1. The midpoints of these bins become the chance node’s branch values, while the normalized probabilities become the branch probabilities. If a distribution has no finite minimum or maximum value, then the minimum value is the 1st percentile and the maximum is the 99th percentile.

- **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 values associated with the branches are the midpoints of these bins.

For decision, chance, and logic nodes, the **Formula** options can be used to quickly assign branch values (and probabilities for chance nodes) for all branches from the current node. The formula can be any standard Excel formula and it 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` will automatically enter the value of 1000 in the top branch from a node, 2000 in the second, 3000 in the third, and so on.
A set of custom keywords are available that can be embedded in formulas for branch value, probability, and payoff formula. Some of these keywords are available only for certain formulas. For example, the `BranchVal` keyword cannot be used in a formula that defines branch value. The available keywords include:

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

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

- **TotalBranches.** This is the total number of branches from the node.

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

The options in the **Cumulative Payoff Contribution** tab of the Advanced Branch Options dialog specify how node values will be used in calculating path payoffs. This is relevant for decision, chance, and logic nodes in a model where the default Cumulative Payoff calculation method is used.
Use of Branch Values

The available options are:

- **Add to Payoff.** This 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 that includes this branch.

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

- **Add Formula to Payoff.** In some cases you might want to display a set of branch values in the tree 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 might 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 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. However, a monetary value should be used for payoff calculations. In this case, a simple payoff formula =BranchVal*70, where 70 is the price of oil per barrel, would convert the displayed branch values to monetary units in the payoff calculations.
Influence Node Settings Command

Displays the settings for a selected influence diagram node.

The Influence Node Settings command from the Settings menu displays the Influence Node Settings dialog for a 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.

There are two ways to display this dialog for a given node.

- The quickest way is to click the name of a node in the diagram.
- You can also select Influence Node Settings from the Settings menu, but the dialog you see will depend on the current selection in the worksheet, and it might not correspond to the node you want.

The Influence Node Settings dialog has two tabs, Node and Outcomes.

Options on the Node tab of the Influence Node Settings dialog include:

- **Node Type.** The four buttons on the left let you change the node type. (Note that these changes can’t be undone with Ctrl+z, so be careful.) 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 the current node name in the diagram.

The Outcomes tab in the Influence Node Settings dialog lists the possible outcomes for that node. You can enter or edit these outcome names. You can also use the four buttons to the right to add, delete, or rearrange outcomes.
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. When you click an arc in an influence diagram, the Influence Arc Settings dialog is displayed. This allows you to specify the type of influence that the predecessor node has on the successor node.

There are two ways to display this dialog for a given influence arc:

- The safest and quickest way is to click an arc in the diagram.
- You can also select Influence Arc Settings from the Settings menu, but the dialog you see will depend on the current selection in the worksheet, so it might not correspond to the arc you want.

Depending on the types of nodes this arc connects and the influence that exists between them, you may be required to select multiple types of influence. (It is also possible that some options will be disabled.) For example, a chance node that influences the values of a decision node must also influence the timing of the decision node (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.
The types of influence options are:

- **Value Influence.** A Value influence specifies that the values for the successor node is 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, suppose 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 the 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 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 would be placed to the left of the successor node in an equivalent decision tree.

- **Structure Influence.** A 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 the outcome of the predecessor node—that is, 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 to Sales Volume influence (where Price is the predecessor node and Sales Volume is the successor node), a Low Price might force the High Sales Volume outcome to occur.
Structure influence can be used to convert influence diagrams into “asymmetric” decision trees, or trees where some of the possible branches (as specified by all possible outcomes defined in the influence diagram) are missing. Asymmetric trees are quite common. Each Oil Drilling example file has an asymmetric tree. Specifically, 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 to Test is made.

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.** This 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.** This 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.** This 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.** This 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 a selected influence diagram node

The **Influence Value Table** command displays the Value Table (in a new Excel worksheet) 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, probabilities of those outcomes). A value is entered for each possible combination of values of the predecessor, or influencing, nodes.

There are two ways to display the Value Table for a given node.

- The quickest way is to right-click the node in the diagram and then select Influence Value Table from the popup menu.
- You can also select Influence Value Table from the Settings menu, but the table you see will depend on the current selection in the worksheet, and it might not correspond to the node you want.

Value tables are standard Excel spreadsheets and can include values, formulas and cell references. (You can refer to the Name box to the left of the Excel formula bar for cell references in the Value Table). Values and formulas can reference other cells in the displayed Value Table (including the outcomes shown for predecessor cells) and other cells in open worksheets. Standard Excel methods 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 **Chance Probabilities** option in the Calculation tab of the Model Settings dialog specifies how chance node probabilities are entered. If Automatically Normalized is selected, PrecisionTree will normalize entered probability values for a chance node so that they sum to 1.

The **Value When Skipped** entry (if any) 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 most cases it is zero, but it also can be non-zero.

Payoff Node

In the Value column 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. (You can refer to the Name box to the left of the Excel formula bar for cell references in the Value Table).

In the following table, the formula for the Payoff node combines the Amount of Oil, Test Decision, and Drill Decision cells. For example, the first cell combines cells D4, E4 and F4 in the Value Table, the cells where the labels Large well, 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 Analysis Menu

The two commands in the Decision Analysis menu are used to provide specific information about a decision model, usually a decision tree model. Although the tree itself contains all the information about the optimal strategy and its consequences, these commands show this information in a more accessible form.
Risk Profile Command

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

The Risk Profile command from the Decision Analysis menu runs a complete decision analysis on the selected model (which can be a decision tree or an influence diagram). 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 you select Risk Profile from the Decision Analysis menu, the Risk Profile dialog appears, prompting you for the name of the model and the starting node (for decision trees) to analyze.

The Analyze options in the Risk Profile dialog include:

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

- **Starting Node.** (Applies only to decision trees) 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 subtree with all paths from that node to the right.
Note: The Risk Profile command can be selected through a popup menu that appears when a node is right-clicked. (It is under the Node Analysis options.) In that case, the Starting Node defaults to the selected node.

- **Paths.** (Only applies to decision trees that start with a decision node) 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. This lets you see several risk profiles in the same graph, one for each decision from the start node.

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

- **Probability Chart.** When selected, creates a report with a Risk Profile Probability chart.
- **Cumulative Chart.** When selected, creates a report with a Risk Profile Cumulative Probability chart.
- **Statistical Summary.** When selected, generates a statistical summary report of the decision analysis.

A Risk Profile probability chart has a bar above each possible monetary outcome, the height of which is the corresponding probability. In the chart shown here, the “All Branches of Starting Node” option was used, so there is a probability graph of each decision (Test and Don’t Test) from the starting node. (A table of values and probabilities, not shown here, is included below the chart.)

![Risk Profile Probability Chart](chart-image)

**Probabilities for Decision Tree 'Oil'**

Choice Comparison for Node 'Test Decision'
A Risk Profile cumulative chart shows an increasing step function, the height of which at any monetary value is the probability of a payoff less than or equal to that value. In the chart shown here, the "All Branches of Starting Node" option was used, so there is a cumulative graph of each decision (Test and Don’t Test) from the starting node. (A table of values and cumulative probabilities, not shown here, is included below the chart.)

If you request a statistical summary, it shows standard statistical summary measures of the payoff distribution. In the table shown here, the "All Branches of Starting Node" option was again used, so there is a summary for each decision (Test and Don’t Test) from the starting node.
Policy Suggestion Command

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

The Policy Suggestion command from the Decision Analysis menu generates a policy suggestion for the selected model (which must be a decision tree, not an influence diagram). The result is a subtree of the original tree that includes only nodes and branches that could be visited when using the optimal strategy.

When you select Policy Suggestion from the Decision Analysis menu, the Policy Suggestion dialog appears, prompting you for the name of the model and the starting node of the tree to analyze.

The Analyze options in the Policy Suggestion dialog 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 to the right.

Note: The Policy Suggestion command can be selected through a popup menu that appears when a node is right-clicked. (It is under the Node Analysis options.) In that case, the Starting Node defaults to the selected node.
The **Include Results** options in the Policy Suggestion dialog 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 can possibly be encountered along the optimal path.

The **Policy Suggestion Decision Table** identifies the optimal choice 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.

<table>
<thead>
<tr>
<th>Decision</th>
<th>Optimal Choice</th>
<th>Arrival Probability</th>
<th>Benefit of Correct Choice (Best - Worst)</th>
<th>Benefit of Correct Choice (Best - Second Best)</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Test Decision' (C41)</td>
<td>Test</td>
<td>100.00%</td>
<td>$15,000</td>
<td>$15,000</td>
</tr>
<tr>
<td>'Drill Decision' (E11)</td>
<td>Don't Drill</td>
<td>38.00%</td>
<td>$184,211</td>
<td>$184,211</td>
</tr>
<tr>
<td>'Drill Decision' (E25)</td>
<td>Drill</td>
<td>39.00%</td>
<td>$615,385</td>
<td>$615,385</td>
</tr>
<tr>
<td>'Drill Decision' (E37)</td>
<td>Drill</td>
<td>23.00%</td>
<td>$1,565,217</td>
<td>$1,565,217</td>
</tr>
</tbody>
</table>

The **Policy Suggestion Optimal Decision Tree** displays a reduced version of the decision tree that shows 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 the model have the most effect on the results. In a sensitivity analysis, the values in selected inputs are varied and the effect of that variation on the value of an output is recorded. You can vary one input at a time (a one-way sensitivity analysis), or you can vary two inputs simultaneously (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 you select the Sensitivity Analysis command, the Sensitivity Analysis dialog appears. This lets you specify the type of analysis to run, the possible inputs and their ranges, and the desired reports.
**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 min-max ranges, but only one is varied at a time. In a two-way sensitivity analysis, two specified inputs are changed simultaneously across their min-max ranges. In either case, the corresponding output values are recorded for later use.

**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 (the expected value of the selected starting node) or an individual worksheet cell can 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: The Sensitivity command can be selected through a popup menu that appears when a node is right-clicked. (It is under the Node Analysis options.) In that case, 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 can 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. In this case, you have to identify one of them for the X-axis and the other for the Y-axis.

Options in the Inputs section include the following.

- The Add, Delete, and Edit buttons on the right let you add a new input to the list, or delete or edit a current input in the list.

- Check boxes displayed next to each input select either the inputs to include in a one-way sensitivity analysis or the inputs to display on the X-axis and Y-axis of graphs for a two-way sensitivity analysis.
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 or two-way sensitivity analysis is requested. The 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.** This graph displays how the output value for each possible initial decision of the model changes as an input value is varied. In this case, the output must be the value of a decision node. The purpose of this graph is to see when (or if) the optimal decision changes as the input varies.

- **Tornado Graph.** This graph summarizes the effect of each input on the output, with bars showing the output change caused by each input. The purpose of this graph (and a spider graph) is to see which inputs have the most effect on the chosen output.

- **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 combination of input values.

- **Strategy Region Graph.** This graph shows regions where different decisions are optimal each combination of the two inputs. This graph is only generated when the output is the value of a decision node.

The **Options** section includes:

- **Report Output in Terms of Percent Change From Current Value.** This option 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.** This option causes PrecisionTree to update the display in Excel as it calculates values during a sensitivity analysis.
When you add or edit an input, you see the Sensitivity Input Definition dialog. This is used to identify the input cell and the values to test for that cell.

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.

- **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 (that is, the value the input will have during the analysis when other inputs are being varied). **Current Cell Value** specifies that the base value will be the cell’s current value; alternatively, any other base value can 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. The options are:
  - **+/− Percent Change from Base Value.** With this option, the entered Min Change and Max Change are percentage reductions or increases in the Base Value. (This option cannot be used if the input has a base value of 0.)
  - **+/− Actual Change from Base Value.** With this option, the entered Min Change and Max Change are actual reductions or increases from the Base Value.
  - **Actual Min and Max.** With this option, 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 values to test across the entered min-max range for the selected input. During a sensitivity analysis, this many equally-spaced values in the min-max range are used for the input, and a new value for the output is calculated for each.
Results of a One-Way Sensitivity Analysis

When PrecisionTree runs a one-way sensitivity analysis, the following graphs and reports can be requested. All such graphs can be edited exactly like any other Excel graphs.

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.

A one-way strategy region graph displays the results of each possible initial decision at each value tested for a given input. In this case, the output must be the expected value of a decision node.
**Tornado Graph** A tornado graph is available for a one-way sensitivity analysis when two or more inputs are selected. This graph has a bar for each input that shows how much the output changes as the input varies. The longest bars appear at the top and correspond to the most influential inputs.

![Tornado Graph Example](image1)

**Spider Graph** A spider graph is available for a one-way sensitivity analysis when two or more inputs are selected. This graph has a line for each input that shows how the output changes as the input varies. The steepest lines correspond to the most influential inputs.

![Spider Graph Example](image2)
Results of a Two-Way Sensitivity Analysis

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

A two-way sensitivity graph is a 3-D chart that displays the value for the output at each possible combination of the two input value. The Inputs are shown on the X and Y axes and the values for the output are shown on the Z axis.
A two-way strategy region graphs shows a point for each combination of the two input values, and each point has a shape corresponding to the optimal decision for that combination. This lets you see how the optimal decision changes (if at all) over the ranges of the two inputs.
Bayesian Revision Command

Performs a Bayesian Revision in a probability tree

The Bayesian Revision command “flips” a decision tree or subtree, using Bayes’ rule to swap unconditional and conditional probabilities. Bayes’ rule is used to revise probabilities as new information is received. You start with prior probabilities of various outcomes and conditional probabilities of information results, given outcomes. For example, in a tree where a person is being tested for drugs, you start with the prior probabilities of drug status (user or nonuser) and the conditional probabilities of test results (positive or negative), given drug status. However, in a decision-making context, where you will observe the test results before learning a person’s drug status, it is necessary to have the opposite probabilities: the unconditional probabilities of test results and the conditional (posterior) probabilities of drug status, given test results. These are found through Bayes’ rule.

Bayesian revision requires a decision tree or subtree tree with chance nodes only and a symmetric structure.

There are two ways to invoke Bayesian Revision:

- The easiest way is to right-click the root node of the decision tree or subtree you want to revise, and then select Bayesian Revision from the Tools group of the resulting popup menu.
- Alternatively, you can click the Bayesian Revision icon on the PrecisionTree ribbon and then select either node just to the right of the root node.

Either way leads to the Bayesian Revision dialog.
Typically you will accept the default Revised Node Order (this is the order of the nodes in the revised tree). When the Bayesian Revision is performed, the tree will “flip” to the revised node order. The probabilities in the flipped tree are calculated from Bayes’ rule (although no formulas show in the revised tree).

Here are two trees: the first prior to Bayesian Revision and the second after:

![Bayesian Trees](image)

Note that if the original tree has formulas on its branches, such as links to input probabilities, these formulas will be replace by values for Bayesian revision. Therefore, any links will be gone.

For more information on Bayesian Revision, see Appendix B: Bayes’ Theorem.
Append Tree Command

Appends a symmetric subtree to an end node in a decision tree

The Append Tree command makes it easy to set up a new tree or sub-tree with a set of nodes that will be added symmetrically as the new tree or sub-tree is built. Once a symmetric tree is set up, you can easily prune off any branches you don’t need.

There are two ways to invoke Append Tree:

- The easiest way is to right-click an end node and then select Append Symmetric Subtree from the Tools group of the resulting popup menu.
- Alternatively, you can click the Append Tree icon on the PrecisionTree ribbon and then select either node just to the right of the end node.

Either way leads to the Append Symmetric Tree dialog. It starts blank, and you can fill it in as desired.

When building a symmetric subtree, each node listed is added to nodes created by the prior entry or row in the Append Symmetric Subtree dialog. For example, in the tree created from the above table, a decision node named “Test” with two branches “Yes” and “No” is created first. Then a decision node named “Drill” with two branches “Shallow” and “Deep” is added after each of the two branches from the Node “Test”. Subsequently, a node named “Oil Amount” with three branches is added after each the branches from the nodes named “Drill”.

When building a symmetric subtree, each node listed is added to nodes created by the prior entry or row in the Append Symmetric Subtree dialog. For example, in the tree created from the above table, a decision node named “Test” with two branches “Yes” and “No” is created first. Then a decision node named “Drill” with two branches “Shallow” and “Deep” is added after each of the two branches from the Node “Test”. Subsequently, a node named “Oil Amount” with three branches is added after each the branches from the nodes named “Drill”.
The resulting symmetric tree is as follows:

In this example, one entry for “Oil Amount” in the table results in four nodes in the created tree—a great time-saver versus entering the nodes manually.
Find Command

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

The **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 button (the middle button at the bottom) specifies the sort order and grouping of nodes and branches by type, name, or cell.

- **Zoom.** Clicking the Zoom button (the right button at the bottom) 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 Model Errors command displays a Model Errors window that lists all errors found in open models (if any). This allows you to debug problems and quickly jump to nodes with errors.

As an example, the following Model Errors window indicates that all the #VALUE! errors in the tree have a single cause: the probabilities for Test Results don’t sum to 1.
Update Links Command

Updates the linked values in a linked model

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

Creates a map with Palisade’s BigPicture add-in that reflects your decision tree

As mentioned earlier in this manual, the purpose of the BigPicture add-in is to create diagrams, called “maps,” of any problem, including decision problems. It makes perfect sense to create the map of the decision problem first, so that everyone involved understands the problem from a high-level view. Then the details can be developed in a decision tree.

However, PrecisionTree’s **View in BigPicture** command lets you go in the other direction. Starting from a decision tree, it *creates* an accompanying map in BigPicture.

When you click the View in BigPicture icon, a dialog opens with a list of all trees in open workbooks, and you can check any you want a BigPicture map for. You can also decide whether you want the map to be in the active workbook or a new workbook.

BigPicture then opens (if it isn’t already open), and it develops the corresponding map, with the optimal decisions highlighted in yellow. The initial map shows only the beginning of the tree.
However, you can expand any of the parts of the map, and you can use any of the other BigPicture tools to modify the map.

For example, if you would rather see a “top down” map, you can choose Top Down from the BigPicture Arrange Map menu.

The numbers in the map are linked to the numbers in the tree. If the numbers in the tree are changed, the map updates automatically. Alternatively, you can right-click a topic and choose **Show Decision Tree Editor** from the BigPicture popup menu. This opens an editor that shows any value(s) for that topic, which you can then change there. This updates the map and the tree.
For example, when the test cost is changed to $550,000, the Don’t Test becomes optimal, and its branch is automatically shaded yellow.

However, if you change the structure of the tree, such as deleting branches, the map does not update; you would have to create a new map.
When a BigPicture map is based on a decision tree, you can click the Paths icon on the BigPicture ribbon to see a list of all paths, optimal and non-optimal, through the tree in a Decision Tree Paths pane.

![Decision Tree Paths](image)

Then if you select any one of the paths, the map shows only the selected path.

![BigPicture Map](image)

For any such path, or for the original map, you can select Export Map to PDF from the BigPicture Import Export menu. This creates a pdf version that you could include in a PowerPoint presentation, for example.
Application Settings Command

Lets you set a variety of program defaults

The Application Settings dialog is displayed when you select the Application Settings command from the Utilities menu. A wide variety of PrecisionTree settings can be set at 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** dialogs discussed elsewhere in this manual.

Note the **Include Descriptive Comments** setting. When it is set to True, cell comments are placed in reports to describe various report details.
Help Menu

The items in the Help menu are mostly straightforward. Note that the License Manager command displays the License Activation dialog, listing the version and licensing information for your copy of PrecisionTree. You can also use this dialog to convert a trial version of PrecisionTree into an licensed copy.
PrecisionTree Context Menus

As with most Windows programs, PrecisionTree has several context menus that are displayed when you right-click an item in a model. Most of the items in these context menus are straightforward or have already been discussed earlier in this manual.

Decision Tree Node Context Menu

This menu is displayed when you right-click a decision tree node.

Copy and Paste Subtree

Probably the most useful commands in this menu are **Copy Subtree** and **Paste Subtree**. These are real time-savers for copying a subtree to another location in the tree. You first right-click the left-most node of the subtree you want to copy and select Copy Subtree. Then you right-click the node (usually an end node) where you want the copy to start and select Paste Subtree. Any formulas in branches of the copied subtree will be copied in the usual Excel manner, so you should develop such formulas with appropriate relative/absolute addresses to ease copying. At worst, you might have to modify the formulas in the pasted version, but you will still save time.
**Collapse Child Branches**
The **Collapse Child Branches** command hides all nodes and branches to the right of the selected node and replaces them with a + symbol. You can then click this symbol to restore the hidden nodes and branches to view.

**Insert Node**
The **Insert Node** command inserts a new node before (to the left of) the current node, that is, the node you right-clicked. The current node and all successor nodes that follow are moved to a branch of the new node. The inserted node by default is a decision node with two branches, but you can then change it to any other type.

**Copy Image to Clipboard**
The **Copy Image to Clipboard command** (under Tools) is also useful. It allows you to copy the image of a tree or subtree to the clipboard. This image can be a bitmap or metafile and is suitable for pasting to a document in Word or a presentation in Powerpoint.

**Decision Tree Branch Context Menu**
A popup menu is displayed when you right-click a decision tree branch. This menu includes additional commands to rename or move a branch and to force the selection of branches.

The last two groups, Node Analysis and Model, provide options that have already been discussed elsewhere in the manual. The popup menu simply provides a quick way to perform common operations.
Influence Diagram Context Menus

Similar to the decision tree context menus, popup menus are displayed when an influence diagram node, arc, or model name is right-clicked. These menus are straightforward. They contain commands to access node and arc settings, rename nodes, delete nodes or arcs, and more.

Note each of these popup menus has a **Convert to Decision Tree** command under **Model**. This allows you to create the equivalent decision tree on another worksheet. If nothing else, this lets you check that your influence diagram is set up the way you intended it to be.
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 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 to retrieve the end node values.

4. If a utility function was specified, convert each of the end values into their corresponding utility.
5. Next “fold back” the tree by following these steps:
   
   A) For each node that has only 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” (i.e., 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 “TRUE” or “FALSE” labels 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), folding back until only a single end node remains in the tree.

6. 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.

7. 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.
Bayes’ theorem (also called Bayes’ rule) is a formal probability rule for updating probabilities as new information is received. As an example, 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 also say that if it rains in New York, it is more likely that it will rain in Boston?

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

![Influence Diagram]

And a decision tree:

![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

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
- $P(A|B)$: the probability that event $A$ will occur, given that $B$ occurs
- $P(\bar{A})$: the probability that event $A$ will not occur, $1 - P(A)$

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

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

We can combine this expression with equation iii:

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

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

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

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

Substituting these expressions into equation v, we get Bayes’ theorem:

Bayes’ Theorem

viii. $P(X|Y) = \frac{P(Y|X)P(X)}{P(Y|X)P(X) + P(Y|\bar{X})P(\bar{X})}$
Bayes’ theorem describes the probability of event X given the occurrence of event Y using values we already know.

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

ix. \[ P(Y) = P(XY) + P(\bar{X}Y) \]

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

x. \[ P(XY) = P(Y|X)P(X) \]

xi. \[ P(\bar{X}Y) = P(Y|\bar{X})P(\bar{X}) \]

Combining these equations leads to the expression:

xii. \[ P(Y) = P(Y|X)P(X) + P(Y|\bar{X})P(\bar{X}) \]
Using Bayes' Theorem

Now the question is how these equations apply to a decision tree. Let’s use Bayes’ theorem on the example we described earlier. First, let’s add probability notation to the two trees.

For the 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:

\[
x_{iii.} \quad P(a|c) = \frac{P(c|a)P(a)}{P(c|a)P(a) + P(c|\bar{a})P(\bar{a})}
\]

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

\[
x_{iv.} \quad P(a|c) = \frac{P(c|a)P(a)}{P(c|a)P(a) + P(c|b)P(b)}
\]

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

\[
x_{v.} \quad P(a|c) = \frac{.5 \times .3}{(.5 \times .3) + (.2 \times .7)} = .52
\]

We can use the same method to solve for \( P(b|c) \), \( P(a|d) \) and \( P(b|d) \).

But, what about \( P(c) \)? This is easy! All we need to do is use equation \( x_{ii} \) (remember that \( P(\bar{a}) = P(b) \)):

\[
x_{vi.} \quad P(c) = P(c|a)P(a) + P(c|\bar{a})P(\bar{a}) = P(c|a)P(a) + P(c|b)P(b)
\]
Fortunately, we know all the values needed to solve this equation:

\[ P(c) = (.5 \times .3) + (.2 \times .7) = .29 \]

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:

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 can 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 “Bayesian revision” to their model.

If you find the equations for Bayes’ theorem fairly mysterious, or at least difficult to remember, you are certainly not alone. Fortunately, the Bayesian Revision tool in PrecisionTree flips the probability tree automatically, finding the updated probabilities for you. So if you don’t want to “plug into” the Bayes’ theorem equations, you don’t have to!
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.

Objective and Subjective Probabilities

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.

Willingness to Accept Risk Is Personal

Consider the following decision between two investments:

<table>
<thead>
<tr>
<th>Investment Model</th>
<th>Investment A</th>
<th>E.V. = $20</th>
<th>50% Earn $50</th>
<th>50% Lose $10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment B</td>
<td>E.V. = $35</td>
<td>50% Earn $500</td>
<td>50% Lose $430</td>
<td></td>
</tr>
</tbody>
</table>

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. Many people would choose Investment A over Investment B. But, how can you place a quantitative measurement on the riskiness of a situation?

Individuals differ in the amount of risk they are willing to accept. For example, two individuals of equal net worth might react quite
differently to the above investment decision. One might choose Investment A, while the other might choose Investment B. One decision maker might be risk averse, preferring 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. A person can also be risk neutral, willing to make decision on the basis of expected value.
Measuring Risk with Utility Functions

You probably have an idea of how much risk you are willing to accept, 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 the risk of a decision. And, you would like to consider your preference for risk as well. That’s where utility functions become relevant.

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 best decision.

The above example contains typical utility functions for risk averse, risk taking, 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 concave (increases at a decreasing rate).

Expected Utility

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

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

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.
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 for this risk averse decision maker. Expected utility might appear to be a meaningless number. After all, you can’t say to your boss “Let’s choose Investment A because it has a utility value of 6.25.” You need to express utility in units that are meaningful 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 pay (if negative) accept (if positive) 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 a decision based on expected utility, you can select the option with the largest certainty equivalent. This always produces the same decision, but it uses units you can 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 the 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

The risk premium is the difference between the expected value and the certainty equivalent of an event. The higher the risk premium, 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 into PrecisionTree and is defined as:

\[ U(x) = 1 - \exp\left(- \frac{x}{R}\right) \]

Here, \( x \) is any monetary value, and \( R \) is the decision maker’s risk tolerance (also called the risk coefficient). The smaller \( R \) is, the more risk averse the decision make is. As \( R \) increases, the decision maker becomes more risk tolerant.

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

Typical Exponential Utility Curves

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.

However, there is a fairly formal way of determining your value of \( R \). Imagine a game where you either win \( R \) dollars or lose \( R/2 \) dollars, based on the flip of a fair coin. If you can determine the value of \( R \) such
you are indifferent between playing the game and not playing, then this R value is your risk tolerance. Of course, this assumes that your utility function is an exponential utility function.

**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 can be a good approximation for some situations, such as when sensitivity analysis determines that varying risk tolerance does not significantly affect the results of the model. But, what do you do when your attitudes toward risk change? Some possibilities are discussed next.
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:

\[ U(x) = \ln(x + R) \]

This logarithmic utility function is also built into PrecisionTree. The constant \( R \) is added 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 (costs or losses), you should choose a large enough value of \( R \) so that \( x + R \) is always positive.

The example above contains a logarithmic utility curve with a risk coefficient of 0 (relevant if no losses are possible). If you change the \( R \) value, the curve merely “shifts” a distance to the left equal to \( R \).

Square-Root Utility Function

The square-root utility function also demonstrates decreasing risk aversion. (It is not built into PrecisionTree, but you can add it with VBA.) 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. If it is possible that your values of \( x \) could be
negative (costs or losses), you should choose a value of R large enough so that \( x + R \) can never be negative.

![Square-Root Utility Curves](image)

The example above displays two square-root utility curves, one with \( R=0 \) and the other with \( R=50 \). They both have the same shape; the R value merely “shifts” the curve along the X-axis.

**Defining Custom Utility Functions**

To create your own utility function, you can write a user-defined function in Excel (see the Excel Help for instructions). Then, you should 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:

\[
\text{Utility\_SquareRoot}(X,R) \\
\text{Inverse\_SquareRoot}(EU,R)
\]

Here, \( X \) is the expected value of a node, \( R \) is the parameter for the square root utility function, and \( EU \) is the expected utility of a chance node.

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

1. Use the utility function to calculate the utility for each chance outcome.
2. Calculate the expected utility for the chance node.
3. Convert the expected utility to a certainty equivalent using the inverse utility function.

Fortunately, once you specify that you are using a utility function, either one of PrecisionTree’s or your own, PrecisionTree performs these steps for you.
To demonstrate these techniques, let’s look at a portion of the oil drilling example:

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, you simply type in `Utility_SquareRoot` and enter an R value. PrecisionTree then recalculates the tree, returning a certainty equivalent at each node.

The final decision tree looks like this:

The optimal decision is still to Drill, but the certainty equivalent is significantly smaller than the expected value. So even though the decision hasn’t changed, the risk involved in the decision makes the option less attractive than it once seemed.

*Note: for more information on defining utility functions, see the example model Oil Drilling 6 - Model with Utility Function.xlsx.*
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


Technical References to Decision Trees and Influence Diagrams


Technical References to Sensitivity Analysis

Examples and Case Studies Using Decision Analysis


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:

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Appendix E: Using PrecisionTree with Other DecisionTools

The DecisionTools Suite

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
- **NeuralTools®** — neural networks in Excel
- **Evolver®** — genetic optimization in Excel
- **StatTools®** — statistics in Excel
- **BigPicture®** — smart drawing in Excel

While the tools listed above can be purchased and used separately, they become more powerful when used together. 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.
Palisade’s DecisionTools Case Study

Excelsior Electronics currently makes desktop computers. They are working on a laptop computer, the Excelsior 5000, and want to know whether the company will profit from this venture. They plan to build a spreadsheet model which spans the next two years. The model should take into account production costs, marketing, shipping, price per unit, units sold, and so on. The bottom line for the planning horizon is overall profit. Excelsior expects some initial setbacks on this venture, but as long as these setbacks are not too bad and profits are up by the end of two years, they will go ahead with the E5000.

Use BigPicture for a High-Level View

The company executive first uses BigPicture to develop a “map,” where the various elements of the problem and their relationships are shown graphically. This map serves as a basis for a discussion of the problem from a high-level view, so that everyone understands the main issues.

Run TopRank First, Then @RISK

Once a basic spreadsheet model of the problem is developed in Excel, TopRank is used on the model to identify the critical variables. The overall profit cell is selected as the critical output, and an automatic what-if analysis is run with TopRank. The results quickly show there are five variables (out of many more) that have the most impact on profit: price per unit, marketing costs, build time, price of memory, and price of CPU chips. Excelsior decides to concentrate on these five input variables.

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.

Research is performed to collect 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 entered into the model.
Simulate with @RISK

Once all the @RISK functions are in place, the profit cell is selected as an @RISK output cell, and a simulation is run. Overall, the results look promising. Although there will be losses initially, there is an 85% chance the company will make an acceptable profit. In fact, there is a 25% chance that the venture will generate even more revenue than had initially been assumed. Therefore, 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 in the face of uncertainty. Their use has been limited because they have been expensive and cumbersome to use. In addition, they have substantial computational requirements. The widespread 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 realized with @RISK (pronounced “at risk”), a system that brings these techniques to the industry standard spreadsheet package, Microsoft Excel. With @RISK and Excel, any risky situation can be modeled, from business to science to engineering. You are the best judge of your analysis requirements, and @RISK, combined with the modeling capabilities of Excel, allows you to design models that best satisfies these requirements. Any time you face a decision or analysis that involves uncertainty, you can use @RISK to gain insight into how the future might unfold.

Why You Need Risk Analysis and @RISK

Traditional analyses combine single “point” estimates of a model's variables to predict a single estimate of results. Estimates of model variables must be used because future values are not known with certainty. In reality, however, many things don't turn out the way you planned. Maybe you were too conservative with some estimates and too optimistic with others. The combined errors in each estimate often lead to real-life results that are significantly different from estimated results. The decision you make based on your “expected” result might be an unwise decision, a decision you would not 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 with a wide range of possible outcomes.

Monte Carlo Simulation

@RISK uses a technique called “simulation” to combine all uncertainties you identify in your situation. You are no longer forced to reduce what you know about a variable to a single number. Instead, you can include all you know about the variable, including its full range of possible values and the likelihoods of their occurrence. @RISK uses all of this information, along with your Excel model, to generate a range of
possible outcomes. 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 enables you to “live” through your situation many times, each time under a different set of conditions with a corresponding set of results occurring.

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

**When Should You Use @RISK?**

Any time you perform an analysis in Excel that involves uncertainty, you can and should use @RISK. Applications in business, science, and engineering are practically unlimited, and you can build on your existing base of Excel models. Consider the decisions and analyses you make every day. If you have ever been concerned with the impact of risk in these situations, you have just found a good use for @RISK!

**@RISK Modeling Features**

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 allows you to use functions to define uncertain cell values as probability distributions. @RISK adds a set of new functions to the Excel function set, each of which allows you to specify a different distribution type for cell values. Distribution functions can be added to any number of cells and formulas throughout your spreadsheet model, and they can include arguments, possibly cell references and expressions, that allow extremely sophisticated specification of uncertainty. To help you assign distributions to uncertain values, @RISK includes a graphical window where distributions can be previewed and added to formulas.

The probability distribution functions provided by @RISK allow you to specify nearly any type of uncertainty in cell values in your model. For example, a cell containing the formula \[=\text{RiskNormal}(100,10)\] will return samples during a simulation drawn from a normal distribution with mean 100 and standard deviation 10. These distribution functions are invoked only during a simulation. In normal Excel operations, they show a single cell value, just as in Excel without @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.

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. The first option, **Expected Values of the Model**, causes @RISK to first sample all distribution functions in the model, and supporting spreadsheets each iteration, then recalculates 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 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 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 output 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:

The results of drilling are divided into three discrete outcomes (Dry well, Small well and Large well). 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, you 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 will look:

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.

But, what about the decision to Drill or Not 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, PrecisionTree has an option Decisions Follow Current Optimal Path to force decisions 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

Suppose you want to know how much it would be worth to learn which uncertain outcome will occur before having to make a decision. In decision analysis, this is called the value of perfect information. PrecisionTree can calculate this value easily. You simply “flip” the tree so that uncertainty is resolved first and then the decisions are made.

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 subtree) to generate a risk profile from an @RISK simulation. Because @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.
Appendix E: Using PrecisionTree with Other DecisionTools

Introduction to TopRank®

Palisade’s TopRank add-in is the ultimate what-if tool for spreadsheets, from Palisade Corporation. TopRank greatly enhances the standard what-if and data table capabilities found in Excel. In addition, it leads naturally to powerful risk analysis with its companion add-in, @RISK.

TopRank and What-if Analysis

TopRank runs an automated what-if sensitivity analysis to help you identify which spreadsheet value(s) or variable(s) affects your bottom-line results the most. You can have TopRank automatically try any number of values for a variable (as in an Excel data table) and tell you the results calculated at each value. You can also have TopRank try all possible combinations of values for a set of variables (a multi-way what-if analysis), giving you the results calculated for each combination.

TopRank is a spreadsheet add-in for Microsoft Excel. It can be used with any pre-existing, or new, spreadsheet model. To set up your what-if analyses, TopRank adds new custom Vary functions to Excel’s function set. These functions specify how the values in your spreadsheet will 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 variables in your spreadsheet model that could affect your bottom-line outputs. It can then vary these variables automatically and identify which are most significant in determining your results.

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 identify the individual product components whose quality most affects final product production rates. A loan officer can have TopRank quickly run a model at any possible interest rate, loan principle amount, and down payment combinations, and 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 that affect your results.

TopRank Applications
TopRank Modeling Features

**Why TopRank?**

As an add-in to Microsoft Excel, TopRank links directly to your spreadsheet 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.

You probably already perform what-if analysis in Excel in an ad hoc manner, by changing input values in various cells and see how results change. You might even use the more structured Excel data tables to vary one or inputs in a systematic manner to see their effect on results. The advantage of TopRank is that it performs these tasks automatically and analyzes their results for you. It instantly performs what-ifs on all input variables in your spreadsheet model that could affect your results, instead of requiring you to individually change values and recalculate. It then shows the what-if results in easily understandable reports and graphs.

TopRank also runs data table combinations automatically, without requiring you to set up tables in your spreadsheet. You can combine more than two variables in its multi-way what-if analysis, and then you can rank the combinations of input values 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 results, including multi-way what-if results, almost instantly. Even the least experienced modeler can get powerful analysis results.

**Multi-Way What-if Analysis**

TopRank defines variations in input variables by using functions. To do this, TopRank adds a set of new functions to the Excel function set, each of which specifies a particular type of variation for your variables. These functions include:

- Vary and AutoVary functions which, during a what-if analysis, change the value of an input variable across a +/- range you define.
- VaryTable functions which, during a what-if analysis, substitute each of a table of values for an input variable.

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.
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 they can include cell references and expressions as arguments. This provides extreme flexibility in defining variation in input variables in spreadsheet models.

TopRank can even automatically enter Vary functions for you. You can use this powerful feature to quickly analyze your spreadsheet model, without manually identifying variables to vary and typing in functions.

When automatically entering Vary functions, TopRank traces back through your spreadsheet and finds all possible input cells that could affect the result cell you identify. When it finds such an input cell, it substitutes in an AutoVaryfunction with the default variation parameters (such as -10% to +10%) you’ve selected. With a set of AutoVary functions inserted, TopRank can then run its what-if analysis, ranking the variables in order of importance.

With TopRank, you can step through your Vary and AutoVary functions and change the variation each function specifies. The default is to use a -10% to +10% variation, but change this as you like. You can also select to not vary an input variable in case its value is fixed and could never be changed.

During its analysis TopRank individually changes values for each Vary function and recalculates your spreadsheet model 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 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 view graphically in a 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 its built in automatic sensitivity analysis, support for what-if tables and multi-way what-if capabilities.

Using TopRank to Run Sensitivity Analyses

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.

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.

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.
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:

- $=\text{RiskVaryTable}(100,\{50,80,120,150,175\})$
- $=\text{RiskVaryTable}(100,A1:A10)$

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.
Introduction to BigPicture™

The BigPicture add-in is the newest addition to Palisade’s DecisionTools Suite, introduced in version 7. BigPicture is a smart drawing program, developed to compete with other “mapping” software on the market. However, unlike other mapping software, BigPicture is totally integrated with Excel, and this provides several important advantages discussed below.

BigPicture is aptly named. Its main purpose is to provide a map, or diagram, of the elements of a problem, along with relationships among these elements, so that decision makers can understand and discuss the problem from a high-level view. This was the original intent of BigPicture, and it remains its primary goal, but the developers of the add-in took advantage of its integration with Excel to provide a wealth of smart features not available in other mapping software.

BigPicture for High-Level Maps

Suppose a company faces an important acquisition decision. There are several directions the company could go, and each involves a number of trade-offs based on monetary and non-monetary outcomes. BigPicture allows the company to “map” the decision alternatives and possible ramifications, and this map can then be the basis for a high-level discussion.

Here is a possible map to get the discussion started.
This map resides in an Excel worksheet, and it consists basically of Excel shapes, but it is much “smarter” than a collection of shapes you could draw with Excel tools only. For example, the plus signs to the right indicate that the map can be expanded in this direction. Here is one possible expansion:

The advantage of being able to expand or contract a large map should be obvious. It lets the decision makers focus on one part of the decision process at a time.
Linking to Cell Data

Each shape in a BigPicture map (the rectangles and ovals) is called a topic, and any type of information can be entered in a topic. You can type in this information, just as with regular Excel shapes, but a big advantage of BigPicture is that you can cell-reference this information. In other words, the text in a topic can be linked to values or formulas in any Excel cells, even those in a different worksheet. Here is an example:

All of the number in this map reference cell formulas in a “calculations” section of the workbook. If the data in this section change, the map will update automatically.
Free-Form Maps

BigPicture maps can be very structured, as in the above travel cost map, where everything “flows” from left to right and topics are lined up nicely. In fact, this structure can be created automatically by BigPicture, so that you don’t need to waste time lining up and resizing shapes. However, BigPicture also allows you to create “free-form” maps, where you can arrange topics and connectors to suit your needs. This is especially useful for showing the elements of a typical @RISK model, such as the following:

In this case, the color-coding was performed manually to indicate the different types of variables in the model.

If you are using such a map to explain a model to an audience, it might be nice to show the map in a step-by-step manner, explaining each step along the way. BigPicture lets you do this by creating slide shows. Each “slide” is a partial map, where you can decide exactly which topics to include, and it can be accompanied by a text box explaining that step. For example, here is the third step for this map:
Org Charts

As mentioned earlier, the original intent of BigPicture was to create maps of the type shown so far. But it evolved to include much more, specifically, data analysis. One example of this is its ability to create organization charts from tables of employee data. The table should include a row for each employee with any relevant data, including whom this employee reports to. Then BigPicture can create an org chart from this table automatically. Here is an example:

This chart not only shows the organization’s structure, but it shows calculations performed on the table data. Specifically, it shows the total salary of a supervisor and all the employees who report directly or indirectly to that supervisor.
An org chart is relevant for data with natural “parent/child” relationships. BigPicture includes similar maps, called linkes maps, for other parent/child data in a non-org chart context.

**Data Maps**

If you have used Excel pivot tables to “slice and dice” data, that is, to break down data by categories, you will love BigPicture’s data maps. They do essentially what pivot tables do, but in a more graphical format. This is a feature, maybe *the* feature, that definitely sets BigPicture above competing mapping software.

As with an org chart, a data map requires a data set in an Excel worksheet. Each column of this data set should correspond to a variable. Some variables will be categorical, representing categories you want to break down by, and others will be numeric. You define the categorical variables and numeric variables to be used in the map, including statistical summary measures of the numeric variable to be shown, and BigPicture does the rest. Here is an example of a company’s sales, broken down by region and product:
In this case, each topic on the right represents all products in a given type. By expanding one of these, you can see a table for the product type broken down by country:

Or broken down by product:
### Appendix F: Glossary of Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>@RISK</td>
<td>Pronounced &quot;at risk,&quot; a risk analysis add-in for Microsoft Excel from Palisade Corporation.</td>
</tr>
<tr>
<td>Arc</td>
<td>An arrow connecting nodes in an influence diagram to indicate dependency between the two nodes.</td>
</tr>
<tr>
<td>Barren Node</td>
<td>A node that has no effect on the decision to be made. In an influence diagram the node has predecessors but no successors.</td>
</tr>
<tr>
<td>Base Case</td>
<td>The state of a decision model before a sensitivity analysis is run, when all variables are set to their most likely value.</td>
</tr>
<tr>
<td>Bayes' Theorem</td>
<td>A formula used to revise probabilities when new information is available. In decision analysis, Bayes’ theorem is used to reorder (or “flip”) two chance nodes in a decision model.</td>
</tr>
<tr>
<td>Branch</td>
<td>In a decision tree, a branch is drawn for each possible decision (from a decision node) or each possible outcome (from a chance node).</td>
</tr>
<tr>
<td>Chance Node</td>
<td>A circle in a decision tree or influence diagram representing an event over which the decision maker has no control.</td>
</tr>
<tr>
<td>Certainty Equivalent</td>
<td>The dollar value that a decision maker believes is “equivalent” to a risky gamble, that is, the amount the decision maker would be willing to trade for to avoid the gamble.</td>
</tr>
<tr>
<td>Collectively Exhaustive</td>
<td>A set of outcomes where one of them must occur. The outcomes corresponding to branches from a decision tree chance node should be collectively exhaustive (and mutually exclusive).</td>
</tr>
<tr>
<td>Constant Risk Aversion</td>
<td>A situation where the decision maker views a risky situation the same way regardless of his or her wealth.</td>
</tr>
<tr>
<td>Cycle</td>
<td>In an influence diagram, a “loop” of arcs in which there is no clear endpoint. Cycles should be avoided in influence diagrams.</td>
</tr>
<tr>
<td>Decision Analysis</td>
<td>The process of modeling a problem situation, taking into account the decision maker’s preferences and beliefs regarding uncertainty, to gain insight and understanding. Decision Analysis provides a systematic method for describing and solving decision problems.</td>
</tr>
<tr>
<td><strong>Decision Node</strong></td>
<td>A square in a decision tree or influence diagram representing an event where the decision maker must choose one of a number of options.</td>
</tr>
<tr>
<td><strong>Decision Tree</strong></td>
<td>A graphical representation of a decision problem describing chance events and decisions in chronological order.</td>
</tr>
<tr>
<td><strong>Decreasing Risk Aversion</strong></td>
<td>A type of risk aversion whether the decision maker is more willing to take risk as his or her wealth increases.</td>
</tr>
<tr>
<td><strong>End Node</strong></td>
<td>A triangle in a decision tree that indicates the end of the problem, where all decisions have been made and all uncertainty has been resolved.</td>
</tr>
<tr>
<td><strong>Event</strong></td>
<td>An outcome or group of outcomes that might result from a given action. Usually refers to the possible outcomes of a chance node.</td>
</tr>
<tr>
<td><strong>Expected Utility</strong></td>
<td>The weighted average of the utility values for outcomes in a chance node or for an entire decision model.</td>
</tr>
<tr>
<td><strong>Expected Value (EV)</strong></td>
<td>The weighted average of possible outcomes, usually monetary values, for a chance node or for an entire decision model.</td>
</tr>
<tr>
<td><strong>Influence Diagram</strong></td>
<td>A graphical representation of a decision problem that emphasizes the relationship between events. Although influence diagrams are less detailed than decision trees, they can show the “big picture” in a way that is easy to explain to others.</td>
</tr>
<tr>
<td><strong>Logic Node</strong></td>
<td>Similar to a decision node, allows the decision maker to evaluate a logical expression for each branch and select the branch (or branches) with value TRUE.</td>
</tr>
<tr>
<td><strong>Mutually Exclusive</strong></td>
<td>A set of outcomes where at most one of them can occur. The outcomes corresponding to branches from a decision tree chance node should be mutually exclusive (and collectively exhaustive).</td>
</tr>
<tr>
<td><strong>Objective Risk</strong></td>
<td>A risk where the probabilities of outcomes can be determined by some type of objective argument that everyone agrees with. Examples are typically from games of chance, such as rolling fair dice, flipping a fair coin, etc.</td>
</tr>
<tr>
<td><strong>One-Way Sensitivity Analysis</strong></td>
<td>An analysis where each input is varied through a range to see its effect on an expected value of the model, while other possible inputs are held at their base values.</td>
</tr>
<tr>
<td><strong>One-Way Sensitivity Graph</strong></td>
<td>A graph comparing an input against the expected value of a model as the value of the input varies over its range.</td>
</tr>
<tr>
<td><strong>Payoff Node</strong></td>
<td>A rectangle with rounded corners in an influence diagram that represents the payoff from a decision.</td>
</tr>
<tr>
<td><strong>Policy Suggestion</strong></td>
<td>A subtree of a full decision tree that shows only the nodes and branches that could be encountered when using the optimal strategy.</td>
</tr>
<tr>
<td><strong>Predecessor Node</strong></td>
<td>The node directly before the selected node.</td>
</tr>
<tr>
<td><strong>PrecisionTree</strong></td>
<td>The decision analysis add-in for Microsoft Excel described in this manual.</td>
</tr>
<tr>
<td><strong>Probability</strong></td>
<td>A measure of how likely a value or event is to occur.</td>
</tr>
<tr>
<td><strong>Reference Node</strong></td>
<td>A diamond in a decision tree representing an exact copy of a subtree in the current tree or another tree, used to make a decision tree more compact.</td>
</tr>
<tr>
<td><strong>Risk</strong></td>
<td>Indicates not only uncertainty about an event, but that this uncertainty will affect a decision maker in a positive negative way.</td>
</tr>
<tr>
<td><strong>Risk Analysis</strong></td>
<td>Any method used to study and understand the risk inherent to a situation of interest. Methods can be quantitative and/or qualitative.</td>
</tr>
<tr>
<td><strong>Risk Averse</strong></td>
<td>Indicates the desire to avoid risky gambles, especially those involving large amounts of money. A risk averse decision maker is willing to sacrifice expected value to avoid risk.</td>
</tr>
<tr>
<td><strong>Risk Neutral</strong></td>
<td>Indicates that the decision maker is willing to use expected value as the criterion for making decisions, that is, he or she is not risk averse.</td>
</tr>
<tr>
<td><strong>Risk Premium</strong></td>
<td>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.</td>
</tr>
<tr>
<td><strong>Risk Profile</strong></td>
<td>A graphical display of the payoff distribution by following a particular decision strategy, usually the optimal strategy. Can be shown as a probability chart (a “spike” chart) or a cumulative chart.</td>
</tr>
<tr>
<td><strong>Risk Tolerance</strong></td>
<td>A constant measuring the decision maker’s attitude towards risk, usually associated with an exponential utility function.</td>
</tr>
<tr>
<td><strong>Sensitivity Analysis</strong></td>
<td>In a decision context, an analysis to determine which inputs are most influential in the results, and how optimal decisions can change as inputs are varied.</td>
</tr>
<tr>
<td><strong>Spider Graph</strong></td>
<td>A graph used in sensitivity analysis to show how the expected value of an output changes as selected inputs vary through their ranges.</td>
</tr>
<tr>
<td><strong>Stochastic</strong></td>
<td>Uncertain or risky.</td>
</tr>
<tr>
<td><strong>Stochastic Dominance</strong></td>
<td>Occurs when two profiles on a cumulative risk profile chart do not cross and there is space between them. There are 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.</td>
</tr>
<tr>
<td><strong>Strategy Region Graph</strong></td>
<td>A graph used in a one-way (or two-way) sensitivity analysis to show how (or if) an optimal decision changes as one input (or two inputs) vary.</td>
</tr>
<tr>
<td><strong>Subjective Risk</strong></td>
<td>A risk where the probabilities of uncertain outcomes differ from one person to the next, depending on personal knowledge, expertise, and experience.</td>
</tr>
<tr>
<td><strong>Successor Node</strong></td>
<td>The node directly after the selected node.</td>
</tr>
<tr>
<td><strong>TopRank</strong></td>
<td>Sensitivity analysis add-in for Microsoft Excel by Palisade Corporation.</td>
</tr>
<tr>
<td><strong>Tornado Graph</strong></td>
<td>A graph for a one-way sensitivity analysis that shows, by means of a bar for each input, how an expected value from the model varies as the input varies over its range. The inputs with the longest bars are the most influential and are placed at the top of the graph.</td>
</tr>
<tr>
<td><strong>Two-Way Sensitivity Analysis</strong></td>
<td>A type of sensitivity analysis where two inputs are varied simultaneously through their ranges (and other inputs are fixed at their base values) to see their effect on an expected value of the model.</td>
</tr>
<tr>
<td><strong>Two-Way Sensitivity Graph</strong></td>
<td>A 3-D graph from a two-way sensitivity analysis that shows how the expected value of a model varies as each of two inputs vary over their ranges.</td>
</tr>
<tr>
<td><strong>Utility Function</strong></td>
<td>A function that measures risk by converting the payoffs to utility units. The expected utility of one decision is then compared to that of another decision to select the best decision.</td>
</tr>
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