Oracle® Crystal Ball

Oracle® Crystal Ball Decision Optimizer Oracle® Crystal Ball Enterprise Performance Management Oracle® Crystal Ball Classroom Student Edition Oracle® Crystal Ball Classroom Faculty Edition Oracle® Crystal Ball Enterprise Performance Management for Oracle Hyperion Enterprise Planning Suite Oracle® Crystal Ball Suite

User's Guide

Release 11.1.2.3



Crystal Ball User's Guide, 11.1.2.3

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Welcome

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Introduction

This guide describes how to use the current release of the following Oracle products:

- Oracle Crystal Ball (including Classroom Faculty and Student Editions)
- Oracle Crystal Ball Decision Optimizer
- Oracle Crystal Ball Enterprise Performance Management

Unless otherwise noted, when this guide refers to Crystal Ball, the information applies to all versions.

Crystal Ball is a graphically oriented forecasting and risk analysis program that takes the uncertainty out of decision-making. It can help you answer questions such as, "Will we stay under budget if we build this facility?" or, "What are the chances this project will finish on time?" or, "How likely are we to achieve this level of profitability?"

Unlike other forecasting and risk analysis programs, you do not have to learn unfamiliar formats or special modeling languages. To get started, all you have to do is create a spreadsheet. From there, this manual guides you step by step, explaining Crystal Ball terms, procedures, and results.

And you do get results from Crystal Ball. Through a technique known as Monte Carlo simulation, Crystal Ball forecasts the entire range of results possible for a given situation. It also shows you confidence levels, so you will know the likelihood of any specific event taking place.

Who Should Use This Program

Crystal Ball is for decision-makers, from the analyst exploring the potential for new markets to the scientist evaluating experiments and hypotheses. Crystal Ball has been developed with a wide range of spreadsheet uses and users in mind.

You do not need highly advanced statistical or computer knowledge to use Crystal Ball to its full potential. All you need is a basic working knowledge of the personal computer and the ability to create a spreadsheet model.

What You Will Need

Crystal Ball runs on several versions of Microsoft Windows and Microsoft Excel. For a complete list of required hardware and software, see the system requirements list in the *Oracle Crystal Ball Installation and Licensing Guide*.

About the Crystal Ball Documentation Set

The *Oracle Crystal Ball User's Guide* is intended for students, analysts, engineers, executives, and others who want to learn how to use the main features of Crystal Ball. As mentioned earlier, unless otherwise noted, the Crystal Ball documentation pertains to all current Crystal Ball releases.

The Oracle Crystal Ball Enterprise Performance Management Integration Guide contains special Crystal Ball integration information for users of Crystal Ball EPM and related products.

The Oracle Crystal Ball Installation and Licensing Guide describes how to install and license Crystal Ball.

For information about distribution defaults and formulas plus other statistical information, topics for advanced users, and examples, see the *Oracle Crystal Ball Reference and Examples Guide*.

The Oracle Crystal Ball Predictor User's Guide, Oracle Crystal Ball Decision Optimizer OptQuest User's Guide, Oracle Crystal Ball Developer's Guide and Oracle Crystal Ball API for .NET Developer's Guide offer additional information about those Crystal Ball products. Notice that the Oracle Crystal Ball Decision Optimizer OptQuest User's Guide is only for users of Crystal Ball Decision Optimizer.

This Oracle Crystal Ball User's Guide includes the following additional chapters and appendices:

• Chapter 2, "Crystal Ball Overview"

Introduces Crystal Ball and explains how it uses spreadsheet models to help with risk analysis and many types of decision-making.

• Chapter 3, "Defining Model Assumptions"

Describes how to define assumption cells in models and how to use the Crystal Balll Distribution Gallery.

• Chapter 4, "Defining Other Model Elements"

Describes how to define decision variable cells and forecast cells in models. It also explains how to set cell preferences.

• Chapter 5, "Running Simulations"

Provides step-by-step instructions for setting up and running a simulation in Crystal Ball.

• Chapter 6, "Analyzing Forecast Charts"

Explains how to use Crystal Ball's powerful analytical features to interpret the results of a simulation, focusing on forecast charts.

• Chapter 7, "Analyzing Other Charts"

Provides additional information to help you analyze and present the results of the simulations using advanced charting features.

• Chapter 8, "Creating Reports and Extracting Data"

Provides information to help you share Crystal Ball data and graphics with other applications, and describes how to prepare reports with charts and data.

• Chapter 9, "Crystal Ball Tools"

Describes tools that extend the functionality of Crystal Ball, such as the Tornado Analysis and Decision Table tools.

• Appendix A, "Selecting and Using Probability Distributions"

Describes all the pre-defined probability distributions used to define assumptions in Crystal Ball, and includes suggestions on how to choose and use them.

• Appendix B, "Extreme Speed Compatibility Issues"

Discusses the optional Extreme Speed feature available with Crystal Ball and describes its benefits and compatibility issues.

• Appendix C, "Crystal Ball Tutorials"

Demonstrates Crystal Ball basics and shows how to use more advanced features in a variety of settings.

• Appendix D, "Using the Process Capability Features"

Discusses the process capability features that can be activated to support Six Sigma, DFSS, Lean principles, and similar quality programs.

• Glossary

Defines terms specific to Crystal Ball and other statistical terms used in this manual.

For additional information about maximizing the accuracy and speed of Crystal Ball simulations and finding related publications, see the *Oracle Crystal Ball Reference and Examples Guide*.

Screen Capture Notes

All the screen captures in this document were taken using a Crystal Ball Run Preferences random seed setting of 999, unless otherwise noted.

Due to rounding differences between various system configurations, you may obtain slightly different calculated results than those shown in the examples.

Getting Help

- > To display online help in a variety of ways as you work in Crystal Ball:
- Click the **Help** button, **(2)**, in a dialog.
- Click the **Help** tool in the Crystal Ball toolbar or ribbon in Microsoft Excel.
- In the Microsoft Excel menu bar, select Help, then Crystal Ball, and then Crystal Ball Help.
- In the Distribution Gallery and other dialogs, press **F1**.
 - Note: In Microsoft Excel 2007 or later, click Help, ⁽²⁾, at end of the Crystal Ball ribbon. Notice that if you press F1 in Microsoft Excel 2007 or later, Microsoft Excel help opens unless you are viewing the Distribution Gallery or another Crystal Ball dialog.
- Tip: When help opens, the **Search** tab is selected. Click the **Contents** tab to view a table of contents for help.

For a table of Help commands, see Table 2 on page 31.

Technical Support and More

Oracle offers a variety of resources to help you use Crystal Ball, such as technical support, training, and other services. For information, see:

```
http://www.oracle.com/crystalball
```

2

Crystal Ball Overview

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About Model Building and Risk Analysis

Subtopics

- Quantifying Risks with Spreadsheet Models
- Monte Carlo Simulation and Crystal Ball

Crystal Ball is an analytical tool that helps executives, analysts, and others make decisions by performing simulations on spreadsheet models. The forecasts that result from these simulations help quantify areas of risk so decision-makers can have as much information as possible to support wise decisions.

The basic process for using Crystal Ball is to:

- 1. Build a spreadsheet model that describes an uncertain situation ("Quantifying Risks with Spreadsheet Models" on page 18).
- 2. Run a simulation on it ("Monte Carlo Simulation and Crystal Ball" on page 19).
- 3. Analyze the results ("Crystal Ball Charts, Reports, and Data" on page 20).

Topics in this section build a foundation for understanding the many ways Crystal Ball and related Oracle products can help you minimize risk and maximize success in many decision-making environments.

Quantifying Risks with Spreadsheet Models

Subtopics

- Assumption Ranges–Model Input
- Forecast Ranges—Model Output
- Analyzing Certainty–Model Results

A model is a spreadsheet that has moved from being a data organizer to an analysis tool. A model represents the relationships between input and output variables using functions, formulas, and data. As the model expands, it more closely matches the behavior of a real-world scenario.

Crystal Ball works with spreadsheet models created in Microsoft Excel and compatible Oracle applications, such as Oracle Hyperion Smart View for Office, to help you identify and quantify risk and the probability of success.

Risk is usually associated with uncertainty, where risk includes the possibility of an undesirable event coupled with severity. It is important to identify risks and to determine how significant they are.

After you identify risks, a model can help you quantify them. Quantifying a risk means determining the chances that the risk will occur and the cost if it does, to help you decide whether a risk is worth taking. For example, if there is a 25% chance of running over schedule, costing you \$100, that may be a risk you are willing to take. But if you have a 5% chance of running over schedule, knowing that there is a \$10,000 penalty, you may be less willing to take that risk.

Finding the certainty of achieving a particular result is often the goal of model analysis. Risk analysis takes a model and sees what effect changing different values has on the bottom line. Risk analysis can:

- Contribute to better decision-making by quickly examining all possible scenarios
- Identify which variables most affect the bottom-line forecast
- Expose the uncertainty in a model, leading to a better communication of risk

Assumption Ranges—Model Input

For each uncertain variable in a simulation, you can define the possible values with a probability distribution. A simulation calculates numerous scenarios of a model by repeatedly picking values from the probability distribution for the uncertain variables and using those values for the cell. In Crystal Ball, distributions and associated scenario input values are called assumptions. They are entered and stored in assumption cells. For more information on assumptions and probability distributions, see "About Assumptions and Probability Distributions" on page 34.

Forecast Ranges-Model Output

Since scenarios produce associated results, Crystal Ball also keeps track of the forecasts for each scenario. These are important outputs of the model, such as totals, net profit, or gross expenses. For each forecast, Crystal Ball remembers the cell value for all the trials (scenarios). After

hundreds or thousands of trials, you can view sets of values, the statistics of the results (such as the mean forecast value), and the certainty of any particular value. Chapter 6 provides more information about charts of forecast results and how to interpret them.

Analyzing Certainty–Model Results

The forecast results in graphic and numeric form show the values generated for each forecast and also the probability of obtaining any value. Crystal Ball normalizes these probabilities to calculate another important number: the certainty. Forecast charts (Table 1, "Crystal Ball Charts," on page 20) are key analysis tools.

The chance of any forecast value falling between –Infinity and +Infinity is always 100%. However, the chance — or certainty — of that same forecast being at least zero (which you may want to calculate to make sure that you make a profit) may be only 45%. For any range you define, Crystal Ball calculates the resulting certainty. This way, not only do you know that the company has a chance to make a profit, but you can also quantify that chance by saying that the company has a 45% chance of making a profit on a venture (a venture you may, therefore, decide to skip).

Monte Carlo Simulation and Crystal Ball

Spreadsheet risk analysis uses spreadsheet models and simulation to analyze the effects of varying inputs on outputs of the modeled system.

Traditional methods of risk analysis have limitations:

- Changing only one spreadsheet cell at a time makes it virtually impossible to explore the entire range of possible outcomes.
- What-if analysis always results in single-point estimates that do not indicate the likelihood of achieving any particular outcome. While single-point estimates may tell you what is possible, they do not tell you what is probable.

Crystal Ball uses Monte Carlo simulation to overcome limitations encountered with traditional spreadsheet analysis:

- You can describe a range of possible values for each uncertain cell in a spreadsheet. Everything you know about each assumption is expressed all at once. For example, you can define the business phone bill for future months as any value between \$2500 and \$3750, instead of using a single-point estimate of \$3000. Crystal Ball then uses the defined range in a simulation.
- With Monte Carlo simulation, Crystal Ball displays results in a forecast chart that shows the entire range of possible outcomes and the likelihood of achieving each of them. In addition, Crystal Ball keeps track of the results of each scenario for you.

Crystal Ball implements Monte Carlo simulation in a repetitive three-step process, described in "Take a Look Behind the Scenes" on page 251.

Monte Carlo simulation randomly generates a range of values for assumptions that you define. These inputs feed into formulas defined in forecast cells. You can use this process to explore ranges of outcomes, expressed as graphical forecasts. You can view and use forecast charts to estimate the probability, or certainty, of a particular outcome.

Monte Carlo simulation was named for Monte Carlo, Monaco, where the primary attractions are casinos containing games of chance. The random behavior in games of chance — roulette wheels, dice, and slot machines — is similar to how Monte Carlo simulation selects variable values at random to simulate a model. When you roll a die, you know that either a 1, 2, 3, 4, 5, or 6 will come up, but you do not know which for any particular trial. It is the same with the variables that have a known range of values but an uncertain value for any particular time or event (for example, interest rates, staffing needs, stock prices, inventory, phone calls per minute).

Crystal Ball Charts, Reports, and Data

Subtopics

- Crystal Ball Charts
- Reports
- Data Extraction

Crystal Ball offers several types of charts and reports to display results graphically and numerically. You can also extract simulation values for use in other applications. These analysis tools are all accessed through the Analyze menu or the Analyze group on the Crystal Ball ribbon.

Crystal Ball Charts

Charts are the main analysis tools provided in Crystal Ball. Each chart offers several views and many customization settings to enhance data presentation.

Table 1 Crystal Ball Charts

Name and Reference	Example	Description
Forecast charts (Chapter 6, "Analyzing Forecast Charts")	Construction Construction<	Forecast charts are the basic tool for Crystal Ball results analysis. They show a range of values representing possible and probable values for a given forecast based on assumption definitions. You can use forecast charts to evaluate the certainty of obtaining a particular value or range of forecast values. You can also fit standard distributions to charted forecasts.

Name and Reference	Example	Description
Overlay charts ("Using Overlay Charts" on page 115)	Coverag Chart 1 C C C C C C C C C C C C C C C C C C	Overlay charts display frequency data from multiple forecasts in one location so you can compare differences or similarities among them. You can customize them and fit distributions as for forecast charts.
Trend charts ("Using Trend Charts" on page 120)	Trend Chart 1 Cartered References Hole 500 Trials Cartered Order 1 Cartered or Metara View 1 1000 Trials Cartered Order 1 Cartered or Metara View 1 1000 Trials Cartered or Metara View Cartered or Metara View 1 1000 Trials Cartered Order 1 Cartered or Metara View 1 1000 Trials Cartered Order 1 Sec. 1 1000 Trials Trials Sec. 1 1000 Trials Trials </td <td>Trend charts display the certainty ranges of all forecasts on a single chart as a series of patterned bands. For example, the band that represents the 90% certainty range shows the range of values into which a forecast has a 90% chance of falling.</td>	Trend charts display the certainty ranges of all forecasts on a single chart as a series of patterned bands. For example, the band that represents the 90% certainty range shows the range of values into which a forecast has a 90% chance of falling.
Sensitivity charts ("Using Sensitivity Charts" on page 126)	Sonsahining heef Yooffi (W) Consultation of Valence View Sons Tarials Consultation of Valence View Sonsitivity: Heef Yooffi (M) Sonsitivity:	Sensitivity charts use rank correlations to show the influence of each assumption cell on a particular forecast cell, indicating which assumptions are the most or least important in the model.
Scatter charts ("Using Scatter Charts" on page 137)	State State <th< td=""><td>Scatter charts show correlations, dependencies, and other relationships between pairs of forecasts and assumptions plotted against each other. Relationships are plotted as a cloud of points or symbols aligned in a grid. In Matrix view, each selected variable is plotted against the other selected variables to show the relationships among them.</td></th<>	Scatter charts show correlations, dependencies, and other relationships between pairs of forecasts and assumptions plotted against each other. Relationships are plotted as a cloud of points or symbols aligned in a grid. In Matrix view, each selected variable is plotted against the other selected variables to show the relationships among them.
Assumption charts ("Using Assumption Charts" on page 134)	Occurrent Control Exit year, Preferences: Help Control 5000 Trails Normal Develution 4.580 Displayer Geoder Body Weight 000 Weight 000 000 Geoder Body Weight 000 Geoder Body Weight 000 Weight 000 000 000 Weight 000 000 000 000 Weight 000 000 000 000 000 Weight 000 000 000 </td <td>Assumption charts show random values for the current simulation layered over the assumption's ideal probability distribution. They are generated automatically each time a simulation runs.</td>	Assumption charts show random values for the current simulation layered over the assumption's ideal probability distribution. They are generated automatically each time a simulation runs.
OptQuest charts ("Goal Optimization with OptQuest" on page 25)	N/A	OptQuest charts, available in Crystal Ball Decision Optimizer, display variable optimization results.

Name and Reference	Example	Description
Predictor charts ("Trend Analysis with Predictor" on page 25)	N/A	Predictor charts display the results of time-series and linear regression analyses performed by the Predictor tool in Crystal Ball.

Reports

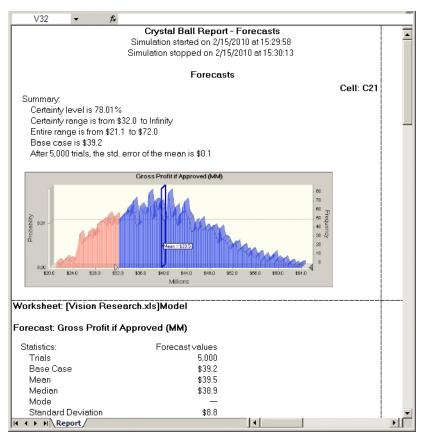
Crystal Ball has powerful reporting capabilities. You can customize reports to include the following charts and data:

- Assumption, forecast, overlay, trend, sensitivity, scatter, and (optionally) OptQuest charts
- Forecast summaries, statistics, percentiles, and frequency counts
- Assumption parameters
- Decision variables

Reports are created as Microsoft Excel workbooks. You can modify, print, or save the report in the same way as any other workbook ("Creating Reports" on page 145)

Figure 1 shows part of a forecast report for the Vision Research example model.

Figure 1 Sample Forecast Report



Data Extraction

You can extract forecast information generated by a simulation manually or automatically and place it in a Microsoft Excel workbook. You can extract several types of data ("Extracting Data" on page 150).

Figure 2 shows statistics data extracted from a sales spreadsheet.

	А	J	
1	Statistics	Ending Sales Year 3 - Q1	Enc
2	Trials	5000	
0			

Figure 2 Extracted Statistics Data

	A	J	K
1	Statistics	Ending Sales Year 3 - Q1	Ending Sales Year 3 - Q2
2	Trials	5000	5000
3	Base Case	\$17,027,748	\$17,879,136
4	Mean	\$17,043,967	\$17,896,466
5	Median	\$17,025,416	\$17,887,088
6	Mode		
7	Standard Deviation	\$1,116,763	\$1,274,922
8	Variance	\$1,247,160,221,992	\$1,625,427,230,498
9	Skewness	0.1885	0.1794
10	Kurtosis	3.20	3.14
11	Coeff. of Variation	0.0655	0.0712
12	Minimum	\$12,711,586	\$13,574,828
13	Maximum	\$21,337,920	\$23,507,537
14	Range Width	\$8,626,334	\$9,932,709
15	Mean Std. Error	\$15,793	\$18,030

Other Crystal Ball Features

Subtopics

- Crystal Ball Tools
- Process Capability Features
- Trend Analysis with Predictor
- Goal Optimization with OptQuest

Topics in this section introduce additional features of Crystal Ball.

Crystal Ball Tools

The Run menu offers a variety of special tools for analyzing data and displaying results in more detail. Select **Run**, then **More Tools** to use tools discussed in the following sections (in Microsoft Excel 2007 or later, select **More Tools** in the Tools group of the Crystal Ball ribbon):

- "Fitting Distributions to Assumptions with the Batch Fit Tool" on page 156 Automatically fits selected probability distributions to multiple data series
- "Measuring Variable Effects with the Tornado Analysis Tool" on page 162 Individually analyzes the impact of each model variable on a target outcome
- "Estimating Data Accuracy with the Bootstrap Tool" on page 172 Addresses the reliability and accuracy of forecast statistics
- "Analyzing Decision Variable Changes with the Decision Table Tool" on page 179 Evaluates the effects of alternate decisions in a simulation model
- "Using the Scenario Analysis Tool" on page 183 Displays what inputs created particular outputs
- "Analyzing Uncertainty and Variability with the 2D Simulation Tool" on page 187 Independently addresses uncertainty and variability using a two-dimensional simulation
- "Importing and Analyzing Data with the Data Analysis Tool" on page 194 Imports one or more series of raw data and performs a variety of analyses on them
- "Working with Smart View Using the Crystal Ball Enterprise Performance Management Connector" on page 198 — Available to users of Crystal Ball EPM and related products, enables Crystal Ball simulations and time-series analyses to be used with Oracle Hyperion Planning and Smart View; for more information about the EPM Connector and other integration tools, see the Oracle Crystal Ball Enterprise Performance Management Integration Guide
- "Comparing Extreme and Normal Speed with the Compare Run Modes Tool" on page 199 — For users of Crystal Ball Decision Optimizer, determines how much faster a model runs in Extreme Speed

All of these tools are discussed in Chapter 9, "Crystal Ball Tools."

Additional tools, Predictor and OptQuest, are also listed on the **Run** menu (or the Tools group in Microsoft Excel 2007 or later) in certain editions of Crystal Ball. For a description of these

features, see "Trend Analysis with Predictor" on page 25 and "Goal Optimization with OptQuest" on page 25.

Note: The Correlation Matrix tool was replaced with an updated Define Correlations feature ("Correlating Assumptions" on page 45).

Process Capability Features

If you use Six Sigma or other quality methodologies, Crystal Ball's process capability features can help you improve quality in the organization. For a brief description of these features and how to use them, see Appendix D, "Using the Process Capability Features."

Trend Analysis with Predictor

You can use Predictor to project trends based on time-series data, such as seasonal trends.

For example, you can look at home heating fuel sales for previous years and estimate sales for the current year. You can also run regression analysis on related time-series data.

For more information about Predictor, see the Oracle Crystal Ball Predictor User's Guide.

Goal Optimization with OptQuest

Decision variables are variables you can control, such as product pricing or investment levels. If you have OptQuest, an optional feature available in Crystal Ball Decision Optimizer, you can use it to find the best values for the decision variables to obtain the preferred outcomes.

For example, you can find the optimal investment mix that maximizes the probability of a portfolio's return being above a certain threshold.

For more information about OptQuest, see the Oracle Crystal Ball Decision Optimizer OptQuest User's Guide.

Steps for Using Crystal Ball

Follow these general steps to create and interpret simulations with Crystal Ball. The remaining chapters provide detailed instructions:

- 1. Create a spreadsheet model in Microsoft Excel format with data and formula cells that represent the situation to analyze ("Quantifying Risks with Spreadsheet Models" on page 18).
- 2. Start Crystal Ball ("Starting and Closing Crystal Ball" on page 26).
- 3. Load a spreadsheet model.
- 4. Using Crystal Ball, define assumption cells and forecast cells. If appropriate for the situation, you can also define decision variable cells.

For more information, see "Entering Assumptions" on page 35 and continue on with Chapter 4.

- 5. Set run preferences for the simulation ("Setting Run Preferences" on page 71).
- 6. Run the simulation ("Starting Simulations" on page 77).
- 7. Analyze the results. See "Using Forecast Charts" on page 84 for suggestions.
- 8. Consider using Predictor or OptQuest, if available, for further analysis.
- 9. Take advantage of the many resources available to help you get the most out of Crystal Ball.

Starting and Closing Crystal Ball

You can start Crystal Ball manually or you can set up Crystal Ball to start automatically whenever you start Microsoft Excel.

Starting Crystal Ball Manually

To start Crystal Ball manually, in Windows, select Start, then All Programs, then Oracle Crystal Ball, and then Crystal Ball.

Microsoft Excel opens with the Crystal Ball menus and toolbar. If Microsoft Excel is already running when you give this command, Crystal Ball opens a new instance of Microsoft Excel.

Starting Crystal Ball Automatically

- > To set Crystal Ball to start automatically each time you start Microsoft Excel:
- 1 In Windows, select **Start**, then **All Programs**, then **Oracle Crystal Ball**, and then **Application Manager**.
- 2 Select Automatically launch Crystal Ball when Microsoft Excel starts.
- 3 Click OK.
 - **Note:** You can also use the Microsoft Excel Add-ins Manager to open Crystal Ball within Microsoft Excel when Microsoft Excel is already open and to close Crystal Ball without closing Microsoft Excel. For instructions, see the *Oracle Crystal Ball Installation and Licensing Guide*.

Crystal Ball Welcome Screen

The first time you start Crystal Ball, the Welcome screen opens, similar to Figure 3, following. Depending on the Crystal Ball version, the license features, and whether you are using a purchased or a trial version, the screen may differ somewhat from this illustration.

Figure 3 Crystal Ball Welcome Screen



You can use the Welcome screen to:

- Set certain preferences according to how you use Crystal Ball
- Enable accessibility preferences to accommodate those with visual impairments (see the online *Oracle Crystal Ball Accessibility Guide*).
- View the Crystal Ball Web site
- Display the Oracle Technology Network, where you can download applications and documentation
- Display the Crystal Ball online documentation in HTML format
- Display instructions for licensing Crystal Ball
- Close the screen and start using Crystal Ball
- Display the dialog for opening workbook files
- Display the Oracle Crystal Ball Examples Guide and open example workbooks

For an explanation of the "primary application type" and "accessibility" settings, click the *low* button.

Closing Crystal Ball

- > To close Crystal Ball, use one of the following options:
- Right-click the Crystal Ball icon, Crystal Ball, in the Windows taskbar and select **Close**, or
- Close Microsoft Excel.

If you want, you can select **Run**, and then **Reset Simulation** to reset the model and then select **File**, then **Save** to save it before you close Crystal Ball.

Crystal Ball Menus, Toolbar, and Ribbon

Subtopics

- Crystal Ball Menus in Microsoft Excel 2003
- Crystal Ball Toolbar in Microsoft Excel 2003
- Crystal Ball Ribbon in Microsoft Excel 2007 or Later

This section describes the Crystal Ball toolbar and associated menus for Crystal Ball used with Microsoft Excel 2003. It also describes the Crystal Ball ribbon used with Microsoft Excel 2007 or later versions. For additional information about Crystal Ball menus and commands, including tables of keyboard equivalents, see the *Oracle Crystal Ball Accessibility Guide*.

Crystal Ball Menus in Microsoft Excel 2003

When Crystal Ball opens in Microsoft Excel 2003, the following special menus are added to the standard Microsoft Excel menus:

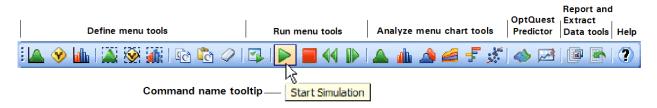
- **Define** menu enables you to define and select assumptions, decision variables, and forecasts; freezes assumptions, decision variables, and forecasts so they are not included in simulations; also lets you copy, paste and clear assumptions, decision variables, and forecasts as well as set cell preferences.
- **Run** menu starts, stops, continues, and resets simulations; runs simulations a step at a time; if available, starts OptQuest or Predictor; opens the Crystal Ball tools: Batch Fit, Tornado Analysis, Bootstrap, Decision Table, Scenario Analysis, 2D Simulation; saves and restores simulation results; and sets run preferences.
- **Analyze** menu creates and opens charts and reports; cascades and closes windows; and extracts data.
- Help, then Crystal Ball menu Opens online help for Crystal Ball; displays the following items: the About Box for Crystal Ball, Oracle Crystal Ball User's Guides and other documentation in Adobe Acrobat format, Crystal Ball examples, the Crystal Ball Welcome Screen, lets you access Crystal Ball licensing features, and more.

For more information on each command, view online help from within Crystal Ball using the **Help** menu or button.

Crystal Ball Toolbar in Microsoft Excel 2003

To help you use Crystal Ball in Microsoft Excel 2003, a customized toolbar provides instant access to the most commonly used menu commands (Figure 4 on page 29).

Figure 4 Crystal Ball Toolbar



As you point to each of the Crystal Ball toolbar buttons, a tool tip identifies it (Figure 4 on page 29).

To hide or display the Crystal Ball toolbar for the current session, select View, then Toolbars, and then Crystal Ball.

Crystal Ball Ribbon in Microsoft Excel 2007 or Later

Subtopics

- Define Commands
- Run Commands
- Analyze Commands
- Tools Commands
- Help Commands

In Microsoft Excel 2007 or later, a single Crystal Ball ribbon contains both menus and tool icons (Figure 5 on page 29.

Figure 5 Crystal Ball Ribbon in Microsoft Excel 2007 or Later



The Crystal Ball ribbon contains five groups, listed at the beginning of this topic.

Note: If you are using Microsoft Excel 2010 or later, the Crystal Ball ribbon may look different from Figure 5 on page 29. If the Microsoft Excel window becomes shorter, icons for one or more of the five Crystal Ball groups can condense into a single icon for each group. To expand the group, click the arrow below the group icon or use the Alt keyboard equivalents for each group.

Define Commands

The Define commands specify settings for the three types of Crystal Ball data cells: assumptions, decision variables, and forecasts and also enable you to perform the following tasks:

- Set cell preferences
- Select Crystal Ball data cells
- Copy, paste, and clear Crystal Ball data
- Freeze data cells to exclude them from Crystal Ball simulations

For details, see Chapter 3, "Defining Model Assumptions" and Chapter 4, "Defining Other Model Elements.".

Run Commands

You can use the basic Run commands to start, stop, continue, reset, and single-step through Crystal Ball simulations. You can use other Run commands to:

- Save or restore Crystal Ball simulation results
- Set run preferences, which control the number of trials, the sampling method, and other simulation options

For details, see Chapter 5, "Running Simulations."

Analyze Commands

You can use the Analyze commands to:

- Create and view Crystal Ball charts
- Create reports
- Extract data for external use

For details, see Chapter 6, "Analyzing Forecast Charts," Chapter 7, "Analyzing Other Charts," and Chapter 8, "Creating Reports and Extracting Data."

Tools Commands

You can use the Tools commands to access the Crystal Ball tools, Predictor, and OptQuest with an appropriate license. For details, see Chapter 9, "Crystal Ball Tools,"

Help Commands

The Help commands display online help, online documents, example models, the Crystal Ball About Box, and more (Table 2, "Crystal Ball Help Commands," on page 31).

Table 2 Crystal Ball Help Commands

Command	Command Action
[Crystal Ball] Help, ወ	Displays online help for Crystal Ball
Resources,	In the Crystal Ball ribbon, displays menus for Crystal Ball technical support, Crystal Ball and EPM documentation, example models, the Welcome screen, and the licensing dialog
Technical Support	Opens the Crystal Ball Web page with a link to technical support
Crystal Ball Documentation	Displays a list of available online documentation for Crystal Ball
Oracle EPM Documentation	Displays the OTN index for Oracle Enterprise Performance Management documentation, including Crystal Ball
Examples Guide	Displays a list of available example models so you can load the choice into Crystal Ball
Welcome Screen	Displays a Welcome screen that enables you to automatically activate the process capability features for quality programs such as Six Sigma, set percentile preferences frequently used in the Oil and Gas industry, and activate accessibility features for those with visual impairments.
Licensing	Displays the Activate a License dialog for entering a Crystal Ball serial number and activating a license
About [Crystal Ball], 🧿	Offers version and other information about the current Crystal Ball release including the current username

Resources for Learning Crystal Ball

The easiest way to learn Crystal Ball is to work through the tutorials in Appendix C. Tutorial 1 is basic and will help you understand what Crystal Ball does and how it works. Tutorial 2 shows more about how to create models and run Crystal Ball simulations. If you are new to Crystal Ball, consider completing the tutorials before you continue using the product.

For information on support, training, and referral services, see the Crystal Ball Web site at:

```
http://www.oracle.com/crystalball
```

3

Defining Model Assumptions

In This Chapter

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Defining Assumptions	34
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Assumptions and Other Crystal Ball Data Cells

Crystal Ball uses three types of data cells as inputs and outputs:

- Assumption cells are input cells that contain values that you are unsure of: the uncertain independent variables in the problem you are trying to solve. The assumption cells must contain simple numeric values, not formulas or text.
- Decision variable cells are input cells that contain values that are within your control to change. The decision variable cells must contain simple numeric values, not formulas or text. These are used by some of the Crystal Ball tools and by OptQuest.
- Forecast cells (dependent variables) are output cells that contain formulas that refer to one or more assumption and decision variable cells. The forecast cells combine the values in the assumption, decision variable, and other cells to calculate a result. A forecast cell, for example, may contain the formula =C17*C20*C21.

Every Crystal Ball model must contain at least one assumption and forecast. Decision variables are optional for basic simulations.

Assumptions can have a range of values, defined with probability distributions ("About Assumptions and Probability Distributions" on page 34).

The topics about assumptions provide step-by-step instructions for defining assumption cells in Crystal Ball models so simulations can be run against them. They also describe how to use

the Distribution Gallery to organize favorite distributions and define categories of distributions to share with others.

If you are a new user, consider working through Tutorial 1 in Appendix C, before you read these topics.

About Assumptions and Probability Distributions

For each uncertain variable in a simulation, or assumption, you define the possible values with a probability distribution. The type of distribution you select depends on the conditions surrounding the variable. Common distribution types are normal, triangular, uniform, and lognormal, as shown in Figure 6.

Figure 6 Common Distribution Types



During a simulation, Crystal Ball calculates numerous scenarios of a model by repeatedly picking values from the probability distribution for the uncertain variables and using those values for each assumption cell. Commonly, a Crystal Ball simulation calculates hundreds or thousands of scenarios, or trials, in just a few seconds. The value to use for each assumption for each trial is selected randomly from the defined possibilities.

Because distributions for independent variables are so important to simulations, selecting and applying the appropriate distribution is the main part of defining an assumption cell. For more information on probability distributions, see "Understanding Probability Distributions" on page 201.

For more information about assumptions, see the other topics in Chapter 3, "Defining Model Assumptions."

Defining Assumptions

- ➤ To define an assumption:
- 1 Review "About Assumptions and Probability Distributions" on page 34.
- 2 Determine the most appropriate probability distribution for each uncertain variable:
 - List everything you know about the conditions surrounding this variable.
 - Review the descriptions of the probability distributions in "Selecting Probability Distributions" on page 205.
 - Consider using Crystal Ball's distribution fitting feature, described in "Fitting Distributions to Historical Data" on page 41.
 - Select the distribution that characterizes the variable.

3 Enter the assumption as described in the next section, "Entering Assumptions" on page 35.

Entering Assumptions

- > To enter an assumption:
- **1** Select a cell or a range of cells. The cells can be blank or have numeric values, but they cannot have formulas or text ("Defining Assumptions" on page 34).
- 2 Select **Define**, and then **Define Assumption**,



(In Microsoft Excel 2007 or later, click the upper half of the **Define Assumption** icon.)

For each selected cell or cells in the selected range, Crystal Ball displays the Distribution Gallery dialog (Figure 7).

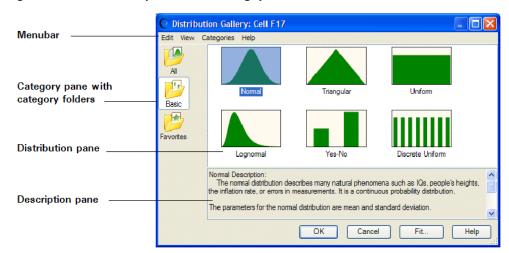


Figure 7 Distribution Gallery with the Basic Category Selected

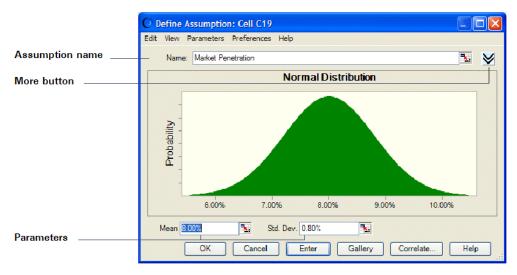
3 In the Distribution Gallery, select the distribution you want from the gallery. The Basic category contains several frequently used distributions. Click All to view all distributions shipped with Crystal Ball. For details, see "Using the Crystal Ball Distribution Gallery" on page 53.

Alternately, click the **Fit** button to fit a distribution to historical data, as described in "Fitting Distributions to Historical Data" on page 41.

For more information on the Distribution Gallery, see "Distribution Gallery Window" on page 54.

4 When the Define Assumption dialog opens (Figure 8), type in a title and the parameters for the distribution. The parameters can be either numeric values or cell references ("Entering Cell References and Formulas" on page 38). For most distributions, you can use alternate parameters ("Using Alternate Parameter Sets" on page 39).

Figure 8 Normal Distribution



To change the distribution type, click **Gallery** to return to the Distribution Gallery and then select another distribution.

5 To see more information, click the More button, 🧐, near the Name text box.

More information is displayed in the Define Assumption dialog as shown in Figure 9.

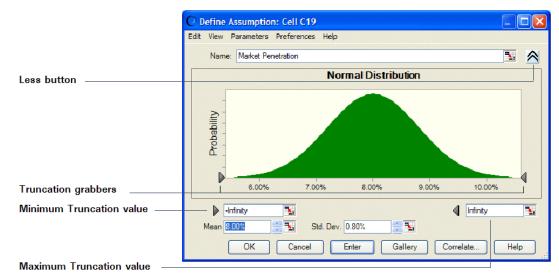


Figure 9 Define Assumption Dialog, Expanded

In the expanded Define Assumption dialog, you can:

- Enter truncation minimum and maximum values in the minimum and maximum truncation text boxes (just below the distribution, accessible by tabbing).
- Use the truncation grabbers to truncate the value range.
- Use numeric spinners (arrows beside the text box) to adjust parameter settings.

• Click the **Less** button, (2), to hide the minimum and maximum value text boxes and truncation grabbers. (For more information about truncating distributions, see "Truncating Distributions" on page 235.)

You can perform the following activities in both the standard and expanded Define Assumption dialog:

- Click the **Gallery** button to display the Distribution Gallery window and select another distribution.
- Click the **Correlate** button to define correlations between assumptions ("Correlating Assumptions" on page 45).
- Select **Edit**, and then **Add** in the menu bar to add the currently defined assumption distribution to the Favorites category or a user-defined category in the Distribution Gallery.
- Use other menu commands to copy the chart, paste it into Microsoft Excel or another application, print data, change the view, use alternate parameters, set assumption and chart preferences, and display help as described in "Additional Assumption Features" on page 37.
- 6 When you have finished entering parameters to define the assumption, click Enter.

The distribution changes to reflect the values you entered. If you click **OK** instead of **Enter**, Crystal Ball accepts the parameters and closes the dialog.

7 Click OK.

If you selected a range of cells, repeat these steps to define the assumption for each cell.

For more information about assumptions, see "Additional Assumption Features" on page 37.

Additional Assumption Features

As you enter assumption parameters, you can use cell references and alternate parameters. If you have historical data available, you can use Crystal Ball's distribution fitting feature to help simplify the process of selecting a probability distribution. You can also specify correlations between assumptions or freeze assumptions to exclude them from a simulation.

The following topics describe additional assumption features available in Crystal Ball:

- "Entering Cell References and Formulas" on page 38
- "Using Alternate Parameter Sets" on page 39
- "Freezing Crystal Ball Data Cells" on page 76
- "Fitting Distributions to Historical Data" on page 41
- "Correlating Assumptions" on page 45
- "Setting Assumption Preferences" on page 40

- "Using the Crystal Ball Distribution Gallery" on page 53
- "Using Assumption Charts" on page 134

Entering Cell References and Formulas

Subtopics

- Dynamic vs. Static Cell References
- Relative References
- Absolute References
- Range Names
- Formulas

In addition to numeric values, you can enter a reference to a specific cell in a parameter text box. Cell references must be preceded by an equal sign (=). Cell references can be either absolute or relative. You can also enter formulas and range names.

If necessary, you can press F4 to change references from relative to absolute or back to relative. This also applies to cell references in text boxes other than assumption parameters.

- **Note:** All cell references in parameters are treated like absolute references when cutting and pasting Crystal Ball data. Crystal Ball always stores the cell reference in A1 format even if the Microsoft Excel preference is set to R1C1 format. The global R1C1 format preference is not affected by running Crystal Ball, but the name ranges are, in fact, changed to A1 format since that is the way Crystal Ball stores them.
- To show cell references instead of current values when you enter them in parameter text boxes, select **Parameters**, and then **Show Cell References** in the Define Assumption dialog.

Dynamic vs. Static Cell References

Cell references in assumption parameters are dynamic and are updated each time the workbook is recalculated. Dynamic cell referencing gives you more flexibility in setting up models because you can change an assumption's distribution during a simulation.

Other types of cell references are static, such as the assumption name text box and correlation coefficients. These cell references are calculated once at the beginning of a simulation.

Relative References

Relative references describe the position of a cell relative to the cell containing the assumption. For example, suppose an assumption in cell C6 refers to cell C5. If the assumption in C6 is copied to cell C9, the relative reference to C5 will then refer to the value in cell C8. With relative references, you can easily set up a whole row or column of assumptions, each having similar

distributions but slightly different parameters, by performing just a few steps. An absolute reference, on the other hand, always refers back to the originally referenced cell, in this case C5.

Absolute References

To indicate an absolute reference, use a dollar sign (\$) before the row and the column. For example, to copy the exact contents of cell C5 into an assumption parameter text box, enter the cell reference =C5. This causes the value in cell C5 to be used in the assumption cell parameter text box. Later, if you decide to copy and paste this assumption in the worksheet, the cell references in the parameter text box will refer to the contents of cell C5.

Range Names

You can also enter cell references in the form of range names, such as *=cellname*. Then, the referenced cell can be located anywhere within a worksheet as long as its name does not change.

Formulas

You can enter Microsoft Excel formulas to calculate parameter values as long as the formula resolves to the type of data acceptable for that parameter. For example, if a formula returns a string, it would not be acceptable in a parameter that requires a numeric value, such as Minimum or Maximum.

Using Alternate Parameter Sets

For all the continuous probability distributions except uniform, you can use percentiles for parameters when defining a distribution. This option gives you added flexibility to set up assumptions when only percentile information is available or when specific attributes (such as the mean and standard deviation) of the variables in a model are unknown.

For example, if you are defining a triangular distribution, but are unsure of the absolute minimum and maximum values of the variable, you can instead define the distribution using the 10th and 90th percentiles along with the likeliest value. This gives you a distribution that has 80%, or four-fifths of the values, occurring between the two specified percentiles.

To change the parameter sets for the continuous distributions, use the Parameters menu in the menu bar of the **Define Assumption** dialog. The currently selected parameter set has a check mark next to it. If you select **Custom** in the **Parameters** menu, you can replace any or all of the standard parameters with any percentile.

To select a parameter set to use as the default when defining new assumptions of this type, select Set Default from the Parameters menu.

Several special parameter sets are available with the lognormal distribution, including geometric and logarithmic sets. For more information, see the "Equations and Methods" chapter in the online *Oracle Crystal Ball Reference and Examples Guide*.

Note: Alternate parameters cannot always be used with highly skewed distributions and extremely large or small parameter values.

Setting Assumption Preferences

The **Define Assumption** dialog has a **Preferences** menu in the menu bar. This menu has the following main options:

 Table 3
 Preferences Menu, Define Assumptions Dialog Box

Setting	Effect
Assumption Preferences	Manage window display during simulations
Chart Preferences	Determine the appearance of the assumption chart

The Chart Preferences settings are discussed in "Setting Chart Preferences" on page 101.

If you select Assumption Preferences, the Assumption Preferences dialog opens.

You can use this dialog to:

- Select a view for the assumption chart:
 - **Probability** shows a graph of all possible values for the assumption variable and the probability of their occurrence.
 - **Cumulative Probability** shows a graph of the probability that the assumption variable will fall at or below a given value.
 - **Reverse Cumulative Probability** shows a graph of the probability that the assumption variable will fall at or above a given value.
 - **Statistics** shows a table of measures of central tendency, variability, minimum and maximum values, and other statistics for the assumption variable.
 - **Percentiles** shows a table of percentiles and their associated values for the assumption variable.
 - **Note:** For examples of each view, see "Changing the Distribution View and Interpreting Statistics" on page 90.
- Determine if and when the assumption chart window opens when a simulation runs.

To show the generated values in the window, turn on the **Store assumption values for sensitivity analysis** run preference. To do so, click the **Run Preferences** button, and then click the **Options** tab.

You can click **Apply To** to copy these settings to other assumptions. If necessary, you can click **Defaults** to restore original default settings. When the settings are complete, click **OK**.

Fitting Distributions to Historical Data

Subtopics

- Using Distribution Fitting for Assumptions
- Confirming the Fitted Distribution
- **Distribution Fitting Notes**
- Locking Parameters When Fitting Distributions
- Filtering Values When Fitting Distributions •

If you have historical data available, Crystal Ball's distribution fitting feature can substantially simplify the process of selecting a probability distribution when creating assumptions. Not only is the process simplified, but the resulting distribution more accurately reflects the nature of the data than if the shape and parameters of the distribution were estimated.

Distribution fitting automatically matches historical data against probability distributions. A mathematical fit determines the set of parameters for each distribution that best describe the characteristics of the data. Then, the closeness of each fit is judged using one of several standard goodness-of-fit tests. The highest ranking fit is chosen to represent the data. You can select from among all distributions supported by Crystal Ball except the yes-no distribution.

For instructions and additional information, see "Using Distribution Fitting for Assumptions" on page 41.

Using Distribution Fitting for Assumptions

When historical data is available, you can use distribution fitting to select an appropriate distribution when defining an assumption. For an overview of distribution fitting, see "Fitting Distributions to Historical Data" on page 41.

- > To use distribution fitting when creating or editing an assumption:
- 1 Select the cell where you want to create an assumption.

It can be blank or contain a simple value, not a formula.

Select Define, and then Define Assumption, 2



(In Microsoft Excel 2007 or later, click the upper half of the **Define Assumption** icon.)

In the Distribution Gallery, click Fit to select the source of the fitted data. 3

The Fit Distribution dialog opens.

- Select a data location. 4
 - If the historical data is in a worksheet in the active workbook, select **Range**, and then enter the data's cell range. If the range has a name, you can enter the name, preceded by an = sign.

• If the historical data is in a separate text file, click **Text File**, and then either enter the path and name of the file or click **Browse** to search for the file. If you want, you can select **Column** and enter the number of columns in the text file.

When you use a file as the source of data, each data value in the file must be separated by either a comma, a tab character, a space character, or a list separator defined in Windows' Regional and Language Options panel. If actual values in the file contain commas or the designated list separator, those values must be enclosed in quotation marks. Allowable formats for values are identical to those allowed within the assumption parameter dialog, including date, time, currency, and numbers.

- 5 Specify which distributions are to be fitted:
 - **AutoSelect** performs a basic analysis of the data to select a distribution fitting option and ranking method. If the data includes only integers, fitting to all discrete distributions (with the exception of Yes-No) is completed using the Chi-square ranking statistic choice.
 - **All Continuous** fits the data to all of the built-in continuous distributions (these distributions are displayed as solid shapes on the Distribution Gallery).
 - All Discrete fits to all discrete distributions except yes-no and uses the Chi-square ranking statistic.
 - **Choose** displays another dialog where you can select a subset of the distributions to include in the fitting.
 - The final setting selects the distribution that was highlighted on the Distribution Gallery when you clicked the Fit button.

If you try to fit negative data to a distribution that can only accept positive data, that distribution will not be fitted to the data.

6 Specify how the distributions should be ranked.

In ranking the distributions, you can use any one of three standard goodness-of-fit tests:

- Anderson-Darling. This method closely resembles the Kolmogorov-Smirnov method, except that it weights the differences between the two distributions at their tails greater than at their mid-ranges. This weighting of the tails helps to correct the Kolmogorov-Smirnov method's tendency to over-emphasize discrepancies in the central region.
- **Kolmogorov-Smirnov**. The result of this test is essentially the largest vertical distance between the two cumulative distributions.
- **Chi-Square**. This test is the oldest and most common of the goodness-of-fit tests. It gauges the general accuracy of the fit. The test breaks down the distribution into areas of equal probability and compares the data points within each area to the number of expected data points. The chi-square test in Crystal Ball does not use the associated p-value the way other statistical tests (e.g., *t* or *F*) do.

The first setting, **AutoSelect**, selects the ranking statistic automatically based on several factors. If all data values are integers, **Chi-Square** is selected.

- 7 **Optional:** If you know the data corresponds to certain shape, location, or other special parameter values for some distributions, select **Lock parameters** and enter appropriate values in the **Lock Parameters** dialog ("Locking Parameters When Fitting Distributions" on page 44).
- 8 **Optional:** By default, only values for the selected ranking statistic are displayed in the **Comparison Chart** dialog. To show values for all three statistics, select **Show All Goodness-of-fit Statistics** at the bottom of the **Fit Distribution** dialog.
- **9 Optional:** To filter data for fitting by excluding or including certain value ranges, select **Filter data** ("Filtering Values When Fitting Distributions" on page 45).
- 10 Click OK.

The Comparison Chart opens ("Confirming the Fitted Distribution" on page 43).

Confirming the Fitted Distribution

When the Comparison Chart opens (Figure 10), the fitted distributions are displayed in the Comparison Chart dialog, starting with the highest-ranked distribution (best fit) down through to the lowest (worst fit).

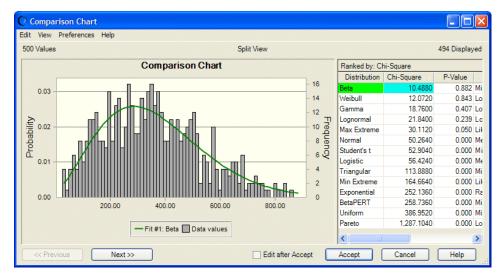


Figure 10 Comparison Chart with Goodness of Fit View, Chi-Square Ranking Statistic

- > To confirm which of the selected distributions to use for an assumption:
- **1** Use the **Comparison Chart** dialog to visually compare the quality of the fits or to view the goodness-offit statistics. You can perform any of these optional tasks:
 - Use the **Next** and **Previous** buttons to scroll through the fitted probability distributions. Each probability distribution is shown superimposed over the data.
 - Select **Preferences**, and then **Chart** to change chart features so that similarities or differences are more clearly accentuated.
 - Select **Edit after Accept** to view the accepted distribution and, optionally, change parameters.

- Click Cancel to return to the Fit Distribution dialog.
- 2 To use the currently displayed distribution, either the best fit or another of the choice, click Accept.

By default, a distribution of the accepted type with default parameters is created in the selected cell. If you selected **Edited after Accept**, the **Assumption** dialog opens with the parameter entries taken from the chosen distribution. You can change the distribution parameters before you click **OK**.

Distribution Fitting Notes

p-Values

When goodness-of-fit values are displayed, as in the distribution fitting comparison chart, *p*-values are displayed for some combinations of ranking methods and fitted distributions. These express the degree to which the actual fit conforms to a theoretical fit for that fitting test and distribution (see "Goodness Of Fit" on page 94 for more information). When the Chi-square method is used, *p*-values are displayed for all continuous and discrete distributions. *P*-values are also displayed for the following continuous distributions when the Anderson-Darling or Kolmogorov-Smirnov methods are used: normal, exponential, logistic, maximum extreme, minimum extreme, uniform, gamma, Weibull, and lognormal. *P*-values for the other distributions are under development.

Since p-values for Anderson-Darling and Kolmogorov-Smirnov statistics are influenced by the number of data points being fitted, an adjustment formula is used to arrive at the asymptotic Anderson-Darling and Kolmogorov-Smirnov statistic for a given sample size. The quality of fitted parameters and the calculated p-value deteriorates as the sample size decreases. Currently, Crystal Ball needs at least 15 data points for fitting all the distributions.

Multiple Fittings

To run fittings on multiple data sets, use the Batch Fit tool.

Locking Parameters When Fitting Distributions

Some distributions can fit the data more accurately if you are able to enter and lock parameter values so the shape, location, or certain other parameters of a distribution better match the data. In most cases where you can fit data to distributions within Crystal Ball, you can also choose to lock parameters.

- > To lock parameters:
- **1** Select **Lock parameters** in a distribution fitting dialog box. For example, you can make that setting in the Fit Distribution dialog for assumptions.

The Lock Parameters dialog opens.

2 Select one of the available distributions and enter a value for one or more of its parameters.

- > To edit parameter locking settings:
- 1 In the Fit Distribution dialog, select Lock parameters, and then click Edit Parameters.
- 2 Change settings in the Lock Parameters dialog, and then click OK.

Filtering Values When Fitting Distributions

When fitting distributions for assumptions, you can filter historical data to use only data values that fall within specified value ranges. Unused values are not permanently deleted, only discarded for the purpose of distribution fitting.

- **Note:** Once used, filter settings are saved as global preferences and are used each time you select **Filter data** in the Fit Distribution dialog until you change the settings.
- > To filter historical values for distribution fitting:
- 1 In the **Fit Distribution** dialog, select **Filter Data**.
- 2 In the **Filter Data** dialog, select one of the following:
 - Include Values In The Range Includes all values for distribution fitting if they fall within the two values in the range text boxes and discards values that fall above or below the entered values. Defaults are -Infinity and +Infinity, which includes all values for fitting.
 - **Exclude Values In The Range** Discards values from the forecast if they fall between the two values in the range text boxes. The range is inclusive; Crystal Ball discards values inside the range as well as values equal to the range endpoints. Defaults are **-Infinity** and **+Infinity**, which discards all values for fitting.
- 3 Click OK.
- > To edit data filtering settings:
- 1 In the Fit Distribution dialog, select Filter data, and then click Edit Filter.
- 2 Change settings in the Filter Data dialog, and then click OK.

Correlating Assumptions

Subtopics

- Correlating Assumptions with Pair-wise Definitions in List View
- Correlating Assumptions in Matrix View
- About Crystal Ball Correlation Matrixes
- About the Define Correlations Dialog

In Crystal Ball, assumption values usually are calculated independently of each other. However, dependencies often exist between assumptions in a system being modeled. When the values of

two assumptions depend on each other, you should correlate them to increase the accuracy of the simulation's forecast results.

These dependent relationships are described in mathematical terms using a correlation coefficient, a number between -1.0 and +1.0 that measures the strength of the relationship. A positive value means that when one assumption is high, the other likely is high. A negative value means that the assumptions are inversely related; when one is high, the other likely is low.

Note: You should never use a coefficient of ± 1 ; represent relationships this closely correlated with formulas in the spreadsheet model.

You can use the Define Correlations feature of Crystal Ball to define correlations among assumptions in two ways:

- Pair-wise in List view, "Correlating Assumptions with Pair-wise Definitions in List View" on page 46
- Using a matrix, "Correlating Assumptions in Matrix View" on page 49

Pair-wise correlation definitions are applied directly to pairs of assumptions. Matrix correlation definitions are created in a block of cells in a dialog or workbook and applied to a group of assumptions. Both methods use the **Define Correlations** dialog, described in "About the Define Correlations Dialog" on page 52.

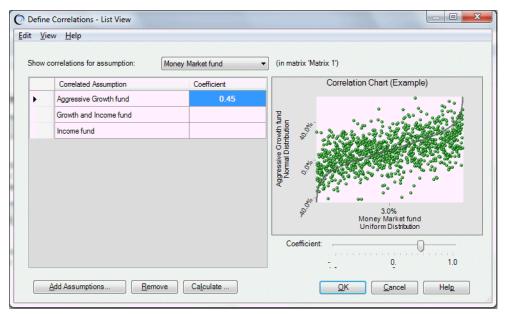
A correlation matrix is created whenever two or more assumptions are correlated. Each assumption can belong to only one matrix. Noncorrelated assumptions can be added to the current matrix at any time. Both List view and Matrix view are views of the same matrix. For more information about correlation matrixes in Crystal Ball, see "About Crystal Ball Correlation Matrixes" on page 52.

Note: Crystal Ball uses Spearman rank order correlation for all correlation computations to relate assumptions with different distribution types. For more information about Spearman correlations, see the "Statistical Definitions" chapter of the *Oracle Crystal Ball Reference and Examples Guide*.

Correlating Assumptions with Pair-wise Definitions in List View

You use the **Define Correlations** dialog to define correlations between assumptions ("About the Define Correlations Dialog" on page 52). In List view, the **Define Correlations** dialog contains a list of correlated assumptions in the first pane and the Correlation Chart in the second pane (Figure 11 on page 47).





Correlation List

The drop-down menu includes all assumptions in the same matrix, named beside the dropdown menu. The selected assumption is displayed in the drop-down menu box. The list box shows assumptions directly correlated with the assumption in the drop-down menu box. When correlations are defined, their Spearman rank order correlation coefficients are displayed in the **Coefficient** column.

Correlation Chart

The points on the Correlation Chart show the pairs of assumption values that would occur when running a simulation. The solid line running through the middle of the chart indicates the location where values of a perfect correlation (+1.0 or -1.0) will fall. The closer the points are to the solid line, the stronger the correlation. You can use the slider below the chart to increase and decrease the correlation. This correlation example enables you to visualize the degree of correlation among assumption pairs. As you move the slider, the correlation coefficient in the **Coefficients** column changes to reflect each new value.

- > To correlate a list of assumptions to each other with graphic assistance:
- **1** Select an assumption cell.
- 2 Select Define, and then Define Assumption,
- 3 In the **Define Assumption** dialog, click **Correlate** and respond to on-screen prompts.

The **Define Correlations** dialog opens in List view.

By default, the selected assumption is displayed in the drop-down menu box. If others have been added, you can click the down arrow to select another assumption in the same correlation matrix.

4 To add assumptions to correlate with the selected assumption, click Add Assumptions.

When you are creating a new set of correlations, the **Choose Assumptions** dialog provides a list of the names of all noncorrelated assumptions defined in the workbook.

By default, the dialog opens in a hierarchical Tree view. If you prefer, you can click the

List icon, , to change it to List view.

5 In the **Choose Assumptions** dialog, select one or more of the assumption names from the list and click **OK**.

The added assumptions are listed in the **Define Correlations** dialog. The **Coefficient** box for the first listed assumption is selected. You can select another.

- 6 Enter a correlation coefficient for the selected assumption using one of the following methods:
 - In the **Coefficient** text box, enter a value between -1 and 1 (inclusive).
 - Click in the **Coefficient** text box and select a cell that contains the correlation coefficient.

If you select a cell with values that change during the simulation, the initial value of the cell is used for the coefficient.

• Click Calculate.

A small dialog opens. Enter the range or ranges of cells in the spreadsheet that contain the pairs of empirical values that Crystal Ball should use to calculate a correlation coefficient.

Enter cell ranges in the standard A1:A2 format. For example, if one set of values is in column Q, rows 10 through 15 and the second set of values is in column R, rows 10 through 15, enter the range in the first text box as Q10:Q15 and the range in the second text box as R10:R15.

When you click **OK**, Crystal Ball calculates the correlation coefficient, enters it in **Coefficient** text box, and moves the slider control to the correct position.

- **Note:** The two cell ranges need not have the same dimensions, but they must contain the same number of value cells and must be in the same workbook. The cell ranges are read in a row-by-row fashion.
- 7 **Optional:** Correlate other assumptions to the assumption in the drop-down menu, or select another assumption in the menu and correlate assumptions to it.

You can specify as many of these paired correlations as you want for each assumption, up to the total number of assumptions defined in the workbook.

When you select the **Coefficient** box again after entering a value, a scatter plot is displayed in the Correlation Chart window and the slider control on the correlation coefficient scale moves to the selected value (Figure 11 on page 47). When you drag the slider control along the correlation coefficient scale, the value you select is displayed in the **Coefficient** text box.

Correlating Assumptions in Matrix View

Subtopics

- Defining Correlations Directly in Matrix View
- Defining Correlations with a Linked Matrix

In Matrix view, the **Define Correlations** dialog shows correlated assumptions in a matrix (Figure 12 on page 49). You can use the menus and buttons to add and remove assumptions and perform other actions ("About the Define Correlations Dialog" on page 52).

Show	correlations for matrix:	Matrix 1	•	Lin <u>k</u> to spreadsh	eet	
		Aggressive Growth fund	Growth and Income fund	Income fund	Money Market fund	
•	Aggressive Growth fund	1.0				
	Growth and Income fund	0.72	1.0			
	Income fund	0.55	0.4023	1.0		
	Money Market fund	0.45	0.3299	0.254	1.0	

Figure 12 Define Correlations Dialog in Matrix View, Unlinked

The correlation matrix is either an upper or lower triangular matrix with 1s along the diagonal. If you follow one assumption along its horizontal row and the second along its vertical column, the value in the cell where they meet is their Spearman rank order correlation coefficient. By default, the matrix contains the correlation coefficients that you enter directly and indirect correlations calculated from those (shown in *italics*). You can use the **View** menu to switch between List view and Matrix view, and you can create matrixes that are linked to a range of correlation values in the worksheet.

If several matrixes are already defined, the **Show correlations for matrix** list enables you to select one.

Defining Correlations Directly in Matrix View

Defining a correlation between just two assumptions is usually more efficient in List view ("Correlating Assumptions with Pair-wise Definitions in List View" on page 46). Matrix view enables you to more easily define correlations among larger groups of assumptions.

- > To correlate a group of assumptions in a matrix directly in the **Define Correlations** dialog:
- 1 Select an uncorrelated assumption cell to include in the matrix.

- 2 Select **Define Correlations** in the **Tools** group or menu.
- 3 Select View, and then Matrix View.
- 4 Click Add Assumptions, and then select at least two assumptions to include in the matrix.

Note: When you create a matrix, only uncorrelated assumptions are offered for selection.

Each assumption can belong to only one matrix. When creating a matrix, you can add only uncorrelated assumptions. You can add more assumptions later. If they are already included in another matrix, the matrixes will merge.

5 Enter the correlation for each assumption pair at the intersection of that pair.

Notice that if you do not enter a correlation for all pairs, by default, the missing correlations are calculated and their correlations are entered in *italics*. you can change this functionality using the **Options** tab of the **Run Preferences** dialog ("Setting Options Preferences" on page 75)

You can use the **Matrix** menu to switch the matrix orientation between lower triangular and upper triangular, that is, to display correlation values in the lower left or upper right triangle of the matrix. By default, recently edited cells are highlighted with **bold** type. You can use the **View** menu to display them in plain type.

Defining Correlations with a Linked Matrix

If you prefer, you can enter a matrix of correlations in a Microsoft Excel worksheet and link a group of assumptions to it (Figure 13 on page 50).

In Figure 13, assumption names are entered beside each row of correlations in the matrix.

r							ſ
	P	Portfolio Allocation-ed.xls [Compat	ibility Mode]				_ = X
		A B	С	D	E	F	G
	24						
					Growth and	Aggressive	
	25		Money Market fund	Income fund	Income fund	Growth fund	
	25 26 27	Money Market fund	1				
	27	Income fund	0.8	1			
	28	Growth and Income fund	0.4	0.75		1	
	29 30	Aggressive Growth fund	0.2	0.64	().8	1 🛄
	31						-
	14 4	▶ ▶ Description Model					► I .::

Figure 13 Matrix of Correlations in Example Spread
--

Note: Notice that the value in the cell in Figure 13 is 1 to show that the Money Market Fund assumption is correlated with itself.

- > To correlate the assumptions in the matrix and link correlations to the spreadsheet:
- 1 Enter a matrix of correlations into the worksheet (Figure 13 on page 50).

Note: You can use the same correlations for more than one matrix.

- 2 Select an uncorrelated assumption to correlate.
- **3** Select **Define Correlations** in the **Tools** group or menu.
- 4 In the **Define Correlations** dialog (Matrix view), select **Link to spreadsheet**.

5 In the Link to Spreadsheet dialog, select the location of the matrix (cells C26 through F29 in this example).

Note: Named ranges are acceptable inputs and are included in the matrix name.

- 6 Indicate whether the matrix is in Lower triangular or Upper triangular orientation (in this case, Lower triangular).
- 7 Select assumptions to correlate. Select one of the following:
 - **Choose from list**—Offers a list of assumptions for selection
 - Adjacent to matrix—Indicates that the defined assumptions to be correlated are located next to the matrix, either to the left or above it
 - **Names are adjacent to matrix**—Indicates that the names of the assumptions to correlate are next to the matrix, either to the left or above it
 - **Cell range**—When selected, enables you to select a range of defined assumptions to correlate

The preview box shows the matrix (the upper left corner for large matrixes), to help you with dialog entries.

In Figure 13 on page 50, the names are adjacent to the matrix.

The matrix size is displayed below the cell range box.

- 8 Click OK.
 - **Note:** If you select **Choose from list** or **Cell range**, up and down arrow buttons are displayed to the left of the matrix grid when you click **OK**. You can use the arrows to rearrange the order of the assumptions.

The linked matrix is displayed in the **Define Correlations** dialog. Now, if you edit any of the correlations in Matrix view, the new value is copied back to the matrix in the worksheet when you click **OK**.

Note: You must select this setting when you first create a matrix. You cannot create an unlinked matrix and then link it later.

Note: If you attempt to unlink a linked matrix, a warning message is displayed. Unlinking the matrix deletes the entire matrix and all correlations defined in it.

You can select **View** and then **List View** to review the scatter plot associated with each correlation.

The **Add Assumptions** and **Remove** buttons are not active. You can edit linked assumptions only by clicking the Edit button to display the **Link to Spreadsheet** dialog.

About Crystal Ball Correlation Matrixes

"Correlating Assumptions with Pair-wise Definitions in List View" on page 46 and "Correlating Assumptions in Matrix View" on page 49 provide specific information about correlating assumptions in different ways. The following is other general information not contained in those topics or in "Correlating Assumptions" on page 45:

- Correlations and correlation matrixes are always contained within single workbooks; they cannot span workbooks.
- Matrixes are named automatically. If you delete Matrix 1, Matrix 2 is renamed Matrix 1, and so on.
- When entering correlations in either List or Matrix view for a matrix that is not linked to a worksheet, you can enter a decimal, a cell reference, or a range name.
- When adding assumptions, you cannot add an assumption that is part of a linked matrix.
- An uncorrelated assumption cannot be correlated with an assumption in a linked matrix. However, it can be added to the linked matrix.
- Correlations that conflict with each other are called *inconsistent*. If you enter inconsistent correlations in an unlinked matrix and try to run a simulation, Crystal Ball tries to adjust the correlations so that they do not conflict. A warning message is displayed. Follow the onscreen prompts to resolve the inconsistency. Click **Edit Correlations** to view or edit the adjusted correlations, or click **OK** to automatically save adjusted coefficients. Click **Cancel** to discard changes and stop the simulation.

About the Define Correlations Dialog

The **Define Correlations** dialog is used to define and modify correlations among assumptions, either in individual pairs (pair-wise in List view) or in a matrix containing two or more assumptions (Matrix view).

To display the **Define Correlations** dialog, do either of the following to open a matrix in either **List** or **Matrix** view:

- Select **Define Assumption**, and then **Correlate**, or
- Select Define Correlations in the Tools menu or group

If the target view is not displayed by default, use the **View** menu to change it.

For more information, see "Correlating Assumptions with Pair-wise Definitions in List View" on page 46 or "Correlating Assumptions in Matrix View" on page 49.

Define Correlations Menu Bar and Buttons

The **Define Correlations** dialog has the following menus and buttons:

- Edit Enables you to copy the assumption list and chart in List view, copy the matrix in Matrix view, and print dialog contents
- View Switches between List and Matrix views, and enables you to display edited cells in bold type
- **Matrix** In **Matrix** view, specifies whether the matrix is a triangle in the upper right corner or the lower left, and enables you to remove the current matrix and all correlations among its assumptions
- Help Displays online help for the Define Correlations dialog
- Add Assumptions Displays the **Choose Assumptions** dialog, where you can select assumptions to correlate from the active workbook
- **Remove** Deletes the selected assumption from the current matrix and removes all correlations with it
- **Calculate** Enables you to calculate the correlation between two ranges of data
- **Note:** For information about the **Link to spreadsheet** checkbox in Matrix view, see "Defining Correlations with a Linked Matrix" on page 50.

Using the Crystal Ball Distribution Gallery

You can use the Distribution Gallery to add, manage, and share libraries of distributions. Workgroups can use this powerful feature to modify and share customized distributions over their local networks when collaborating on custom models. They can also e-mail these to other Crystal Ball users for use with their models.

Displaying the Distribution Gallery

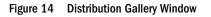
- ➤ To display the Distribution Gallery:
- 1 With Crystal Ball open within Microsoft Excel, click in a cell.
- 2 Click the **Define Assumption** tool, *Leave and the constant of the constant*

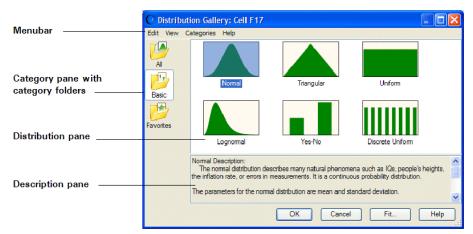
(In Microsoft Excel 2007 or later, click the upper half of the **Define Assumption** icon. Or, click the bottom half of the **Define Assumption** icon and then select **Distribution Gallery** at the bottom of the distribution list.)

The Distribution Gallery opens, as shown in Figure 14.

Distribution Gallery Window

As shown in Figure 14, the **Distribution Gallery** has a menu bar, a category pane with folders containing distributions, a distribution pane that displays all distributions in the selected category, and a description pane that describes the selected distribution.





The following sections explain each part of the Distribution Gallery:

- "Distribution Gallery Menu Bar and Buttons" on page 54
- "Category Pane" on page 55
- "Distribution Pane" on page 55
- "Description Pane" on page 55

Distribution Gallery Menu Bar and Buttons

The **Distribution Gallery** menu bar has the menus summarized in Table 4.

Table 4 Distribution Gallery Menus

Menu	Command Summary
Edit	Commands that copy, paste, modify, and delete distributions. You can copy from any category you are allowed to use but you can only paste, modify, and delete within the Favorites category or new categories you or others have created. You cannot modify or delete distributions in the Basic and All categories; these categories are reserved only for unmodified distributions shipped with Crystal Ball.
Categories	Commands that create, delete, view and modify properties of, and rearrange category folders in the Category pane. You can use two additional commands to share categories with others (Publish) and use categories others have shared (Subscribe).
View	Commands that change how distributions are displayed in the Distribution pane (as Thumbnails, Large Icons, or Small Icons) and hide or show distribution details and descriptions.
Help	Commands that display online help for the Distribution Gallery and the selected distribution.

The Fit button at the bottom of the Distribution Gallery opens the Crystal Ball distribution fitting feature. This feature can help you select an appropriate distribution for the assumption

you are defining. For more information, see "Fitting Distributions to Historical Data" on page 41.

The Help button displays online help for the currently selected distribution.

Category Pane

Categories are groups of distributions contained in folders.

- **Basic** is the default category. It contains several of the most common distributions: normal, triangular, uniform, lognormal, yes-no, and discrete uniform.
- All contains all distributions shipped with Crystal Ball, in unmodified form, including those also supplied in the Basic category.
- **Favorites** is the default category for distributions that are copied or modified by users. For example, if you want to copy a triangular distribution from Basic and modify it, you could paste it to Favorites and change it there.

You can use the Categories menu to create new category folders for holding distributions. Then, you can use the Edit commands to add distributions to the new categories and modify them.

Distribution Pane

The Distribution pane shows all distributions in the selected category. You can use the View menu to change how they are displayed, as shown in Table 5.

View Command	Example
Thumbnails	Normal Triangular
Large Icons	Normal Triangular Uniform
Small Icons	Normal Triangular Uniform Lognormal Yes-No Discrete Uniform
Details	Name Parameters Summary Normal Mean, Standard Deviation Familiar bell curve used to describe natural phenom Triangular Minimum, Likeliest, Maximum Used for rough estimation when data is limited

 Table 5
 Distribution View Examples

Description Pane

The Description pane is displayed at the bottom of the Distribution Gallery and provides a detailed description of the selected distribution.

You can clear **Show Description** in the **View** menu to show more distributions in the Distribution pane.

Adding and Modifying User-defined Distributions in the Distribution Gallery

Several Crystal Ball features enable you to add user-defined distributions to the Distribution Gallery for future use and share them with other Crystal Ball users. This section describes how to add a user-defined distribution from the **Define Assumption** dialog. Then, you can select a user-defined distribution and use the **Edit** menu of the Distribution Gallery or right-click and use the shortcut menu to copy, paste, modify, delete, print, or e-mail the distribution. You can also use the **View** menu to edit Distribution Gallery summaries and descriptions. For more information, see "Distribution Gallery Menu Bar and Buttons" on page 54.

- > To add a user-defined distribution to the Distribution Gallery:
- 1 With Crystal Ball running, select a cell and follow the steps in "Defining Assumptions" on page 34 to open the **Define Distribution** dialog, select a distribution, and enter parameters.
- 2 Alternatively, select an existing assumption and open the Define Distribution dialog.
- 3 In the Define Assumption dialog, select Edit, and then Add To Gallery.
- 4 The Add To Gallery dialog opens, where you can name the new distribution and select a category for it.
- 5 Click OK.
 - **Note:** If you created correlation data, it is not saved although the distribution type and any parameter settings are saved.

The new distribution is available for use just as another other distribution in the Distribution Gallery.

Creating, Managing, and Sharing Categories

You can use distribution categories to organize distributions and share them with other users. After you define a category, you can use the **Categories** menu in the Distribution Gallery to modify it and share it with other users. For more information, see "Distribution Gallery Menu Bar and Buttons" on page 54.

Creating Categories

- ► To create a category:
- 1 Select Categories, and then New.
- 2 In the New Category dialog, enter the name of the category.

- **Note:** If you enter an ampersand (&) before a letter in the category name, that letter becomes a shortcut key. You can then use it to select the category from the keyboard by holding down the Alt key and pressing the shortcut key. Shortcut keys are displayed underlined when you press the Alt key. The new category should use a different shortcut key from other categories.
- 3 **Optional:** Enter a description, the name, and a version number (helpful for shared categories).
- 4 Click OK.

The new folder is displayed in the Category pane and the category can be selected and used like Favorites or any other user-defined category.

Using Shared Categories

If other users have published categories in a shared folder on their computers or the network, you can access them for use with the Distribution Gallery. This is called subscribing to categories.

- > To subscribe to a category, learn its name and location, and then:
- **1** Open the Distribution Gallery and select **Categories**, and then **Subscribe**.
- 2 In the Subscribe to a Category dialog, click Add.
- 3 Locate the target folder and click **OK** to add the new path to the **Subscribe to a Category** dialog box.
- 4 Click **OK** to load all categories in the listed paths.

All loaded categories are available for use as if they were on the local computer.

- **Note:** Shared categories can be used like local categories in most ways. However, they cannot be modified unless they also exist in a folder on the local computer. If several users copy a published category locally and then modify it, they can publish their own versions and overwrite each others' changes. If you are publishing a category, you may want to make the shared folder read-only to avoid this problem.
- > To edit or delete a path, or rearrange the path order:
- **1** Open the **Subscribe to a Category** dialog as described in step 2 in the previous steps.
- 2 Select the path to a target category.
- 3 Click an action button: Edit, Delete, Move Up, or Move Down.
- 4 When you are finished, click **OK**.

If you delete a path to a subscribed category, that category disappears from the Category pane of the Distribution Gallery. You can resubscribe to it at any time to use it again.

Note: For more information, see the Oracle Crystal Ball Reference and Examples Guide.



Defining Other Model Elements

In This Chapter

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Defining Decision Variable Cells	59
Defining Forecasts	60
Working with Crystal Ball Data	65
Setting Cell Preferences	68
Saving and Restoring Models	

Introduction

Chapter 3 describes how to start building a spreadsheet model by defining assumption cells. These topics provide step-by-step instructions for completing models in Crystal Ball so you can run simulations against them. As you work through these instructions, you will learn to define decision variable cells and forecasts and how to cut, copy, and paste Crystal Ball data.

Defining Decision Variable Cells

Decision variables are the variables that you can control, such as rent to charge or the amount of money to invest. Decision variables are not required for simulation models, but they can be useful when comparing and optimizing alternate scenarios. Several of the Crystal Ball tools discussed in Chapter 9, "Crystal Ball Tools", use and benefit from decision variables.

You also use decision variables with OptQuest, if available.

- > To define one or more decision variable cells:
- **1** Select a cell or range of cells.

Select value cells or blank cells only. You cannot define a decision on a formula or nonnumeric cell.

2 Select Define, and then Define Decision,

The Define Decision Variable dialog opens.

3 Click the More button, 🥙, to display all settings.

- 4 Complete the Define Decision Variable dialog:
 - **Name** is the name of the decision variable.
 - **Bounds** are the upper and lower limits for the decision variable range.
 - **Type** defines whether the variable type is:
 - **Continuous** can assume any value between the lower and upper bounds
 - **Discrete** can assume values at specific intervals between the lower and upper bounds

With Discrete selected, **Step** specifies the interval between values for discrete variables. For example Step = 1 could be used to specify whole dollars, while Step = .5 could specify 50-cent increments.

- **Binary** is 0 or 1 to represent a yes-no decision, where 0 = no and 1 = yes
- Category can assume any discrete integer between the lower and upper bounds (inclusive), where the order of the values does not matter. This type, used for attributes or indexes, is mostly used when numeric values represent conditions or groups instead of numeric values. Example model Groundwater Cleanup.xls contains a decision variable named Remediation Method, expressed as integers 1, 2, and 3. These are not numeric values, but instead they represent three different remediation methods for groundwater cleanup and can be defined using the Category type.
- **Custom** can assume any value from a list of two or more specific values or a cell range reference. When values are entered directly, separate them by a valid list separator a comma, semicolon, or other value specified in the Windows regional and language settings. If a cell range reference is used, it must include more than one cell so there will be two or more values. Blanks and non-numeric values in the range are ignored.

You can use cell referencing to name a decision variable, define the lower and upper limits, set the step size, and define custom values (" Entering Cell References and Formulas" on page 38).

- 5 Click OK.
- 6 Repeat these steps for each decision variable in the model.
 - **Note:** There is no absolute limit to the number of data cells you can define per worksheet. In general, you should define less than 1000 assumptions, decision variables, and forecasts per worksheet.

Defining Forecasts

After you define the assumption cells and decision variables, you are ready to select and define forecast cells. Forecast cells usually contain formulas that refer to one or more assumption and decision variable cells. The forecast cells combine cells in the model to produce the results you need.

- ➤ To define forecast cells:
- **1** Select a formula cell or a range of formula cells.
- 2 Select Define, and then Define Forecast,

The Define Forecast dialog opens .

If you have activated Crystal Ball's process capability features, additional text boxes are displayed. These are described in "Setting Specification Limits and Targets" on page 277.

- 3 Complete the Define Forecast dialog:
 - **Name** is the name of the forecast.
 - **Units** is the name of the units that are displayed at the bottom of the forecast chart, such as Millions.
- 4 To set additional forecast preferences, click the **More** button, 💓, to expand the Define Forecast dialog.

The expanded Define Forecast dialog has four tabs of additional options and text boxes, listed in "Setting Forecast Preferences" on page 61.

5 Click OK.

6 Repeat steps 1-4 for each forecast in the model.

Clicking **Defaults** in the expanded Define Forecast dialog restores the original default settings in place of any new settings you have made. You can also click **Apply To** to use the settings in other charts and worksheets.

Setting Forecast Preferences

The forecast preference settings are displayed when you click the More button, \bigotimes , in the Define Forecast dialog box or select Preferences, then Forecast in a forecast chart menu bar. The tabs in this dialog control several important aspects of Crystal Ball:

- "Forecast Window Tab" on page 62 window display and distribution fitting for the forecast
- "Precision Tab" on page 62 precision control settings
- "Filter Tab" on page 63 value filtering, which discards values inside or outside a range for the current forecast
- "Auto Extract Tab" on page 63 automatic data extraction to Microsoft Excel when a simulation stops.
 - **Note:** See information about confidence intervals in the *Oracle Crystal Ball Reference and Examples Guide* for more information about how absolute and relative precision relate to the confidence interval.

When you expand the Define Forecast dialog or open the Forecast Preferences dialog, the Forecast Window tab is displayed by default.

Forecast Window Tab

The Forecast Window tab of the Forecast Preferences dialog offers the following settings to manage window display and distribution fitting for the forecast:

- View settings Set the forecast window's display type ("Changing the Distribution View and Interpreting Statistics" on page 90).
- Window settings Set whether to display the forecast window automatically while the simulation runs or when the simulation stops. You can display one or more forecasts while the simulation is running. If you decide not to display the forecast, the simulation continues to run. You can override this option and close all the forecast windows using the Suppress Forecast Windows option in the Run Preferences dialog ("Setting Run Preferences" on page 71).
 - Window, then While Running Simulation Displays the forecast window automatically during simulations. This slows down the simulation.
 - Window, then When Simulation Stops Displays the forecast window automatically after the simulation stops. This is faster than displaying the window during simulations.
- Fit Distribution Fits a probability distribution to the forecast. After selecting this checkbox in this group, you can click Fit Options to select the distribution and goodness-of-fit tests you want.

Click OK to apply settings on the current tab to the active forecast. Or, you can click Apply To to apply settings on the active tab to the active worksheet, the active workbook, or all workbooks. At any time, you can click Defaults to restore the original default settings on the active tab in the dialog.

Precision Tab

The Precision tab of the Forecast Preferences dialog manages the precision control settings that determine when to stop a simulation based on confidence intervals for selected statistics.

The current simulation must be reset before precision control settings will take effect.

Select from the following settings:

- Specify The Desired Precision For Forecast Statistics Activates the precision control settings for the forecast. Crystal Ball uses these settings only if the simulation is set to stop when it reaches the specified precision from the Run Preferences dialog ("Setting Run Preferences" on page 71). The statistics available for precision control are the mean, the standard deviation, and an indicated percentile. Select any or all. If you select Percentile, you can enter any percentile value greater than 0 and less than 100 to use as a precision control statistic.
- Must Be Within Plus Or Minus Selects which range to use for precision control, absolute units or relative percentage.

- Units Determines the size of the confidence interval, in actual forecast units, used to test the precision of the forecast statistics.
- **Percent** Determines the size of the confidence interval, in percentage terms, used to test the precision of the forecast statistics.

Click OK to apply settings on the current tab to the active forecast. Or, you can click Apply To to apply settings on the active tab to the active worksheet, the active workbook, or all workbooks. At any time, you can click Defaults to restore the original default settings on the active tab in the dialog.

Filter Tab

You can use the Filter tab of the Forecast Preferences dialog to discard values inside or outside a range for the current forecast or globally for all forecasts in a model. The values are not permanently deleted, only discarded for the purposes of the current analysis.

Select from the following settings:

- Set A Filter On The Forecast Values Activates the filter settings for the forecast.
- Include Values In The Range Discards values from the forecast if they fall above or below the two values in the range text boxes. Endpoints are included, not excluded.
- Exclude Values In The Range Discards values from the forecast if they fall between the two values in the range text boxes. The range is inclusive; Crystal Ball discards values inside the range as well as values equal to the range endpoints.
- When filtering values for this forecast, remove values for the same trial from other forecasts too For each trial that a value is not included or is excluded, removes the value for that trial from all other forecasts in the model, and assumptions too. For example, if the filter for the current forecast is set to include values from 4 through 10 and the value for the third trial is 12, the value for the third trial will be filtered from the current forecast and all other forecasts and assumptions in the model, regardless of the values in the other forecasts. If this setting is selected and you run a Forecasts report, "globally filtered" is displayed for the forecast in the Summary data following the filter description.
 - **Note:** This setting can be selected in the Define Forecast dialog for several forecasts with different filter settings. In that case, filtering for each selected forecast will be applied across all forecasts.

Click OK to apply settings on the current tab to the active forecast. Or, you can click Apply To to apply settings on the active tab to the active worksheet, the active workbook, or all workbooks. At any time, you can click Defaults to restore the original default settings on the active tab in the dialog.

Auto Extract Tab

You can use the Auto Extract tab of the Forecast Preferences dialog to specify which statistics to extract automatically to Microsoft Excel after the simulation stops.

The Auto Extract settings create tables of unformatted statistics primarily for use in other analyses. To extract formatted data, see "Extracting Data" on page 150.

You can select from the following settings:

- Extract forecast statistics automatically to your spreadsheet when the simulation stops Activates the auto-extract feature.
- [listbox] The list of statistics you can extract. Select the statistics you want, then use the up and down arrows to rearrange their order, if you want.
 - **Note:** All statistics are calculated from trial values except **Fitted Parameters**. These are the distribution parameters calculated if distribution fitting is selected on the Forecast Window tab of the Forecast Preferences dialog. For details, see "Extracting Fitted Parameters" later in this topic.
- Starting Cell The first cell on the forecast's worksheet where the statistics will be copied. Be sure no data entries are displayed to the right of this cell and below it because data could be overwritten without warning.
- Formatting Whether to include labels on the extracted statistics and use Microsoft Excel's AutoFormat for the cells.
- Direction Whether the extraction proceeds vertically (downward) or horizontally (to the right) on the worksheet.

Click OK to apply settings on the current tab to the active forecast. Or, you can click Apply To to apply settings on the active tab to the active worksheet, the active workbook, or all workbooks. At any time, you can click Defaults to restore the original default settings on the active tab in the dialog.

Extracting Fitted Parameters

- > To automatically extract parameters for a distribution fitted to a forecast:
- **1** Select **Fit a probability distribution to the forecast** on the **Forecast Window** tab of the **Forecast Preferences** dialog.
- 2 Click the Auto Extract tab of the Forecast Preferences dialog.
- 3 In the statistics list, select **Fitted Parameters**.
- 4 In the **Fitted Parameters dialog**, select one or more types of information to extract:
 - **Distribution name**—The name of the distribution that was fitted to the forecast, such as normal or lognormal
 - **Distribution identifier**—The unique integer that identifies the distribution in the Crystal Ball developer kit, primarily for developer kit users (see "CB.DefineAssumND" in Chapter 3 of the *Oracle Crystal Ball Developer's Guide*).
 - **Parameters**—The parameters of the fitted distribution, such as mean or standard deviation

Working with Crystal Ball Data

You can use special commands to copy, paste, and clear Crystal Ball cell definitions from cells. These are different from similar Microsoft Excel commands and must be used to copy Crystal Ball cell definitions (data). Other Crystal Ball commands select data and highlight it for review.

The following sections describe these special commands:

- "Editing Crystal Ball Data" on page 65
- "Selecting and Reviewing Crystal Ball Data Cells" on page 67

Editing Crystal Ball Data

Subtopics

- Copying Crystal Ball Data
- Pasting Crystal Ball Data
- Clearing Crystal Ball Data
- Clearing All Crystal Ball Data of a Single Type

You can use the Crystal Ball editing commands to copy, paste, and clear Crystal Ball data cells. You can set up an entire row or column of assumptions, decision variables, or forecasts with just a few steps.

Important! To copy Crystal Ball cell definitions, use only the Crystal Ball Copy Data, Paste Data, or Clear Data commands. Using the Microsoft Excel copy and paste commands only copies the cell value and attributes, including cell color or pattern.

Copying Crystal Ball Data

- To copy Crystal Ball assumptions, decision variables, or forecasts from one area of the spreadsheet to another area in the same workbook or a different workbook:
- **1** Select a cell or a range of cells that contains the Crystal Ball data to copy.
- 2 Select Define, and then Copy [Data],

If you select a range of cells with more than one kind of Crystal Ball data — for example, an assumption and a forecast — Crystal Ball prompts for which data type to copy.

3 Select the type or types to copy and click **OK**.

Pasting Crystal Ball Data

- ► To paste Crystal Ball data:
- **1** Select a cell or a range of cells that to paste into.

It should contain cells with values if you are pasting assumptions or decision variables (unless the range is all blank) and cells with formulas if you are pasting forecasts.

If you are pasting assumptions or decision variables into a completely blank range of cells, Crystal Ball pastes them along with the underlying cell value from each copied cell. Forecasts must be pasted into a cell with a formula.

Select Define, and then Paste [Data], 2



Crystal Ball pastes all selected data types (assumptions, decision variables, and forecasts) from the copied range into the range selected in step 1. Any existing Crystal Ball data in the range selected for pasting will be overwritten.

For best results, use the Paste Data command immediately after the Copy Data command.

Clearing Crystal Ball Data

- ► To clear Crystal Ball data:
- Select a cell or a range of cells that contains the Crystal Ball data to clear. 1
- Select Define, and then Clear [Data], 2

If you select a range of cells with more than one kind of Crystal Ball data, Crystal Ball prompts for which data type to clear.

3 Select the type or types to clear and click OK.

Clearing All Crystal Ball Data of a Single Type

- > To clear all of one type of Crystal Ball data from all cells in the active worksheet:
- Select Define and then a Select command: Select All Assumptions, 1



(In Microsoft Excel 2007 or later, select **Define**, and then **Select** and then select one of the **Select** commands.)

Select **Define**, then **Clear** [Data]. 2

Crystal Ball clears the Crystal Ball data from all the selected cells in the active worksheet.

Optional: Select Edit, then Clear, and then All; this also clears all Crystal Ball data from selected cells.

Selecting and Reviewing Crystal Ball Data Cells

After you define assumptions, decision variables, or forecast cells and return to the spreadsheet, you may want to confirm that the cell definitions are defined as you intended.

Note: For **Select** dialog help, see "Reviewing Selected Cells" later in this topic.

- > To review all data cells of one type:
- 1 Select **Define**, and then one of the **Select** commands: **Select All Assumptions**,



In Microsoft Excel 2007 or later, select **Define**, then **Select** and then select one of the **Select** commands.

2 Select Define, and then one of the Define commands: Define Assumption, is ; Define Decision,



The Define dialog for the first cell opens.

- **3 Optional**: Change the definition.
- 4 Click OK.

If you have more than data cell of that type, each is displayed in turn. Repeat steps 3 and 4 to review the definition for each cell.

Reviewing Selected Cells

- > To review Crystal Ball data cells on any open workbook:
- 1 Select **Define**, and then **Select**. (In Microsoft Excel 2007 or later, select **Define**, then **Select** and then select one of the **Select** commands.)

The **Select** dialog opens.

By default, the dialog opens in hierarchical Tree view. All the assumptions are listed first, then all the decision variables, and finally all the forecasts.

You can click the **Assumption**, **Decision Variable**, and **Forecast** buttons to show and hide assumptions, decision variables, and forecasts, respectively. If you prefer to view available

cells in list format, click the **List** button,

- 2 Select the cells to review. They can be of any or all types.
- 3 Click **OK** to highlight all the selected cells so you can change their preferences or perform other actions on them.

· Select All

Note: You can use the Select dialog to select cells on more than one worksheet but you need to activate each worksheet in turn to review and, if you want, apply a command to all the selected cells.

Setting Cell Preferences

You can change the appearance of Crystal Ball assumption, forecast, and decision variable cells so you can quickly identify them in spreadsheets. You can set Crystal Ball to change the appearance of these cells as you define them, or you can change the appearance of predefined cells.

- ► To set cell preferences:
- 1 Select Define, and then Cell Preferences.

(In Microsoft Excel 2007 or later, select Define, and then Cell Prefs.)

The Cell Preferences dialog opens.

- 2 Click the tab for the kind of cell to format: Assumptions, Decision Variables, or Forecasts.
- 3 Make appropriate settings for the chosen cell type:
 - **Color** Changes the color of each Crystal Ball data cell of the type modified by the selected tab.
 - **Pattern** Changes the pattern of each Crystal Ball data cell of the type modified by the selected tab.
 - Add Comment To Cell Adds a Microsoft Excel comment that provides more information about the Crystal Ball data within each cell. (Crystal Ball only updates cell comments when you define or redefine an assumption, decision variable, or forecast.)
 - **Note:** If you change values in cells referenced by assumption or decision variable parameters, any cell comments for that cell will indicate the old value. Re-create those assumptions or decision variables to ensure that cell comments are updated
 - **Set Cell Value To Distribution:** Changes assumption cell values to the selected value (Mean or Median) when no simulation is running.
 - Set Cell Value To Range: Changes decision variable cell values to the selected value (range Midpoint, Minimum, or Maximum) when no simulation is running.
- 4 Click **Apply To** and select whether to apply settings from only the current tab or all tabs in the Cell Preferences dialog.
- 5 Select whether to apply the settings to all cell preferences of the chosen type(s) on the current Microsoft Excel worksheet, all worksheets in the current workbook, or all open workbooks and any new workbooks to be created later.

(The default is All Open and New Workbooks.)

6 Click **OK** to close the Apply To dialog and apply the settings to the chosen cell types and worksheets.

Note: Like some other preferences, cell preferences must be applied to all cells of the selected type(s) on the chosen worksheet(s) or workbook(s). If necessary, you can click the Defaults button before choosing Apply To to clear current cell preference settings and restore the original defaults.

Saving and Restoring Models

The distributions specified for each assumption cell, the settings specified for each forecast cell, and the range information for each decision variable cell are saved with their spreadsheet through the Microsoft Excel save process. When you open the spreadsheet again, Crystal Ball retains the assumption, forecast, and decision variable cells.

Note: When you run simulations, as described in the next chapter, you can also save and restore simulation results in a separate file for future display and analysis ("Saving and Restoring Simulation Results" on page 80).

Compatibility and File Conversion Issues

Microsoft Excel 2007 or later workbooks can be saved in several file formats that are significantly different from those for previous versions of Microsoft Excel. This version of Crystal Ball has been carefully designed to preserve Crystal Ball data in existing workbooks as long as you follow a few simple rules when opening and saving files created in previous versions of Microsoft Excel.

In general:

- 1. Be sure Crystal Ball is loaded before opening a workbook with extension .xls that contains Crystal Ball data or before saving a model to any format in Microsoft Excel 2007 or later.
- 2. Always save files in .xls format to share with users of Crystal Ball who are using Microsoft Office 2003, XP, or 2000.

For detailed information, see the migration appendix in the Oracle Crystal Ball Installation and Licensing Guide.

Files from earlier versions of Crystal Ball — including the Crystal Ball Example files — are converted automatically when you save them in the current version of Crystal Ball on Microsoft Excel 2007 or later or earlier versions of Microsoft Excel. Files from earlier versions are opened in compatibility mode. [Compatibility Mode] is displayed after the workbook name in the title bar.

Note: When you open the Example files in Windows Vista, they are read-only. To edit or customize them, save them under another name before you run a simulation.

5

Running Simulations

In This Chapter

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About Crystal Ball Simulations

After you define assumption, forecast, and decision variable cells in a spreadsheet model, you are ready to run a simulation. Then, you can analyze the results.

To run simulations in Crystal Ball, follow these basic steps:

- 1. Define assumptions ("Entering Assumptions" on page 35), forecasts ("Defining Forecasts" on page 60), and decision variable cells if appropriate ("Defining Decision Variable Cells" on page 59).
- 2. If you want, customize the appearance of each cell ("Setting Cell Preferences" on page 68).
- 3. Set run preferences ("Setting Run Preferences" on page 71).
- 4. **Optional:** Exclude certain data cells from the simulation by "freezing" them ("Freezing Crystal Ball Data Cells" on page 76).
- 5. Run the simulation ("Running Simulations" on page 77).

Setting Run Preferences

Run preferences control how Crystal Ball runs a simulation.

- > To change run preferences:
- 1 Reset the previous simulation if necessary, \P .

2 Select **Run**, and then **Run Preferences**,



- 3 In the **Run Preferences** dialog, click the tab with the preferences to change:
 - "Setting Trials Preferences" on page 72 Specify when to stop a simulation, namely number of trials, calculation errors, and precision control.
 - "Setting Sampling Preferences" on page 73 Set the sampling seed value, method, and sample size.
 - "Setting Speed Preferences" on page 73 Determine whether a simulation runs in Normal, Demo, or Extreme (if available) and set additional speed control options.
 - "Setting Options Preferences" on page 75 Set a number of run preferences, including whether sensitivity data and assumption values are stored, whether assumption correlations are activated, whether user macros are run, whether the Crystal Ball Control Panel opens, and whether advanced accessibility settings are activated.
 - "Setting Statistics Preferences" on page 75 Determine how Crystal Ball displays percentiles and activates process capability features.
- 4 Change any preferences on any tab.
- 5 Click OK.
- 6 To reset settings on the active tab to the original defaults, click Defaults.

Setting Trials Preferences

The Trials tab of the Run Preferences dialog sets preferences that stop a simulation: number of trials, calculation errors, and precision control. For general instructions, see "Setting Run Preferences" on page 71.

The current simulation must be reset before precision control settings will take effect.

The **Trials** tab of the Run Preferences dialog has these settings:

- Number Of Trials To Run Defines the maximum number of trials that Crystal Ball runs before it stops the simulation. If you select either of the checkboxes on this dialog, Crystal Ball only uses the maximum number of trials if forecast results do not meet the other stop criteria first.
- **Stop On Calculation Errors** When selected, stops the simulation when a mathematical error (such as division by zero) occurs in any forecast cell. If a calculation error occurs, to help you find the error, Crystal Ball does not restore the cell values. If no calculation errors occur, the simulation continues until it reaches the Number Of Trials To Run or (if set) when the specified precision is reached.

Note: In Extreme Speed, the simulation stops at the end of a burst of trials when an error occurs, and not immediately upon detecting the error.

• **Stop When Precision Control Limits Are Reached** — When selected stops the simulation when certain statistics reach a specified level of precision. You select the statistics and define the precision that triggers this option in each Define Forecast dialog. For instructions, see

"Precision Tab" on page 62. Any forecasts set to use precision control must all reach their specified precision within the confidence level to stop the simulation. If all the forecasts set to use precision control don't meet the specified precision, the simulation stops when it reaches the Number Of Trials To Run. By default, precision control is on.

• **Confidence Level** — Sets the precision level (confidence level) that indicates when to stop a simulation.

Setting Sampling Preferences

The Sampling tab of the Run Preferences dialog sets the sampling seed value, sampling method, and sample size. For general instructions, see "Setting Run Preferences" on page 71.

The **Sampling** tab of the Run Preferences dialog has these settings:

- Use Same Sequence Of Random Numbers Sets the random number generator to generate the same set of random numbers for assumptions, so you can repeat simulation results. When you select this option, enter an integer seed value in the Initial Seed Value text box.
- **Initial Seed Value** Determines the first number in the sequence of random numbers generated for the assumption cells (integer).
 - Note: To reproduce the sample results shown in this manual, select Use Same Sequence Of Random Numbers and use a seed value of 999.
- **Sampling Method** Indicates whether to use Monte Carlo or Latin Hypercube simulation sampling. Latin Hypercube sampling generates values more evenly and consistently across the distribution, but requires more memory.
- **Sample Size** For Latin Hypercube sampling, divides each distribution into the specified number of intervals (bins). A higher number increases the evenness of the sampling method, while reducing the randomness.
 - **Note:** If you are using Microsoft Excel 2007 or later with multithreading, there is no guaranteed order of execution for user-defined functions included in Crystal Ball models. For this reason, they will not always return consistent results, even if a seed is set.

Setting Speed Preferences

The Speed tab of the Run Preferences dialog adjusts how fast a simulation runs. Extreme speed is only available in Crystal Ball Decision Optimizer. Extreme speed is the default simulation speed, if it is available. Otherwise, Crystal Ball only runs in Normal or Demo speed. If you select Normal or Demo speed, the Options button is active and you can make additional settings.

Note: If the Crystal Ball license includes Extreme speed, read Appendix C, "Extreme Speed Compatibility Issues" on page 241, for important information about model compatibility.

For general instructions, see "Setting Run Preferences" on page 71.

The **Speed** tab of the Run Preferences dialog has these settings:

- **Run Mode** settings Determine overall simulation speed.
 - **Extreme Speed** Available in Crystal Ball Decision Optimizer. This setting runs simulations up to 100 times faster than Normal mode but is not suitable for some models ("Extreme Speed Compatibility Issues" on page 241).
 - Normal Speed The standard simulation option for general model processing.
 - **Demo Speed** Runs simulations slowly to make it easier to watch values change in spreadsheet cells and charts.
- **Options** settings Set update rules for the active worksheet in Normal and Demo speeds ("Speed Tab Options Settings" on page 74).
- Chart Windows settings Set the redraw rate for any charts open during a simulation.
 - **Redraw Every** <u>Seconds</u> Defines the redraw rate in terms of time. The default value is 0.5.
 - **Suppress Chart Windows (Fastest)** Closes all charts during simulation. Selecting this option overrides the Show Window preferences set for any charts. This option produces the fastest simulations.

Speed Tab Options Settings

Speed options are provided for Normal and Demo speed.

Normal Speed

- **Update Every Trial** Updates Crystal Ball data in Microsoft Excel after each simulation trial. Dynamic references are still updated internally if another setting is chosen.
- Update Every _ Seconds Defines the update rate in terms of time. The default value is 0.5
- **Minimize Workbooks (Fastest)** Minimizes the Microsoft Excel window. This option produces the fastest simulations.
- Bring Microsoft Excel 2007 or Later To The Foreground While Running Normal Speed Simulations (Faster) This option is available when Crystal Ball is running on Microsoft Excel 2007 or later. When selected, Microsoft Excel runs in the foreground in Normal speed and performance improves.

Demo Speed

• **Maximum Number of Trials/Second** — With optimal processing, what is the greatest number of trials to run each second. The default value is 10.

Setting Options Preferences

The Options tab of the Run Preferences dialog sets a variety of run preferences. For general instructions, see "Setting Run Preferences" on page 71.

The **Options** tab of the Run Preferences dialog has these settings:

- Store assumption values for sensitivity analysis Stores values randomly generated during the simulation for export to a spreadsheet using the Extract Data command. This setting also saves data for display in sensitivity charts ("Using Sensitivity Charts" on page 126). Sensitivity charts are not available unless you select this option before you run a simulation.
- **Enable correlations** Activates any defined correlations between assumptions.
- **Assume zeroes for unspecified correlations** When selected, inserts a zero in empty cells of a correlation matrix; otherwise, values are calculated from existing correlations.
- **Run user-defined macros** Runs any user-defined macros as part of the simulation process. For details, see "Running User-Defined Macros" on page 82.
- **Show control panel** When selected, activates the Crystal Ball Control Panel. For more information, see "Crystal Ball Control Panel" on page 78.
- Leave control panel open on reset When selected, continues to display the Control Panel after a simulation is reset.
- Alerts level Controls the display of warnings and other alerts, mostly reset prompts, at a global level:
 - **Show all alerts** Displays all alerts.
 - Show only important alerts Displays only warning alerts, not reset prompts.
 - **Don't show any alerts** Does not display any alerts except those regarded as essential.
- **Do not show...** checkboxes When **Reset** is clicked, prompts to clear all selected **Do not show again** checkboxes in dialogs that offer that setting; **Yes** clears the checkboxes and dialogs are displayed again when appropriate.
- **Enable accessibility options** When selected, activates a number of user interface enhancements of special interest to individuals with visual impairments and other disabilities. For details, see the online *Oracle Crystal Ball Accessibility Guide*.

Setting Statistics Preferences

The Statistics tab of the Run Preferences dialog determines how Crystal Ball displays percentiles. Settings on this tab also activate capability metrics to support Six Sigma and other quality programs. For general instructions, see "Setting Run Preferences" on page 71.

The **Statistics** tab of the Run Preferences dialog has these settings:

• **Calculate Percentiles As** settings — Determine how Crystal Ball defines percentiles. Selecting either of these options also affects the percentiles used for the assumption alternate parameters.

- **Probability Below A Value** Defines percentiles as the percent chance (probability) that the associated variable value is at or below a particular value. This setting is the default.
- **Probability Above A Value** Defines percentiles as the percent chance (probability) that the associated variable value is at or above a particular value.
- **Format Percentiles As** settings Determine how Crystal Ball displays percentiles in charts and reports, with a percent sign or the percentile preceded by P.
- **Calculate Capability Metrics** Activates the process capability features in Crystal Ball; when selected Crystal Ball displays capability metrics indicating process quality, provided at least an upper or lower specification limit is entered in the Define Forecast dialog (Appendix D, "Using the Process Capability Features").
- **Options** button When **Calculate Capability Metrics** is selected, displays the **Capability Options** panel for specifying short-term or long-term capability metrics formulas, a Z-score shift value, and other capability metrics calculation settings ("Setting Capability Calculation Options" on page 276).

Freezing Crystal Ball Data Cells

You can use the Freeze command to "freeze" or exclude certain Crystal Ball assumption, decision variable, and forecast cells from a simulation. Then, you can investigate the effect certain cells have on the model while holding others to their worksheet values.

The Freeze command is useful when you have multiple workbooks open and do not want to include all of their data cells in a simulation. You can freeze any unwanted cells instead of closing the workbooks that contain them.

➤ To freeze Crystal Ball data cells:

- **1** Select **Define**, and then **Freeze**.
- 2 Select one or more assumptions, decision variables, or forecasts listed in the Freeze dialog.

Use the **Show** buttons to hide and show cells of a particular type. Use the Select buttons to select all or none of the listed cells.

You can also click **View List** to change from Tree view to List view,

3 Click OK.

Running Simulations

Subtopics

- Starting Simulations
- Stopping and Continuing Simulations
- Resetting Simulations
- Single-stepping Simulations
- Crystal Ball Control Panel

After you have defined assumption and forecast cells — and, optionally, decision variable cells — in a worksheet model, you are ready to run a simulation. During the simulation, Crystal Ball creates a forecast chart for each forecast cell using frequency distributions to show the range of possible results.

During a Crystal Ball simulation, you can stop, reset, and continue the simulation at any time and manipulate the forecast charts independently, displaying or hiding them as needed. You can use the Crystal Ball Control Panel to perform many of the procedures described in this section ("Crystal Ball Control Panel" on page 78).

During the simulation, Crystal Ball saves the forecast values for later chart analysis and, optionally, reporting and export (Chapter 8, "Creating Reports and Extracting Data").

Starting Simulations

> To start a simulation, select **Run**, and then **Start [Simulation]**,

You can then stop, continue, single step, or reset the simulation.

After you start the simulation, the **Run**, then **Start [Simulation]** command changes to **Stop [Simulation]**. If you then select **Stop [Simulation]**, the simulation halts and the command changes to **Continue Simulation** (in Microsoft Excel 2003 or earlier). Choosing **Continue Simulation** restarts the simulation where it left off, and changes the menu command back to **Stop [Simulation**].

(In Microsoft Excel 2007 or later, select Run, and then Start to continue the simulation.)

Stopping and Continuing Simulations

- To stop a simulation, select Run, and then Stop [Simulation] or click the Stop button on the Crystal Ball toolbar or Control Panel,
- > To continue a simulation, select **Run**, and then **Continue [Simulation]** or click the **Continue**

button on the Crystal Ball toolbar or Control Panel, 🚩

(In Microsoft Excel 2007 or later, select **Run**, and then **Start** or click the **Start** button.)

Resetting Simulations

- > To reset the simulation:
- 1 Select Run, and then Reset [Simulation] or click the Reset button on the Crystal Ball toolbar or Control

Panel, **1**

2 Click **OK** to confirm the reset.

Crystal Ball resets the number of trials to 0 and clears the list of values and statistics for each assumption and forecast. However, the assumption and forecast definitions remain.

3 **Optional:** Change the model or run preferences and rerun the simulation.

Single-stepping Simulations

Before you run a simulation or after you stop it, you can use the Single Step command to watch the simulation process generate one set of values (a *trial*) at a time for the assumption cells and recalculate the spreadsheet. This feature is useful if you are trying to track down a calculation error or verify that the values being produced for the assumption cells are valid.

> To observe an individual trial:

1 Select **Run**, and then **Reset [Simulation]** or click the **Reset** button on the Crystal Ball toolbar or Control



2 Select Run, and then [Single] Step or click the Single-Step or Step button to run one trial of the

simulation. Click the button again to run another.

Crystal Ball Control Panel

You can use the Crystal Ball Control Panel to perform many simulation and analysis commands. By default, the Control Panel opens when you run a simulation.

> To hide the Control Panel, clear Show Control Panel on the Options tab of the Run Preferences

dialog (click the **Run Preferences** tool or select **Run**, and then **Run Preferences**).

By default, the Control Panel stays open following a reset. To close it, clear **Leave Open On Reset** on the **Options** tab of the Run Preferences dialog.

Figure 15 Crystal Ball Control Panel

1 4	Control Panel		
Menubar	Run Analyze Help		
	Simulation complete	≥ -	More button
Progress bar	0 Total trials: 1.000 1.000		
Task buttons —	- 🖾 🕨 🖬 📢 🕪		

When you click the **More** button, \bigotimes , simulation statistics are displayed below the controls. They show how fast the simulation ran and how many assumptions, decision variables, and forecasts were included in it.

The Control Panel menus contain many of the same commands available on the main Crystal Ball menus or ribbon.

Managing Chart Windows

By default, charts are displayed when you run a simulation. You can close the forecast and other chart windows at any time and the simulation will continue. Running a simulation with the windows closed decreases the time required to run the simulation.

- To specify whether charts display when simulations are running, see "Setting Forecast Preferences" on page 97.
- > To close one chart window, click the **Close** icon in the corner of the chart window.
- To display, cascade, and close all chart windows, select Analyze and then one of the following commands (in Microsoft Excel 2007 or later, select Analyze, then View Charts, and then the command):
- **Open Selected Cells** Opens charts for all assumption and forecast cells in the selected range
- Cascade Neatly stacks all windows in front of Microsoft Excel
- **Close All** Closes all chart windows and clears the current simulation results and stored results from memory.

The remaining commands in the Analyze menu or group open charts of each type ("Opening Charts" on page 111).

Saving and Restoring Simulation Results

Subtopics

- Saving Crystal Ball Simulation Results
- Restoring Crystal Ball Simulation Results

You can save all open forecast windows and other charts as well as simulation data after you run a simulation in Crystal Ball. You can only save results after a simulation stops. Although only results are saved and not an entire model, restored results files are displayed in Crystal Ball chart, report, and Extract Data dialogs so you can work with them. You can run new charts and reports against them and extract their data to worksheets. Only results from the current simulation are saved.

Because the saved files contain only results and are not complete models, you can load more than one results file at a time and you do not need to reset the current simulation before loading results.

Saving Crystal Ball Simulation Results

- ➤ To save Crystal Ball results:
- 1 Select Run, and then Save Results. The Save Results dialog opens.

(In Microsoft Excel 2007 or later, select **Run**, then **Save or Restore**, and then **Save Results**.)

- 2 Navigate to the correct folder to save the results file.
- 3 Name the results file. The default name is the name of the active workbook.
- 4 Click OK.

The saved results file has a .cbr extension. Crystal Ball saves all results data and charts that existed when the results were saved.

Note: Only results from the current simulation are saved. Previously restored results are not saved. Suppose current and restored forecasts are both used in an overlay chart. If the overlay chart is then saved as part of the current simulation results, when it is restored it will only contain forecasts from the saved current results set. Forecasts from the previously restored results will no longer be included in the chart.

Restoring Crystal Ball Simulation Results

- > To restore Crystal Ball simulation results that you saved earlier:
- 1 Select **Run**, and then **Restore Results**. If you are using Crystal Ball in Microsoft Excel 2007 or later, select **Run**, then **Save or Restore**, and then **Restore Results**.
- 2 Select the results file (.cbr file type) to restore and click Open.

To remove restored results from memory, select Analyze, and then Close All. In Microsoft Excel 2007 or later, select Analyze, then View Charts, and then Close All.

Notes

Because you are restoring results and not simulation cell definitions or data, you do not need to reset the simulation before restoring results.

Results files can be restored at any time, regardless of whether the original workbooks are open or whether another simulation has run or not. You can open as many results files as you want, but you can only select one at a time in the Restore Results dialog.

After you have restored one or more Crystal Ball results files, you can open and close restored charts, create new reports using them, and extract their data to spreadsheets. You can create overlay and trend charts with restored results and results from the current simulation to compare data. The results are displayed in dialogs following those for the current simulation.

If you calculate capability metrics, store the results in a .cbr file, and then restore the results, the restored results use the preference settings on the computer where the results are restored. These may be different from the settings when the original simulation was run and stored. Crystal Ball refits the data when the results are restored, so results may differ somewhat from the original results.

Using Spreadsheet Functions

You can use subroutines and functions in the Crystal Ball Developer Kit to automate certain Crystal Ball operations.

The following Crystal Ball functions are available as spreadsheet functions for use in Microsoft Excel models:

- CB.GetAssumFN Retrieves information for a specific assumption cell
- CB.GetAssumPercentFN Returns the value corresponding to a percentile for an assumption cell
- CB.GetCertaintyFN Returns the certainty level of achieving a forecast value at or below a specific threshold
- CB.GetForeDataFN Returns the value for the given trial for a specific forecast
- CB.GetForePercentFN Returns the value corresponding to a percentile for a specific forecast
- CB.GetForeStatFN Returns statistic for a specific forecast cell
- CB.GetRunPrefsFN Returns a Run Preference setting
- CB.IterationsFN Returns the number of trials run in a simulation

These spreadsheet functions can be inserted directly into Crystal Ball model workbooks. For more information, see the spreadsheet functions section of the *Oracle Crystal Ball Developer's Guide*.

Running User-Defined Macros

You can run user-defined Microsoft Excel VBA macros automatically during a simulation by naming them with predefined names. For more information, see the user-defined macros section of the *Oracle Crystal Ball Developer's Guide*.

6

In T

Analyzing Forecast Charts

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Guidelines for Analyzing Simulation Results

The main tools for analyzing simulation results are the Crystal Ball charts, especially forecast charts. During a simulation, Crystal Ball creates a forecast chart for each forecast cell. Forecast charts condense much information into a small space. You can display that information graphically and numerically. You can also display other kinds of charts (Chapter 7, "Analyzing Other Charts"), generate reports, and extract data for further processing using Microsoft Excel or other analysis tools (Chapter 8, "Creating Reports and Extracting Data").

The following steps can help with analysis by focusing on details and general trends:

1. Look at the "big picture".

Consider each forecast chart from a high-level viewpoint. Look at the shape of the distribution:

- Is it distributed normally or skewed negatively or positively?
- Is it "flat" (spread out on both sides of the mean) or "peaked" (with most values clustered closely around the mean)?
- Does it have a single mode (most likely value) or is it bimodal with several peaks or humps?
- Is it continuous or are there groups of values separated from the rest, maybe even extreme values that fall outside of the display range?

The statistical concepts in the *Oracle Crystal Ball Reference and Examples Guide* can help with this part of the analysis.

2. Look at the certainty level, the probability of achieving values within a certain range.

You can enter a range, such as all values greater than \$0 dollars if you are analyzing profits, and view the certainty of falling within the range (\$0 to + Infinity, in this case). You can also

enter a certainty, say 75%, and see what range of values would be required to meet that level ("Determining the Certainty Level" on page 86).

3. Focus on the display range.

You can change the display range to focus on different sections of the forecast chart. For example, you can set the display range to focus on just the upper or lower tail of the forecast ("Focusing on the Display Range" on page 88).

4. Look at different views of the forecast.

Use the View menu to switch among different ways of viewing the forecast distribution graphically (frequency, cumulative frequency, or reverse cumulative frequency) or numerically (statistics, percentiles, goodness of fit data, or capability metrics). You can also select whether to show charts and statistics simultaneously or separately ("Changing the Distribution View and Interpreting Statistics" on page 90).

5. Customize the forecast chart.

Use the chart preferences to change graphic presentations from bars to areas or lines, or experiment with different colors, 2D versus 3D, more or fewer plotted intervals or data points, and other display variations for presentation and analysis ("Setting Chart Preferences" on page 101).

6. Create other kinds of charts (Table 1, "Crystal Ball Charts," on page 20).

Selecting different views of the data can help you analyze it and present it to others.

- 7. Create reports with charts and data ("Creating Reports" on page 145).
- 8. Extract simulation results to Microsoft Excel for numeric analysis and presentation or for further export into other analytical tools ("Extracting Data" on page 150).
- 9. Use Crystal Ball tools for different types of analyses ("Crystal Ball Tools" on page 24).

Using Forecast Charts

Subtopics

- Determining the Certainty Level
- Focusing on the Display Range
- Formatting Chart Numbers
- Changing the Distribution View and Interpreting Statistics
- Setting Forecast Preferences
- Setting Forecast Chart Preferences

Each trial of a simulation generates a value for every assumption cell and these feed into associated forecast cells. The generated values are saved, divided into value-range intervals (bins), and counted. Forecast charts show the number (frequency) of values occurring in each plotted interval. As Crystal Ball generates the forecast values, the number of values in each interval increases.

To display a forecast chart, follow the instructions in "Opening Charts" on page 111. Other topics listed at the beginning of this section describe how to change the contents and appearance of forecast charts.

Figure 16 shows the elements of forecast charts.

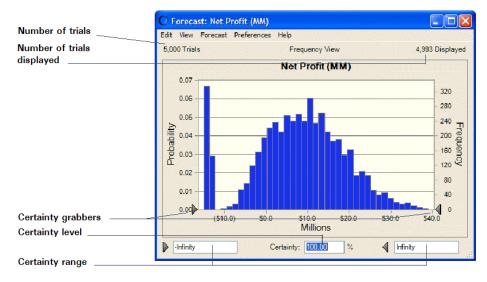


Figure 16 Forecast Chart

The frequency scale shows the number of values in each charted interval. The probability scale shows the probability of values falling in each interval (the percentage of the total)

The certainty level (Certainty) is displayed below the forecast chart. The certainty minimum is displayed in the first box, to the left of the certainty level. The certainty maximum is displayed in the third box, to the right of the certainty level. The certainty range is the difference between the minimum and maximum values. The certainty level is calculated by comparing the number of forecasted values in the certainty range with the number of values in the entire range.

Crystal Ball forecasts the entire range of results. By default, forecast charts show only a display range including about 99% of the forecast values and excluding extremely high and low values. The number of trials run for a forecast is displayed at the top of the forecast chart, near the Probability scale. The number of trials in the display range is displayed at the top of the chart near the Frequency scale (right vertical axis).

Note: To display all trials, change the chart axis preferences to display fixed endpoints between –Infinity and +Infinity ("Focusing on the Display Range" on page 88).

In Figure 16 on page 85, the mode (the x-axis value that occurred the most frequently) has a frequency of about 300, meaning that the interval expressed by that column contains 300 values. The mode has a probability of about 0.06 (or 6%), meaning that there is a 6% chance of a value falling within this interval. The certainty range includes all values between –Infinity and +Infinity. The certainty level is 100%. The display range excludes only one trial out of the total 5000.

Determining the Certainty Level

Subtopics

- Using the Certainty Grabbers
- Changing the Certainty Minimum and Maximum Text Boxes
- Anchoring Grabbers and Entering Certainty Directly
- Resetting the Certainty Range

The certainty level is one of Crystal Ball's key statistics because it shows the probability of achieving values within a specific range (the certainty range). The certainty range for the forecast includes all trials between the certainty grabbers, triangles at each end of the certainty range. By default, Crystal Ball calculates the certainty level based on the entire range of forecast values, so the certainty level is the percentage of values in the certainty range compared to all values, expressed as a decimal.

You can determine the certainty level for a specific value range either by moving the certainty grabbers on the forecast chart or typing the certainty minimum and maximum in the text boxes. You can also type a certainty level in the Certainty text box to get a certainty range centered around the median.

Note: When the certainty grabbers are at –Infinity and +Infinity, the certainty range includes every forecast value regardless of the size of the display range (and the certainty level is 100%).

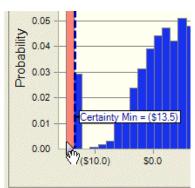
When you move the certainty grabbers, the certainty range changes and Crystal Ball recalculates the certainty level. When you type minimum and maximum values, Crystal Ball moves the certainty grabbers for you and recalculates the certainty level. When you type the certainty level in the Certainty text box, Crystal Ball moves the certainty grabbers to show you the value range for the certainty level you specified.

Using the Certainty Grabbers

- > To determine the certainty level for a specific value range using certainty grabbers:
- 1 Select a forecast chart.
- 2 Move the certainty grabbers on the forecast chart (Figure 17).

Click the grabber and then drag it when the cursor changes to a hand.

Figure 17 Moving a Certainty Grabber



Crystal Ball shades the columns outside the certainty grabbers a different color to show that those values have been excluded (Figure 18).

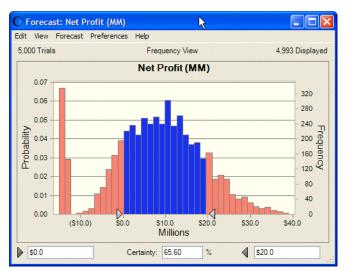


Figure 18 Certainty Level: Values \$0 to \$20 (in Millions)

The Net Profit forecast chart in Figure 18 is the same as the example in Figure 16 on page 85, except that the certainty grabbers have been moved to a minimum value of \$0.0 and a maximum of \$20.0. The certainty level is now 65.6%; you can be 65.6% confident of making a net profit between \$0 and \$20 million.

Changing the Certainty Minimum and Maximum Text Boxes

To determine the certainty level for a specific value range using the certainty minimum and maximum text boxes, type a value in each box and press Enter. The certainty grabbers move to correspond to the values you entered.

Anchoring Grabbers and Entering Certainty Directly

- To anchor a certainty grabber, move the grabber or click a grabber without moving it. The certainty grabber turns to a lighter color and is considered anchored.
- > To free an anchored certainty grabber, click it. It turns dark.

Note: To free or anchor both certainty grabbers, press Ctrl+click or Shift+click.

You can anchor a certainty grabber and then enter the certainty level. Crystal Ball moves the free grabber to correspond to the value range for the level.

If both grabbers are free and you enter a certainty level, the distribution is centered on the median.

You also can cross over the certainty grabbers to determine the certainty level for the two tails (ends).

You can determine the certainty level for specific value ranges at any time, either during or after a simulation.

Resetting the Certainty Range

To reset the original certainty range to include all values, either move the certainty grabbers until –Infinity and +Infinity show in the certainty minimum and maximum text boxes, or type those values directly into the text boxes.

Focusing on the Display Range

With Crystal Ball, you can focus on a particular range of the forecast results by changing axis settings in the Chart Preferences dialog. For instructions, see "Customizing Chart Axes and Axis Labels" on page 109.

- ► To define the display range:
- 1 In a forecast chart, select Chart Preferences, then Axis, then Scale, and then Type.
- 2 Select a scale type:

- **Auto** Crystal Ball uses a default display range of 2.6 standard deviations from the mean, which includes about 99% of the forecast values. (See Standard Deviation, following.)
- **Fixed** Sets the display range end points manually so you can focus on particular value ranges. For example, you can focus on positive values only to look at the profit for a profit/loss forecast.
- **Standard Deviation** Sets the display range end points in terms of standard deviations; defines the number of standard deviations worth of value to display on each side of the mean and centers values around the mean. If you choose to set the display range in terms of standard deviations, you can change the display range to 1 standard deviation from the mean to look at approximately 68% of the forecast values.
- **Percentile** Sets the display range end points in terms of percentiles.

By default, the *x*-axis value numbers are automatically adjusted to round numbers to make the forecasts easier to read. The Axis chart preference settings include Round Display Range, which constrains the display range to round numbers. You can clear this setting to display actual, unrounded numbers.

Other chart customizations are available to help you interpret the results of the simulation by viewing the data in different ways ("Setting Chart Preferences" on page 101).

Also see "Setting Preferences with Shortcut Keys" on page 102 for ways to change the appearance of charts without using menu commands.

Showing Statistics for the Display Range

After you have changed the display range, you can display statistics for just that range.

- > To show statistics for a display range:
- 1 Set the display range as described in "Focusing on the Display Range" on page 88.
- 2 Notice the values for the display range minimum and maximum.
- 3 In the forecast chart menu bar, select **Preferences**, then **Forecast**, and then **Filter**.
- 4 On the **Filter** tab of the **Forecast Preferences** dialog, set a filter on the forecast values and include values in the range between the display range minimum and maximum.
- 5 When the settings are complete, click **OK**.
- 6 Select View, then Statistics in the forecast chart menu bar to show statistics for the display range (or, in Split View, look at the statistics table).

Formatting Chart Numbers

By default, the number format displayed on the forecast chart comes from the underlying format of the forecast cell. You can select another cell format using the Chart Preferences dialog.

- > To change the format of numbers in a forecast chart:
- 1 In the forecast window, select **Preferences**, and then **Chart**.
- 2 In the **Chart Preferences** dialog, click the **Axis** tab.
- 3 Select a format from the drop-down list in the Format Number group. Formats are similar to Microsoft Excel formats. For most formats, you can specify the number of decimal places and whether to use a thousands separator.
- 4 Click **OK** or use **Apply To** to create a default, as described in "Applying Settings to Multiple Charts" on page 110.

Changing the Distribution View and Interpreting Statistics

The forecast settings related to distribution type determine the overall appearance of a forecast chart. You can also choose to display a table of statistics or percentiles instead of or in addition to a chart.

- > To set the distribution type or display a data table:
- 1 Open the **View** menu in the forecast window.
- 2 Select a distribution type or other view to display on the forecast chart:
 - **Frequency** Shows the number or frequency of values occurring in a given interval. This is the default distribution type.
 - **Cumulative Frequency** Shows the number or proportion (percentage) of values less than or equal to a given amount.
 - **Reverse Cumulative Frequency** Shows the number or proportion (percentage) of values greater than or equal to a given amount.
 - **Statistics** Shows a full set of descriptive statistics for a simulation in the forecast window.
 - **Percentiles** Shows percentile information in 10% increments, where a percentile is the percent chance, or probability, of a forecast value being less than or equal to the value that corresponds to the percentile (by default).
 - **Goodness Of Fit** If distribution fitting is selected in the Forecast or Preferences, then Forecast menus, shows goodness-of-fit statistics for the selected distributions and ranking methods.
 - **Capability Metrics** If process capability metrics are set for display, shows a table of process capability (quality) statistics for the simulation ("Viewing Capability Metrics" on page 278).
 - **Split View** Shows all selected views simultaneously ("Using Split View" on page 95).

See "View Examples" on page 91 for descriptions and illustrations of each view.

View Examples

The following sections provide descriptions and illustrations of each view:

- "Frequency" on page 91
- "Cumulative Frequency" on page 91
- "Reverse Cumulative Frequency" on page 92
- "Statistics" on page 93
- "Percentiles" on page 93
- "Goodness Of Fit" on page 94
- "Capability Metrics" on page 94
- "Split View" on page 95

Frequency

Frequency, the default forecast view, shows a simple count of values (the frequency) for each interval on the *x*-axis. Figure 19 shows a frequency chart of net profit values for a simulation where there is a 75% probability of net profit falling between \$0.00 and \$27.4 million. The chart has a median of \$8.4 million. This is also the 50th percentile. By default, there is a 50% probability that net profit will be at or below this value.

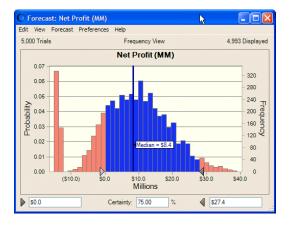
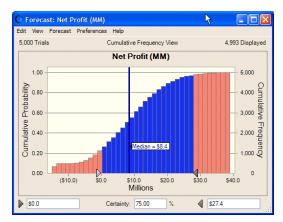


Figure 19 Forecast Chart–Frequency

Cumulative Frequency

Figure 20 shows the Net Profit forecast chart as a cumulative distribution. This chart shows the number or proportion (percentage) of values less than or equal to a given amount.

Figure 20 Forecast Chart–Cumulative Frequency



To create this chart, the frequencies are added cumulatively, starting from the lower end of the range, and then plotted as a cumulative frequency curve. To understand the cumulative distribution, look at a particular value, \$8.4 million (in the previous example). The chart shows that the probability of \$8.4 million is about 50%; approximately 50% of the values are less than \$8.4 million, while approximately 50% are greater. This would be correct for a median value. Notice also that the chart shows that the probability for \$27.4 million is about .95 while the probability for \$0 is about .20. This is also correct, since the probability of Net Profit falling between those two values is .75 (.95 - .20 = .75) or Certainty = 75%.

Reverse Cumulative Frequency

Figure 21 shows the Net Profit forecast chart as a reverse cumulative distribution. This chart shows the number or proportion (percentage) of values greater than or equal to a given amount.

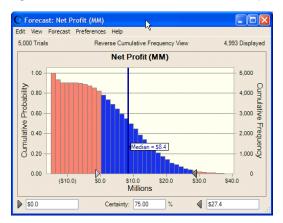


Figure 21 Forecast Chart–Reverse Cumulative Frequency

To create this chart, the frequencies are added cumulatively starting at the higher end of the range, and then plotted as a declining cumulative frequency curve. To understand the reverse cumulative distribution, look at a particular value, \$8.4 million (in the previous example). The chart shows that the probability of \$8.4 million is about 50%; approximately 50% of the values are less than \$8.4 million, while approximately 50% are greater. This would be correct for a median value. Notice also that the chart shows that the probability for \$27.4 million is about

0.05 (of having a greater value) while the probability for \$0 is about .80. This is also correct, since the probability of Net Profit falling between those two values is .75 (.80 - .05 = .75) or Certainty = 75%. Notice in this chart that the reverse cumulative frequency values are complements of the cumulative frequency values: .20 + .80 = 1.00 and .95 + .05 = 1.0 (the probability values for \$0.0 and \$27.4 million, respectively).

Statistics

You can display a full set of descriptive statistics for a simulation in the forecast window by choosing View, and then Statistics.

0	100 Trials	Statistics View	Model!C23
2	Statistic	Forecast values	
•	Trials	5,000	
	Base Case	\$9.2	
	Mean	\$7.9	
	Median	\$8.4	
	Mode		
	Standard Deviation	\$11.1	
	Variance	\$122.9	
	Skewness	-0.1734	
	Kurtosis	2.86	
	Coeff. of Variation	1.41	
	Minimum	(\$15.0)	
	Maximum	\$44.1	
	Mean Std. Error	\$0.2	

The example in Figure 22 shows statistics for the entire range of values (100% of the forecast values, including extreme values excluded from the default display range). Statistical terms listed in this table are discussed in the *Oracle Crystal Ball Reference and Examples Guide* and the Glossary in this user's guide.

Note: If the Precision Control feature is selected in the Run Preferences dialog and the forecast has Precision Control options set, the Precision column opens in the Statistics view.

Percentiles

You can display percentile information in 10% increments in the forecast window by choosing View, then Percentiles. A percentile is the percent chance, or probability, of a forecast value being less than or equal to the value that corresponds to the percentile (the default). For example, Figure 23 displays the percentile view of the Net Profit forecast, where the 90th percentile corresponds to \$21.6 million, meaning that there is a 90% chance of a forecast value being equal to or less than \$21.6 million. Another interpretation is that 90% of the forecast values are equal to or less than \$19.3 million.

Notice that the Median in Statistics view is the same as the 50th percentile in Percentiles view — in this case, \$8.4 million.

Figure 23 Forecast–Percentiles View

5,0	000 Trials	Percent	iles View	Model!C23
	Percentile	Forecast values		
•	0%	(\$15.0)		
	10%	(\$7.3)		
	20%	(\$0.5)		
	30%	\$2.6		
	40%	\$5.6		
	50%	\$8.4		
	60%	\$11.0		
	70%	\$13.6		
	80%	\$17.1		
	90%	\$21.6		
	100%	\$44.1		

If the Precision Control feature is selected in the Run Preferences dialog and the forecast has Precision Control options set, the Precision column is displayed in the Percentiles view.

Goodness Of Fit

If you have selected distribution fitting, described in the next section, you can select the Goodness Of Fit view to display comparative fit statistics for each of the selected distribution types. The distributions are ordered according to the selected ranking method. Figure 24 shows statistics for the Anderson-Darling ranking method and each continuous distribution type. Notice that Beta is ranked highest for this forecast.

	eferences H		
) Trials		Goodnes	s of Fit View Mod
ked by: Anderson-Da	arling		
Distribution	A-D	P-Value	Parameters
Beta	.1776		Minimum=(\$4,297.32),Maximum=\$8,174.12 ,Alp
Weibull	.2886	0.469	Location=(\$4,079.05),Scale=\$7,256.92 ,Shape=
Normal	.9747	0.013	Mean=\$2,499.01 ,Std. Dev.=\$1,824.86
Lognormal	.9758	0.000	Location=(\$14,415,655.60),Mean=\$2,499.01,St
Gamma	1.2023	0.000	Location=(\$55,285.18),Scale=\$57.84 ,Shape=99
Logistic	2.2420	0.000	Mean=\$2,522.17 ,Scale=\$1,063.95
Min Extreme	6.7291	0.000	Likeliest=\$3,401.62 ,Scale=\$1,723.42
Max Extreme	12.2481	0.000	Likeliest=\$1,579.88 ,Scale=\$1,799.20
Triangular	15.5277		Minimum=(\$3,367.28),Likeliest=\$2,816.98,Maxi
BetaPERT	20.3123		Minimum=(\$4,297.32),Likeliest=\$2,779.31,Maxi
Student's t	25.1784		Midpoint=\$2,499.01 ,Scale=\$778.48 ,Deg. Freed
Uniform	96.0794	0.000	Minimum=(\$3,144.51),Maximum=\$7,645.84
Pareto			
Exponential			

Capability Metrics

If the process capability features are activated on the Statistics tab of the Run Preferences dialog and if either an LSL, USL, or both are entered into the Define Forecast dialog, the Capability Metrics view is available for the forecast chart. For a definition of each statistic, see the capability metrics list in the *Oracle Crystal Ball Reference and Examples Guide*.

Figure 25 Capability Metrics View

	: View Forecast Preference	is hep	8
C	000 Trials Capa	ability Metrics View	Model!K
ł	ormality test passed (p-value =	= 0.199)	
	Metric	Fit: Normal	
•	Mean	49.2546	
	Standard Deviation	1.2764	
	Ср	0.8705	
	Cpk-lower	0.5204	
	Cpk-upper	1.22	
	Cpk	0.5204	
	Cpm	0.6003	
	Z-LSL	1.56	
	Z-USL	3.66	
	Zst-total	1.56	
	Zlt	0.0603	
	p(N/C)-below	0.0592	
	p(N/C)-above	1.2527e-04	
	p(N/C)-total	0.0593	
	PPM-below	59,222.22	
	PPM-above	125.27	
	PPM-total	59,347.49	
	LSL	47.2617	
	USL	53.9283	
	Target	50.5950	
	Z-score shift	1.50	

Split View

Split View shows forecast charts and related statistics onscreen at the same time. For more information, see "Using Split View" on page 95.

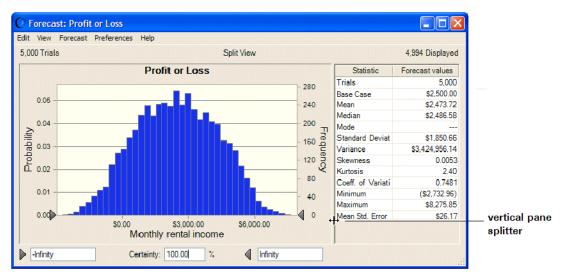
Using Split View

Split View displays charts and statistics at the same time. If you are using Crystal Ball's process capability features, Split View is the default. Otherwise, you can activate Split View through the View menu or the Preferences, then Forecast menu in the forecast chart window.

- ➤ To activate Split View:
- 1 In the forecast window, select **View** to open the **View** menu.
- 2 Select **Split View** at the bottom of the menu.

The Frequency chart and statistics are both displayed, similar to the next figure.

Figure 26 Frequency Chart and Statistics in Split View



You can resize the window and use the vertical pane splitter to adjust the size of the chart and the statistics pane.

3 If you want, continue opening the View menu and choosing charts or data.

The following figure shows a Frequency chart, a Cumulative Frequency chart, plus Statistics and Percentiles tables.

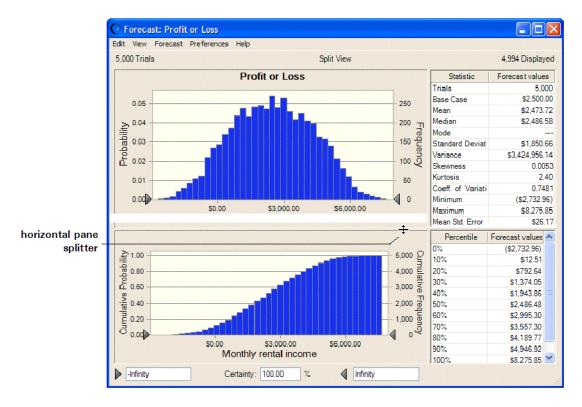


Figure 27 Frequency and Cumulative Frequency Charts with Statistics and Percentiles in Split View

You can click in any of the Split View panes and use the chart shortcut keys to modify them without using the View or Preferences menus. For a list, see Table 6.

You can also resize the chart window and drag the horizontal and vertical pane splitters to resize each part of the Split View window.

To clear Split View or remove any of the views from the window, open the **View** menu and clear each view you want to close.

Setting Forecast Preferences

You can set a number of specific forecast preferences to customize how Crystal Ball calculates and displays forecast charts. These are in addition to the general chart preferences discussed in "Setting Chart Preferences" on page 101.

You can control several forecast features with preference settings:

- Change the forecast chart view ("Forecast Window Tab" on page 62)
- Determine when the forecast window opens ("Forecast Window Tab" on page 62)
- Fit a distribution to the forecast ("Fitting a Distribution to a Forecast" on page 99)
- Set precision controls for forecast statistics ("Precision Tab" on page 62)
- Filter ranges of forecast values ("Filter Tab" on page 63)
- Automatically extract forecast data to a spreadsheet ("Auto Extract Tab" on page 63)

For an overview, see "Basic Instructions for Setting Forecast Preferences" on page 97.

Basic Instructions for Setting Forecast Preferences

Forecast preferences can be set differently for each forecast chart.

- > To set forecast preferences:
- 1 Select **Preferences**, and then **Forecast** in a forecast chart's menu bar.
- 2 In the Forecast Preferences dialog, click a tab and set preferences as required:
 - "Forecast Window Tab" on page 62 Manages window display and distribution fitting for the forecast.
 - "Precision Tab" on page 62 Manages precision control settings.
 - "Filter Tab" on page 63 Discards values inside or outside a range for the current forecast.
 - "Auto Extract Tab" on page 63 Specifies which statistics to extract automatically to Microsoft Excel when a simulation stops.

Also see the previous section, "Setting Forecast Preferences" on page 97.

See information on confidence intervals in the *Oracle Crystal Ball Reference and Examples Guide* for more information about how absolute and relative precision relate to the confidence interval.

- **3 Optional:** To reset forecast preference defaults to the original settings shipped with Crystal Ball, click **Defaults**.
- 4 **Optional:** To copy preferences to other forecasts, click **Apply To**.
- 5 When all settings are complete, click **OK** to apply them.

Setting Forecast Chart Preferences

To customize the appearance of forecast charts, select Preferences, and then Chart
 Preferences in the forecast chart menu bar ("Setting Chart Preferences" on page 101).

The following preference settings help interpret charts:

- **Chart type** Shows forecast charts as columns, areas, or lines in two or three dimensions so you can view the data plot from different perspectives and grasp the overall situation more easily
- **Chart density** Increases and decreases the number of bars or data points so you can spot trends more easily.
- Grid lines Make it easier to determine frequencies and probabilities.
- **Marker lines** Make it easier to locate means, medians, modes, percentiles, and other important values.
- **Axis scaling and rounding** Shows more or fewer axis values to read chart frequencies and probabilities more easily.

You can copy forecast charts and paste them into other applications. For more information, see "Copying and Pasting Charts to other Applications" on page 112.

Using Additional Forecast Features

Previous topics in this chapter described how to analyze forecast charts by switching among different views, how to set forecast preferences, and how to set forecast chart preferences. The topics in this section include "Fitting a Distribution to a Forecast" on page 99 and "Defining Assumptions from Forecasts" on page 100.

You can also create a sensitivity chart from within a forecast chart to show which assumptions contributed the most to that forecast distribution. For details, see "Using Sensitivity Charts" on page 126.

Fitting a Distribution to a Forecast

Note: This topic concerns distribution fitting for forecasts. If you are using distribution fitting to select the best distribution type for an assumption, see "Fitting Distributions to Historical Data" on page 41.

When analyzing a forecast chart, you can investigate some characteristics of the chart by determining the type of frequency distribution that fits it the best:

- You can select **Forecast**, and then **Fit Probability Distribution** in the forecast chart menu bar to do a quick fit with the default or currently selected distributions and ranking method. You can also use this command to switch off distribution fitting that is set with either the **Forecast** menu or **Preferences** menu.
- You can select **Preferences**, then **Forecast**, and then **Forecast Window** in the forecast chart menu bar to specify particular distributions and to select a fit ranking method. Then, you can also change the fit options or use Apply To to set these preferences for other forecasts.
- To fit a probability distribution to a forecast chart using the Forecast command on the Preferences menu:
- 1 Create a model and run a simulation.
- 2 Select a forecast chart.
- 3 In the forecast chart menu bar, select Preferences, and then Forecast.
- 4 In the Forecast Window tab of the Forecast Preferences dialog, select Fit a probability distribution to the forecast and then click Fit Options.

The Fit Options panel opens.

- 5 Specify which distributions to fit:
 - **AutoSelect** performs a basic analysis of the data to select a distribution fitting option and ranking method. If the data includes only integers, fitting to all discrete distributions (with the exception of Yes-No) is completed using the Chi-square ranking statistic choice.
 - **All Continuous** fits the data to all of the built-in continuous distributions (these distributions are displayed as solid shapes on the Distribution Gallery).
 - All Discrete fits to all discrete distributions except Yes-No.
 - **Choose** displays another dialog from which you can select a subset of the distributions to include in the fitting.
- 6 Specify how the distributions should be ranked. In ranking the distributions, you can use one of three standard goodness-of-fit tests:
 - Anderson-Darling This method closely resembles the Kolmogorov-Smirnov method, except that it weights the differences between the two distributions at their tails greater than at their mid-ranges. This weighting of the tails helps to correct the Kolmogorov-Smirnov method's tendency to over-emphasize discrepancies in the central region.

- **Kolmogorov-Smirnov** The result of this test is essentially the largest vertical distance between the two cumulative distributions.
- **Chi-Square** This test is the oldest and most common of the goodness-of-fit tests. It gauges the general accuracy of the fit. The test breaks down the distribution into areas of equal probability and compares the data points within each area to the number of expected data points.

The first setting, **AutoSelect**, enables Crystal Ball to select the ranking statistic. If all data values are integers, **Chi-square** is selected.

- 7 **Optional:** If you know location, shape, or other parameter values that may help create a more accurate fit with certain distributions, select **Lock Parameters** and enter appropriate values in the **Lock Parameters** dialog ("Locking Parameters When Fitting Distributions" on page 44).
- 8 **Optional:** By default, values for all appropriate ranking statistics are calculated but only values for the selected ranking statistic are displayed in Goodness Of Fit view. To show values for all three statistics, select **Show All Goodness-of-fit Statistics** at the bottom of the **Distribution Options** panel.
- 9 Click **OK** to perform the fit.

During a simulation, Crystal Ball disables distribution fitting on forecast charts and overlay charts after 1,000 trials and until the simulation stops to enhance performance. A final fit is performed at end of the simulation.

Defining Assumptions from Forecasts

It is sometimes convenient to use results from one simulation as inputs to another simulation. For example, the simulation results from a departmental revenue model can be used as input assumptions to a total company revenue model. It is not necessary for the two models to share the same simulation. You can use the Define Assumption from Forecast feature in Crystal Ball to convert a forecast distribution into an assumption in one of two ways. You can either fit a standard probability distribution to the forecast data, or use the forecast data directly as a custom distribution.

- > To define an assumption from a forecast:
- 1 Run a Crystal Ball simulation and open a chart for the target forecast.
- 2 In the forecast chart menu bar, select Forecast, and then Define Assumption from Forecast.
- 3 In the Define Assumption from Forecast dialog:
 - Enter a cell location for the new assumption. You can type it or click the cell selector to point to the cell.
 - Select a distribution type for the assumption. You can select the best fitting distribution or define a custom distribution.
 - If you select Best fitting distribution, the current fitting defaults are used. You can click Fit Options to display the Fit Options dialog described in "Fitting a Distribution to a Forecast" on page 99. If you select Show comparison chart, you

can view a chart of each fitted distribution and optionally override the best fit selection ("Confirming the Fitted Distribution" on page 43).

- If you select **Custom distribution** (with forecast data), when you click **OK**, the **Define Assumption** dialog opens for the custom distribution. It contains the data taken from the filtered range (if any) of the forecast. If you prefer, you can follow the instructions in "Using the Custom Distribution" on page 231 to modify the data.
- Optional: If you select Custom distribution (with forecast data), you can select Sample sequentially (instead of randomly) to use sequential sampling. For details, see "Sequential Sampling with Custom Distributions" on page 239.
- **Optional:** Indicate whether to display the new assumption's type and parameters in adjacent cells, either downward or to the right, and indicate whether to show names (labels) with the values.
- 4 When settings are complete, click OK to perform distribution fitting (unless you selected **Custom distribution**) and open the **Define Assumption** dialog.

You can save the assumption with the indicated defaults, or modify the assumption as if you were defining it in the usual way. Most assumption definition features are available. You can enter different parameters and correlate the assumption with another. However, you cannot add the assumption to the Gallery until after it has been created.

5 To finish defining the assumption, click **OK** in the **Define Assumption** dialog.

After you have defined the new assumption, you can select it and select Define Assumption to change the distribution type or perform any other modifications, including adding it to the Gallery.

Setting Chart Preferences

Subtopics

- Setting Preferences with Shortcut Keys
- Basic Customization Instructions
- Setting General Chart Preferences
- Setting Chart Types, Colors, and Marker Lines
- Customizing Chart Axes and Axis Labels
- Applying Settings to Multiple Charts

You can set a number of chart preferences to customize the appearance of Crystal Ball charts. The following customizations can help you analyze and present the data, followed by references to instructions:

- Add or edit and format a title ("Adding and Formatting Chart Titles" on page 104)
- Change the chart type ("Setting the Chart Type" on page 106)
- Show more or fewer columns or data points ("Changing the Chart Density" on page 104)

- Show or hide grid lines ("Showing Grid Lines" on page 105)
- Show or hide the chart legend ("Showing the Chart Legend" on page 105)
- Set special chart effects such as transparency or 3D lines, areas, and columns ("Setting Special Chart Effects" on page 106)
- Set chart colors ("Setting Chart Colors" on page 108)
- Show mean, median, mode, standard deviation, percentile, or capability limit/target marker lines ("Showing the Mean and Other Marker Lines" on page 108)
- Hide and show vertical and horizontal axes, create and edit axis labels, and change an axis scale ("Customizing Chart Axes and Axis Labels" on page 109)
- Format chart numbers ("Formatting Chart Numbers" on page 89)
- Specify whether to use these preferences for more than the current chart ("Applying Settings to Multiple Charts" on page 110)

Also see "Setting Preferences with Shortcut Keys" on page 102, for ways to change the appearance of charts without using menu commands. See "Basic Customization Instructions" on page 103 and "Setting General Chart Preferences" on page 104 for other general customization tips.

Setting Preferences with Shortcut Keys

Table 6 lists key combinations that can be used to cycle through settings available in the Chart Preferences dialog. Most of these commands work on the primary distribution — the probability distribution for assumptions, and frequency for forecasts and overlay charts.

Note: You can also use Ctrl+(view number) to cycle through views in Split View, while Ctrl+ (chart number) cycles through multiple open charts.

Shortcut Key	Command Equivalent	Description
then View		Cycles through chart views – Frequency, Cumulative Frequency, Reverse Cumulative Frequency (for assumption and forecast charts)
Ctrl+b; Ctrl+g Preferences, then Chart Preferences, then General, then Density		Cycles through bin or group interval values to adjust the number of columns or data points
Ctrl+l	Preferences, then Chart Preferences, then General, then Gridlines	Cycles through gridline settings: None, Horizontal, Vertical, Both
Ctrl+t	Preferences, then Chart Preferences, then Chart Type, then Type	Cycles through chart types: Area, Line, Column; for sensitivity charts: Bar (direction), Bar (magnitude), Pie (in Contribution To Variance view)
Ctrl+w Preferences, then Chart Preferences, then General, then 3D Chart		Cycles between two-dimensional and three-dimensional chart display

Table 6 Shortcut Keys for Chart Preferences

Shortcut Key	Command Equivalent	Description
		Cycles through central tendency marker lines: None, Mean, Median, Mode (except for sensitivity and trend charts)
Ctrl+n	Preferences, then Chart Preferences, then General, then Legend	Toggles the legend display on and off
Ctrl+p	Preferences, then Chart Preferences, then Chart Type, then Marker Lines, then Percentiles	Cycles through percentile marker lines: None, 10%, 20%, 90%
Ctrl+Spacebar	View menu; Preferences, then chartname Preferences	Cycles through window views: Chart, Statistics, Percentiles, Goodness Of Fit (if distribution fitting is selected — except for trend charts)

Basic Customization Instructions

These instructions apply most specifically to forecast charts. However, many of them apply to other charts as well. For that reason, they are as general as possible, although not all settings will apply to every type of chart.

- ► To customize a chart:
- 1 Create or display a chart and be sure it is the active chart window.
- 2 Either double-click the chart or select **Preferences**, and then **Chart Preferences** from the chart's menu bar.

The Chart Preferences dialog opens. Tab contents are as follows:

- **General** Chart title, overall appearance of the chart
- **Chart Type** Data sets (series) to display in the chart, chart type and color of plotted series, marker lines to display (optional)
- **Axis** Vertical and horizontal axes to display, axis labels, axis scales, and axis number formats
- 3 Make appropriate settings.
- **4 Optional**: To apply the settings to more than one chart, click **Apply To**. Then, specify whether to apply all chart preferences or just the current tab and whether to apply them to the current Microsoft Excel sheet, all sheets in the workbook, or all open and new workbooks and click **OK**. Otherwise, go to step 5.
- 5 Click **OK** to apply the settings on all tabs to the active chart.

For a list of customizations you can perform on each tab, see "Setting General Chart Preferences" on page 104.

Setting General Chart Preferences

Subtopics

- Adding and Formatting Chart Titles
- Changing the Chart Density
- Showing Grid Lines
- Showing the Chart Legend
- Setting Special Chart Effects

You can change chart titles, legends, and other features to support analysis and presentation of simulation results. Related settings:

- "Setting Chart Types, Colors, and Marker Lines" on page 106
- "Customizing Chart Axes and Axis Labels" on page 109
- "Applying Settings to Multiple Charts" on page 110

For basic chart customization instructions, see "Basic Customization Instructions" on page 103.

Adding and Formatting Chart Titles

- > To add or change a chart title:
- 1 Display the General tab of the Chart Preferences dialog.

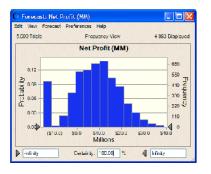
By default, Auto is selected in the Chart Title group and a default title is displayed.

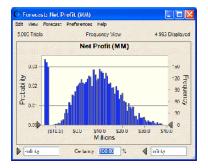
- 2 **Optional:** Clear **Auto** and type a new title in the text box.
- 3 Change another setting or click **OK**.

Changing the Chart Density

You can show more or less detail in a chart by changing the number of bins (intervals) used to group similar values. The level of detail is called the chart density. Higher densities more accurately reflect the actual distribution of data; lower densities highlight the data trend.

- > To change the chart density:
- **1** Display the **General** tab of the **Chart Preferences** dialog.
- 2 Select a density level from the **Density** drop-down list.





Lowest density

Highest density

- 3 To show a space between each column (bin) select Show Column Gaps.Gaps will always be displayed in a discrete distribution.
- 4 Change another setting or click **OK**.

Showing Grid Lines

Grid lines are vertical or horizontal lines that help you compare charted data with axis values.

- > To hide or show grid lines:
- 1 Display the General tab of the Chart Preferences dialog.
- 2 Optional: Select a setting from the Gridlines drop-down list to show only horizontal grid lines (Horizontal), only vertical grid lines (Vertical), both horizontal and vertical grid lines (Both), or select None to hide both horizontal and vertical grid lines.
- **3** Change another setting or click **OK**.

Note: You can press Ctrl+l to toggle the horizontal grid lines on and off.

Showing the Chart Legend

The legend shows the name and color for each series in the chart.

- > To hide or show a chart legend:
- 1 Display the General tab of the Chart Preferences dialog.
- 2 **Optional:** Select a setting from the **Legend** drop-down list to show the legend at the right side of the chart (**Right**), the left side of the chart (**Left**), or the bottom of the chart (**Bottom**). To hide the legend, select **None**.
- **3** Change another setting or click **OK**.

Note: You can press Ctrl+n to toggle the chart legends on and off.

Setting Special Chart Effects

Special effects help present data most effectively. Transparency ensures that all chart series and values are visible. Three-dimensional effects add graphic depth that can be so useful when many series are charted (for example, bars become blocks as shown in the chart density figure in "Changing the Chart Density" on page 104).

- ► To set special chart effects:
- 1 Display the General tab of the Chart Preferences dialog.
- 2 Locate the Effects group at the bottom of the page.
- **3** You can select any or all of the available effects to see how they enhance the chart. If you select **Transparency**, you can also select a percent. 0% is completely opaque and 100% is completely transparent.
- 4 Change another setting or click **OK**.

Note: You can press Ctrl+w to toggle the horizontal grid lines on and off.

Setting Chart Types, Colors, and Marker Lines

Subtopics

- Setting the Chart Type
- Setting Chart Colors
- Showing the Mean and Other Marker Lines

Customizing chart types, colors and patterns, and marker lines supports simulation analysis and product accessibility.

Setting the Chart Type

Depending on the basic chart type (assumption, forecast, trend, overlay, or sensitivity), you can select from among several chart display types, such as column, line, area, bar, or pie.

- > To change the chart display type:
- **1** Select the **Chart Type** tab of the **Chart Preferences** dialog.

If more than one series is displayed in the list box at the top of the tab, the settings on the tab apply to the selected series.

2 To change the chart display type, open the **Type** drop-down list and select a display type. Depending on the basic chart and series types, you can select from among these display types (not including scatter charts):

Table 7 Chart Types

Example	Туре	Description
Character Lorent April & Account (Ann)	Column	Displays data as vertical columns that correspond to the group intervals (chart bins) of the data. The column chart is the default chart type for generated data in assumption, forecast, and overlay charts.
Concept Constructor Assessment (MM)	Line	Shows data as an outline of the peaks and valleys.
Construct Group Fund of Automated RMA Ext Two Foreast: Profession RMA Ext Two Foreast: Profession RMA Groups Profession RMA Construction Reservation Construction Reservation Construction Co	Area	Shows data as darkened peaks and valleys.
65.2% 25.5% -7.2% 2.0%	Bar (directional)	Shows sensitivity data as horizontal bars to the right and left of the 0 line showing magnitude and direction of sensitivity
65.2% 25.5% 7.2% 2.0%	Bar (magnitude)	Shows sensitivity data as horizontal bars to the right of the 0 line showing magnitude of sensitivity but not direction
2.0% 7.2% 65.2%	Pie	Shows sensitivity data as a circle divided into proportional "slices" showing the magnitude of sensitivity

- **3 Optional:** Consider adjusting the chart color ("Setting Chart Colors" on page 108) and marker line settings ("Showing the Mean and Other Marker Lines" on page 108) too.
- 4 When settings for the current series are complete, follow steps 2 through 3 to customize settings for any other series in the chart.

5 When all settings are complete, click **OK**.

Setting Chart Colors

This preference sets the color or pattern of the current chart series. This is the color that is displayed for the series in the chart legend, if visible.

- > To change the chart colors:
- **1** Display the **Chart Type** tab of the **Chart Preferences** dialog. The **Chart** group is displayed in the middle of the page.

The settings on the page apply to the selected series.

- 2 Open the **Color** drop-down list and select a color or pattern (see "Setting Options Preferences" on page 75 for information about setting Crystal Ball to offer pattern settings).
- **3 Optional:** Consider adjusting the chart type ("Setting the Chart Type" on page 106) and marker line settings ("Showing the Mean and Other Marker Lines" on page 108) for that series.
- 4 **Optional:** When settings for the current series are complete, follow steps 2 through 3 to customize settings for any other series in the chart.
- 5 When all settings are complete, click **OK**.

Showing the Mean and Other Marker Lines

You can display mean, mode, median, standard deviation, certainty, and other marker lines on assumption, forecast, and overlay charts. These lines help you locate various values in the charted distribution.

Note: If you have activated the process capability features and have entered an LSL, USL, or Target value, you can include marker lines for them in forecast charts ("Viewing LSL, USL, and Target Marker Lines" on page 278).

Base Case is the value in an assumption, decision variable, or forecast cell prior to running the simulation. For forecasts, **Certainty Range** shows lines at the certainty range endpoints. Marker lines are shown with labels, such as **Mean = \$125**.

You can press **Ctrl+m** to cycle through the median, mean, and base case or mode, depending on chart type. Press **Ctrl+p** to cycle through every 10th percentile.

- ➤ To display marker lines:
- 1 Display the Chart Type tab of the Chart Preferences dialog.

The settings apply to the selected series.

2 In the Marker Lines group, select an item to display. If you select Standard Deviation, Percentile, or Value, another dialog opens:

- For **Standard Deviation**, enter the standard deviation(s) where you want a marker to be displayed. If you enter more than one, separate them with commas. Then, select whether you want the marker(s) to be displayed below the mean (technically indicating negative standard deviations), above the mean, or both above and below.
- For **Percentile**, select the group of percentiles where you want markers to be displayed or select **Custom** and create a group of percentile points separated by commas.
- For Value, enter the x-axis value where the line should be displayed and click Add. Optional: Enter a label. Select Show Value On Marker Line. Optional: Click New to add another value.
- 3 Consider adjusting the chart type ("Setting the Chart Type" on page 106) and color ("Setting Chart Colors" on page 108) for the selected series.
- 4 **Optional:** Follow steps 2 and 3 to customize settings for any other series in the chart.
- 5 When all the settings are complete, click **OK**.
 - **Note:** If the marker lines fall outside the maximum or minimum value displayed on a chart, they will not appear on the chart. This can happen with standard deviations of plus or minus 2 or 3 for uniform distributions.

Customizing Chart Axes and Axis Labels

You can customize the label, scale, and format of the main axis in Crystal Ball charts.

- > To customize chart axes:
- 1 Display the Axis tab of the Chart Preferences dialog.
- 2 By default, **Auto** is selected in the **Axis Label** group. A label is automatically assigned. To enter a custom axis label, clear **Auto** and type a more descriptive label.
- **3 Optional:** Adjust the **Scale** settings. By default, **Auto** is displayed and end points are automatically selected. To use another scale, select it from the **Type** list and enter the minimum (**Min**) and maximum (**Max**) values.

Most chart/axis combinations offer **Fixed** as an alternative. The value axis for assumption, forecast, and overlay charts also offers **Standard Deviation** and **Percentile**.

- 4 The Format Number settings control the format of the axis label numbers:
 - For Format settings, Cell Format uses the format of the underlying cell. Most choices are similar to those used in Microsoft Excel: General, Number, Currency, Scientific, Percentage, or Date.
 - The **Decimal** settings control the number of decimal points.
 - When selected, **Thousand Separator** inserts a thousands-separator symbol where appropriate (except when **Scientific** formatting is set). The thousands separator that is displayed is the one defined in Windows' **International or Regional Options** settings.

- **Note:** The **Format Number** settings also control the format of assumption parameters in the **Define Assumption** dialog and assumption charts.
- 5 When settings are complete, click **OK**.

Applying Settings to Multiple Charts

If you would like to apply the current settings to other charts in the model, you can select which settings to apply and where to apply them. (These instructions apply anywhere the **Apply To** button is displayed.) **Apply To** settings are both flexible and powerful. They can be used as focused or broad defaults.

- > To specify how chart settings should be applied:
- **1** Click the **Apply To** button.
- 2 In the Apply To dialog, indicate the tab or tabs of settings to apply:
 - This Tab applies only settings on the current tab.
 - All Tabs applies all the current settings in the entire dialog.
- 3 Indicate where the settings should be applied.
 - **This Sheet** applies the settings to only the current sheet of the current workbook.
 - **This Workbook** applies the settings to all sheets of the current workbook.
 - All Open And New Workbooks applies the settings to all workbooks that are currently open and all workbooks to be created.

All Open and New Workbooks effectively changes the global Chart Preferences defaults to the settings on the current tab or all tabs, depending on the setting in the previous dialog group.

Managing Charts

Previous sections of this chapter have described how to create and customize new charts. The following sections describe how to open, copy, paste, print, close, and delete existing charts:

- "Opening Charts" on page 111
- "Copying and Pasting Charts to other Applications" on page 112
- "Printing Charts" on page 113
- "Closing Charts" on page 113
- "Deleting Charts" on page 114

Opening Charts

After you create an assumption or forecast chart, it is saved with the workbook that contains it. Other charts are saved with the active workbook model. You can display charts again, with current data, anytime you rerun the model with associated workbooks open.

- ► To open a chart:
- 1 Open the model containing the chart and run a simulation or restore saved results ("Restoring Crystal Ball Simulation Results" on page 80).
- 2 Open the **Analyze** menu and select the type of chart to display:
 - Assumption Charts ("Using Assumption Charts" on page 134)
 - **I**, Forecast Charts ("Using Forecast Charts" on page 84)
 - **Arrow**, **Overlay Charts** ("Using Overlay Charts" on page 115)
 - Frend Charts ("Using Trend Charts" on page 120)
 - **F** , Sensitivity Charts ("Using Sensitivity Charts" on page 126)
 - Scatter Charts ("Using Scatter Charts" on page 137)
 - **OptQuest Charts** Available in Crystal Ball Decision Optimizer if you have just run an optimization (*Oracle Crystal Ball Decision Optimizer OptQuest User's Guide*)
 - Predictor Charts Available if you have just run a Predictor forecast (*Oracle Crystal Ball Predictor User's Guide*)

Note: For a description of each chart type, see Table 1, "Crystal Ball Charts," on page 20.

- 3 When the dialog for that chart opens, select the box in front of each chart to display.
- 4 Click **Open**.

Crystal Ball You may need to click the Crystal Ball and Microsoft Excel icons in the Windows task bar to activate charts that have disappeared behind the spreadsheet.

In Microsoft Excel 2007 or later, select Analyze, then View Charts, and then Forecast Charts.

To open a number of charts at one time, select the Crystal Ball data cells and select **Analyze**, and then **Open Selected Cells**. All charts for the selected cells open and are displayed in front of any other open charts. In Microsoft Excel 2007 or later, select **Analyze**, then **View Charts**, and then **Open From Selection**.

Copying and Pasting Charts to other Applications

You can copy and paste assumption, forecast, overlay, trend, and sensitivity charts to other applications such as Microsoft Word, Powerpoint, and Microsoft Excel.

For instructions, see the following sections:

- "Copying Charts" on page 112
- "Pasting Charts from the Clipboard" on page 112

Copying Charts

- > To copy charts for use in other applications:
- **1** Select the chart to copy.
- 2 Open its View menu and select the view to be copied.

If you select a data view such as **Percentiles**, **Statistics**, or **Goodness Of Fit**, the data will be pasted into many applications as alphanumeric data, ready to edit, add, and so on. This is true for Microsoft Excel and Word, but not Powerpoint. Data is pasted into Powerpoint as a graphic.

Graphic views, such as **Frequency**, are pasted as bitmap images.

3 In the chart's menu bar, select Edit, and then Copy.

The chart is copied to the Clipboard, ready to paste into another application.

Pasting Charts from the Clipboard

- > To paste a chart into another application using the application's Paste commands:
- **1** Copy the Crystal Ball chart as described in the previous section.
- 2 Open a document (spreadsheet, slide, and so on) in the application to receive the chart.
- 3 Within that application, select Edit, and then Paste or Edit, and then Paste Special.

(To paste in Microsoft Excel 2007 or later, press Ctrl+v or click the **Home** tab and select **Clipboard**, and then **Paste**.)

As described previously, if you copied a data view such as **Percentiles**, **Statistics**, or **Goodness of Fit**, the data is pasted into many applications as editable numbers or text.

Graphic views, such as **Frequency**, are pasted as bitmap images.

Printing Charts

> To print a chart, display it and select **Edit**, and then **Print** in the chart's menu bar.

Before printing, you can select **Edit**, and then **Page Setup** to format the chart on the page. Then, select **Edit**, and then **Print Preview** to view the chart as it will print on the selected paper size.

For example, Figure 28 shows the Print Preview dialog for a forecast chart from Toxic Waste Site.xls in Landscape orientation on Letter paper.

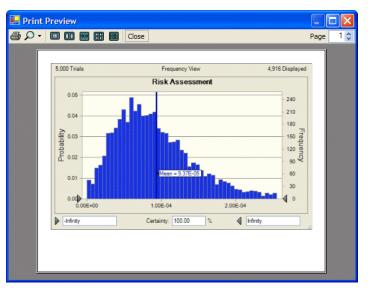


Figure 28 Print Preview Dialog for a Forecast Chart

Closing Charts

When you close a chart, you remove it from memory but do not delete it permanently.

- ► To close a chart:
- **1** Open the **Analyze** menu and select the type of chart to close.

If you are using Crystal Ball in Microsoft Excel 2007 or later, select **Analyze**, then **View Charts**, and then select a command.

- 2 When the dialog for that chart opens, select the box in front of each chart to close.
- 3 Click Close.

The selected chart or charts are closed without prompting.

You can use **Analyze**, and then **Close All** to close all chart windows from the current simulation and restored results. In Microsoft Excel 2007 or later, select **Analyze**, then **View Charts**, and then **Close All**.

Deleting Charts

You do not need to open a chart to delete it, as long as the model or saved results file containing it is open.

- > To delete a chart (except assumption and forecast charts):
- **1** Open the model containing the chart.
- 2 Open the Analyze menu and select the type of chart to delete.

If you are using Crystal Ball in Microsoft Excel 2007 or later, select **Analyze**, then **View Charts**, and then select a chart type.

- 3 When the dialog for that chart opens, select the box in front of each chart to delete.
- 4 Click Delete.

The selected chart or charts are deleted without prompting. Assumption and forecast charts cannot be deleted in this way.

Selecting Assumptions, Forecasts, and other Data Types

When defining Crystal Ball charts and performing other procedures, you must sometimes select assumptions, forecasts, and other types of Crystal Ball data or objects. The following instructions apply to several types of selection situations.

- > To select a Crystal Ball data cell or other object:
- **1** Perform an operation that displays a **Choose...** dialog.

By default, these dialogs open in a hierarchical Tree view. If you prefer, click the List button

to change the view from a tree to a list.

- 2 Select the boxes in front of the assumptions, forecasts, decision variables, or other objects to include.
- 3 When the selection is complete, click **OK**.



Analyzing Other Charts

In This Chapter

About Crystal Ball Charts	
Using Overlay Charts	
Using Trend Charts	
Using Sensitivity Charts	
Using Assumption Charts	
Using Scatter Charts	

About Crystal Ball Charts

These topics extend the information on analyzing simulation results provided in Chapter 6. You will learn how to use additional charts to interpret and present data. For a list of Crystal Ball charts, see Table 1, "Crystal Ball Charts," on page 20.

If you have OptQuest, you can also display OptQuest charts with optimization results.

For information on customizing charts, managing chart windows, and printing charts, see Chapter 6.

Using Overlay Charts

Subtopics

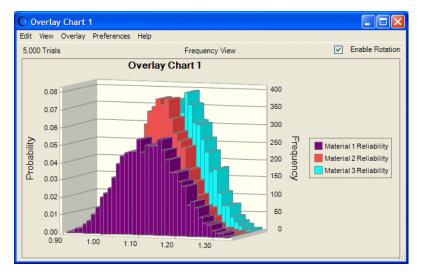
- Creating Overlay Charts
- Customizing Overlay Charts
- Using Distribution Fitting with Overlay Charts

After completing a simulation with multiple related forecasts, you can create an overlay chart to display the relative characteristics of those forecasts on one chart. The frequency data from selected forecasts is superimposed in one location to show similarities and differences that otherwise may not be apparent. There is no limit to the number of forecasts you can view at one time on an overlay chart.

Figure 29 shows the relative reliabilities of three manufacturing materials.

Note: Figure 29 and other figures may differ from the default view.

Figure 29 An Overlay Chart with 3D Formatting and Rotation



Creating Overlay Charts

- > To create an overlay chart:
- 1 Run a simulation in Crystal Ball (or restore results).

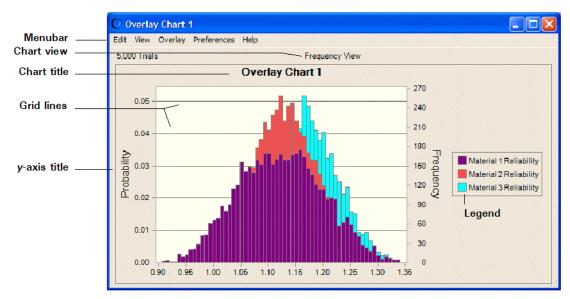
For overlay charts, the simulation should have more than one forecast.

2 Select Analyze, and then Overlay Charts.

(If you are using Crystal Ball in Microsoft Excel 2007 or later, select **Analyze**, then **View Charts**, and then **Overlay Charts**.)

- 3 To create a new overlay chart, click New.
- 4 In the **Choose Forecasts** dialog, select two or more forecasts to include.
- 5 Click **OK** to create a new overlay chart with the selected forecasts (Figure 30).

Figure 30 Overlay Chart for Selected Forecasts



- 6 **Optional:** Follow the steps in "Customizing Overlay Charts" on page 117 and "Setting Chart Preferences" on page 101 to change a variety of chart features and highlight those of greatest interest.
- 7 **Optional:** Choose Overlay, and then Fit Probability Distributions to select and display the best fitting distribution for each forecast in the chart ("Using Distribution Fitting with Overlay Charts" on page 119).

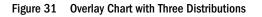
You can copy overlay charts and paste them into other applications. For more information, see "Copying and Pasting Charts to other Applications" on page 112.

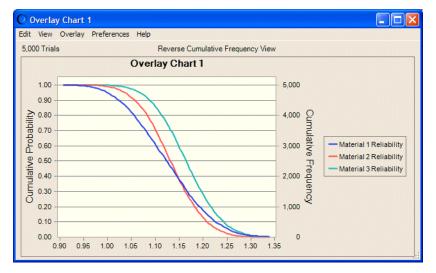
Customizing Overlay Charts

You can customize overlay charts in a variety of ways:

- Select the **View** menu in the overlay chart window to switch among several graphic and numeric views.
- Select the **Overlay** menu to add additional forecasts to the chart or remove them all and toggle between the default view and **Goodness Of Fit** view.
- Select **Preferences**, and then **Overlay** to select a view, determine when the overlay chart window should be displayed, and specify whether to fit distributions to all forecasts (described in "Using Distribution Fitting with Overlay Charts" on page 119).
- Select **Preferences**, and then **Chart Preferences** to further customize the chart's appearance as described in "Setting Chart Preferences" on page 101.
- **Note:** You can also use shortcut keys (keyboard equivalents) for commands to quickly change the chart preferences. For a list of these, see Table 6 on page 102.

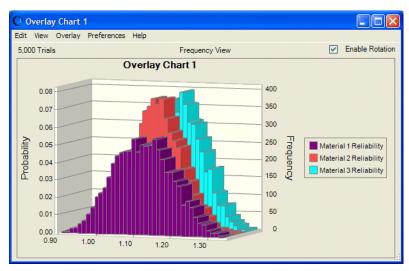
Customizing overlay charts helps you compare forecasts by viewing their differences in several ways. For example, the area and column chart types may obscure parts of some distributions behind other distributions, but the outline or line chart type shows virtually all of each distribution. Figure 31 shows what happens if you press Ctrl+d several times to display the reverse cumulative chart view, and then press Ctrl+t to display the outline chart type. This chart in outline view most clearly suggests that Material 3 has superior reliability and is dominant since a greater proportion of its distribution is to the right of 1.00 and its values for all probability levels are higher than the others.





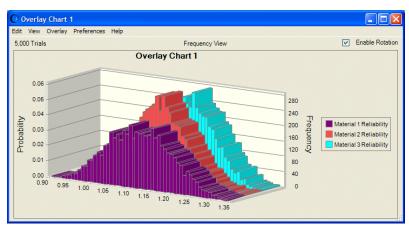
For best display of many types of data, you can select 3D view and then rotate the chart as shown in Figure 33 on page 119. To display this chart with shortcut keys, press Ctrl+d until the frequency distribution is displayed. Press Ctrl+t to display the column chart. Try pressing Ctrl +b to change the number of frequency bins (columns, in this view). Then, press Ctrl+w to make the chart three-dimensional (Figure 32 on page 118).





If you want, you can drag either side of the chart to give it a taller, narrower look (Figure 32 on page 118) or a stretched look (Figure 33 on page 119).

In 3D view, the Enable Rotation checkbox is displayed at the top of the chart, accessible with the Tab key. When it is selected, you can click inside the chart and drag to rotate it. This can enhance the data display for both analysis and presentation. Figure 33 on page 119 shows a rotated overlay chart, stretched to emphasize x-axis differences.





Note: Rotation settings are for the current session only and are not saved with the chart.

Using Distribution Fitting with Overlay Charts

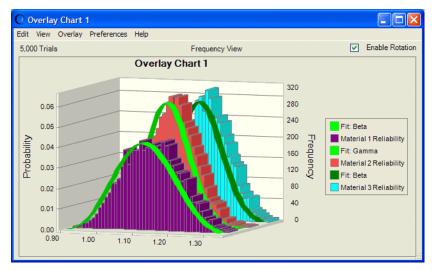
You can fit distributions to forecasts in overlay charts two ways:

- Select **Overlay**, and then **Fit Probability Distributions** in the overlay chart menu bar to do a quick fit with the default or currently selected distributions and ranking method. You can also use this command to switch off distribution fitting that is set with either the **Overlay** menu or **Preferences** menu.
- Select **Preferences**, then **Overlay**, and then **Overlay Window** in the overlay chart menu bar to specify particular distributions and to select one of three fit ranking methods. Then, you can also change the fit options or use **Apply To** to set these preferences for other overlay charts.
- To fit a probability distribution to all forecasts in an overlay chart using the Preferences menu:
- **1** Follow the steps for forecast charts given in "Fitting a Distribution to a Forecast" on page 99. Wherever the instructions say **Forecast**, as in **Preferences**, and then **Forecast**, substitute **Overlay**.
- 2 Click OK.

Crystal Ball fits the distributions, and then displays a probability distribution for each forecast as shown in Figure 34. As the legend shows, the forecast in the middle fits best to a gamma distribution, while the other two are beta fits. The **Chart Type** tab of the **Chart**

Preferences dialog was used to change the colors of the lines of best fit for greater contrast in the figure.





Note: This overlay chart is shown in 3D, rotated view with legend to the right.

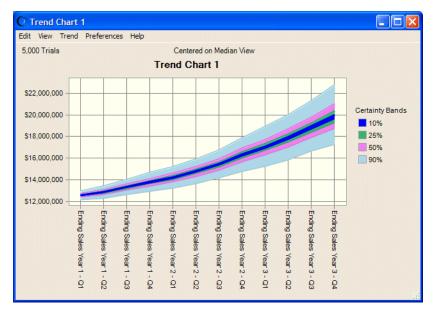
Using Trend Charts

Subtopics

- Creating Trend Charts
- Customizing Trend Charts

Trend charts summarize and display certainty levels from multiple related forecasts, making it easy to discover and analyze forecast trends. The trend chart in Figure 35 displays certainty ranges on a quarterly basis over a three year period.

Figure 35 Upward Trending Sales Figures, By Quarter



Trend charts display certainty ranges for multiple forecasts in a series of colored bands. Each band represents the certainty ranges into which the actual values of the forecasts fall. For example, the band that represents the 90% certainty range shows the range of values into which a forecast has a 90% chance of falling. By default, the bands are centered around the median of each forecast. The bands grow wider as forecast standard deviations increase. In this way, they show how uncertainty increases as predictions move into the future.

Creating Trend Charts

- > To create a trend chart:
- 1 Run a simulation in Crystal Ball (or restore results).

The simulated model should have more than one related forecast.

2 Select Analyze, and then Trend Charts.

In Microsoft Excel 2007 or later, select Analyze, then View Charts, and then Trend Charts.

- 3 In the Trend Charts dialog, click New.
- 4 Select two or more forecasts to include in the trend chart.
- 5 Click OK.

The trend chart opens as shown in Figure 35.

As with overlay charts, you can change the scale and proportions of the chart by dragging its edges. See "Customizing Trend Charts" on page 122.

Customizing Trend Charts

Subtopics

- Changing Trend Chart Views
- Setting Trend Chart Display Preferences
- Adding, Removing, and Ordering Forecasts
- Changing the General Appearance of Trend Charts
- Setting Certainty Band Type and Colors
- Selecting Certainty Bands
- Changing Value Axis Preferences

You can customize trend charts in several ways.

For some of the settings, you can use shortcut keys to bypass the Trend Preferences dialog (Table 6 on page 102)

Changing Trend Chart Views

Use the trend chart View menu to change the placement of the certainty bands within the trend chart. The default setting centers the bands around the median of each forecast. You can change the location of the bands so that they are anchored at either the high end or the low end of the projected forecast ranges.

Smaller bands are always displayed on top of larger bands. This obscures the larger bands. Do not confuse the actual width of a band with the portion that is visible. To change band size and display bands one at a time, see "Selecting Certainty Bands" on page 125..

- > To change the placement of the certainty bands:
- 1 In the trend chart, open the View menu or choose Preferences, and then Trend.
- 2 Select a view (Table 8).
 - **Note:** To use a Crystal Ball shortcut key instead of the **View** menu, press Ctrl+d to cycle through views.

View	Effect	
Centered On Median		The default; displays forecasts centered around the median of each forecast value.

Table 8 Trend Chart Views

View	Effect	
Cumulative		Displays the forecasts anchored at the lower end of the forecast range; shows the certainty that the forecast values will be at or below a given value (cumulative probability).
Reverse Cumulative		Displays the forecasts anchored at the higher end of the forecast range; shows the certainty that the forecast values will be at or above a given value (reverse cumulative probability).

Setting Trend Chart Display Preferences

- > To set trend chart display preferences:
- **1** Select **Preferences**, and then **Trend**.

The Trend Preferences dialog opens.

- 2 To change the trend chart view, use the View list ("Changing Trend Chart Views" on page 122).
- 3 Use settings in the **Windows** group to determine whether the chart opens automatically.

If **Show Automatically** is selected, you can select whether to display the chart while the simulation is running or after it stops.

- 4 Optional: Click Defaults at any time to restore original default settings for the Trend Preferences dialog.
- 5 When all settings are complete, click **OK**.

Adding, Removing, and Ordering Forecasts

- > To add and remove forecasts from a trend chart:
- 1 In the trend chart menu bar, select **Trend**, and then **Choose Forecasts**.
- In the Choose Forecasts dialog, select and clear forecasts to add and remove them from the chart.To clear all forecast selections, select Trend, and then Remove All in step 1.
- **3** Click **OK** to accept the settings.
- > To change the order of forecasts:
- 1 In the trend chart menu bar, select **Preferences**, then **Chart**, and then **Chart Type**.

All charted forecasts are displayed in the **Series** list in their display order.

- 2 Select a forecast and use the up and down arrow keys to move it up or down the list.
- **3 Optional:** Select **Defaults** at any time to restore all settings to their original default values.
- 4 **Optional:** To apply the settings to more than one chart, click **Apply To** ("Applying Settings to Multiple Charts" on page 110).
- 5 When forecasts are in order, click **OK**.

Changing the General Appearance of Trend Charts

When you first select **Preferences**, and then **Chart** in the trend chart menu bar, the **General** tab of the **Chart Preferences** dialog opens.

Except for the disabled **Chart Bins** preferences, the **General** tab settings are the same as those for forecast and other charts:

- Chart title ("Adding and Formatting Chart Titles" on page 104)
- Gridlines ("Showing Grid Lines" on page 105)
- Legend ("Showing the Chart Legend" on page 105)
- Chart effects ("Setting Special Chart Effects" on page 106)

Setting Certainty Band Type and Colors

- > To change the trend chart type or color settings:
- **1** Select **Preferences**, then **Chart**, and then **Chart Type**.
- 2 Optional: To change all certainty bands from areas to lines, select Line in the Chart Type list.
- **3 Optional:** To change the color of a certainty band:
 - a. Select the certainty band to change.
 - b. Select a color from the **Band Color** list.
- 4 **Optional:** To select a different set of certainty levels or define one, click the **Certainty Bands** button and follow the steps in "Selecting Certainty Bands" on page 125
- 5 **Optional:** You can select **Defaults** at any time to restore all settings to their original default values.
- 6 **Optional:** To apply the settings to more than one chart, click **Apply To** ("Applying Settings to Multiple Charts" on page 110).
- 7 When settings are complete, click **OK**.
 - **Note:** You can use the **Chart Series** list on the **Chart Type** tab to change the order of forecasts in the forecast axis ("Adding, Removing, and Ordering Forecasts" on page 123).

Selecting Certainty Bands

- > To change or define a set of certainty bands:
- 1 In the trend chart menu bar, select **Preferences**, then **Chart**, and then **Chart Type**.
- 2 On the Chart Type tab, click the Certainty Bands button.
- 3 The Percentiles dialog opens.
- 4 Select a set of certainty bands to display on the trend chart.
- 5 To create a set, select **Custom** and enter a series of certainty bands, separated by commas.
- 6 Click OK.
 - **Note:** If the chart legend does not include all bands, drag the top or the bottom of the trend chart to increase its height until all bands are displayed.

Changing Value Axis Preferences

Use the trend chart axis preferences to name the value axis, set number formats, and set value rounding. Changing Scale settings from Auto to Fixed and specifying a range minimum and maximum enables you to show the probability that given forecasts will fall in a particular part of a value range.

- > To change value axis settings:
- 1 In the trend chart menu bar, select **Preferences**, then **Chart**, and then **Axis**.

The Axis tab of the Chart Preferences dialog opens.

- 2 Optional: By default, no name displays for the value axis. To add one, type it in the Axis Label text box.
- **3 Optional:** By default, **Scale** is set to **Auto** and displays all selected bands completely. To limit the display to a subset of values, set **Scale** to **Fixed** and enter a minimum and maximum value.

By changing the minimum or maximum endpoint values, you can zoom in or out on selected ranges of the trend chart.

4 The Format settings are similar to those for forecast charts ("Customizing Chart Axes and Axis Labels" on page 109).

The number format for the axis values is taken from the first forecast that is displayed on the trend chart.

- 5 **Optional:** You can select **Defaults** at any time to restore all settings to their original default values.
- 6 **Optional:** To apply the settings to more than one chart, click **Apply To**. Then, specify how they should be applied (see "Applying Settings to Multiple Charts" on page 110 for details) and click **OK**.
- 7 When settings are complete, click **OK**.
- **Note:** You can copy trend charts and paste them into other applications. For more information, see "Copying and Pasting Charts to other Applications" on page 112.

Using Sensitivity Charts

Subtopics

- Benefits and Limitations of Sensitivity Charts
- Creating Sensitivity Charts
- Sensitivity Chart Views
- Customizing Sensitivity Charts

Sensitivity charts show the influence of each assumption cell on a particular forecast cell. The overall sensitivity of a forecast to an assumption is a combination of two factors:

- The model sensitivity of the forecast to the assumption
- The assumption's uncertainty

During a simulation, Crystal Ball ranks the assumptions according to their importance to each forecast cell. Sensitivity charts display these rankings as a bar chart, indicating which assumptions are the most important or least important in the model (Figure 36). You can add sensitivity charts to reports or copy them to the clipboard.

Figure 36 Assumptions and Their Effects on Toxicity Risk

O Sensitivity: Risk Assessm	ent			
Edit View Sensitivity Preferen	ces Help			
5,000 Trials Contribution to Variance View				
Sensitivity: Risk Assessment				
	0.0%	21.0%	42.0%	63.0%
Volume of Water per Day			65.6%	
CPF		27.4%		
Body Weight	-5.7%		•	
Concentration of Contaminan	1. <mark>3</mark> %			
				I

Note: For more information about what sensitivity charts display, see "Sensitivity Chart Views" on page 128.

Benefits and Limitations of Sensitivity Charts

Sensitivity charts provide these key benefits:

- You can find out which assumptions are influencing forecasts the most, reducing the amount of time needed to refine estimates.
- You can find out which assumptions are influencing the forecasts the least, so that they can be ignored or discarded altogether.

• With sensitivity information, you can construct more realistic spreadsheet models and greatly increase the accuracy of the results.

Sensitivity charts have several limitations and might be less accurate or misleading for the following:

- Correlated assumptions, which are flagged on the sensitivity chart. Turning off correlations in the Run Preferences dialog may help you to gain more accurate sensitivity information.
- Assumptions that have **non-monotonic relationships** with the target forecast. That is, an increase or decrease in the assumption is not accompanied by a strict increase or decrease in the forecast. Logarithmic curve relationships are monotonic but sine curve relationships are not.

The Tornado Analysis tool can help you discover if any of the assumptions have nonmonotonic relationships with the target forecast ("Measuring Variable Effects with the Tornado Analysis Tool" on page 162).

• Assumptions or forecasts that have a small set of discrete values. When a large percentage of assumption or forecast values are similar or identical, this loss of information grows and can significantly distort the calculation of correlations.

Be aware of this problem, for example, for:

- Assumptions, when using distributions such as Binomial with a small Trials parameter (for example, < 10).
- Forecasts, when formulas in the spreadsheet result in identical values (for example, ifthen logic, INT functions, and so on).

Creating Sensitivity Charts

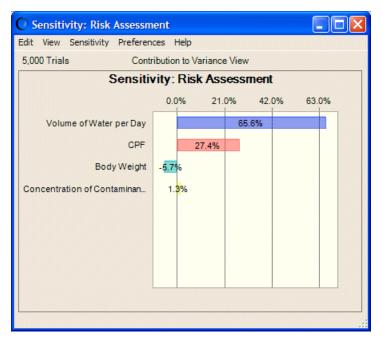
- > To create a sensitivity chart:
- **1** Close any spreadsheets that are currently open.
- 2 Open the spreadsheet to analyze (or restore results).
- 3 Select Run, then Run Preferences, and then Options.
- 4 Confirm that Store assumption values for sensitivity analysis is selected and click OK.
- 5 Run a simulation (not necessary for stored results).
- 6 Select Analyze, and then Sensitivity Charts.

(In Microsoft Excel 2007 or later, select **Analyze**, then **View Charts**, and then **Sensitivity Charts**.)

- 7 In the Sensitivity Charts dialog, click the New button.
- 8 In the **Choose Forecast** dialog, select the forecast to include in the chart.
- 9 Click **OK** to create a new sensitivity chart (Figure 37).

Note: The illustrated chart has a transparency effect applied using the chart preferences to make sensitivity values easier to read ("Setting Special Chart Effects" on page 106).

Figure 37 Sensitivity Chart for the Selected Forecast



The assumptions are listed beside the bar chart, starting with the assumption with the highest sensitivity. If necessary, use the scroll bar to view the entire bar chart. You can drag the edges of the chart to resize it — make it narrower, wider, taller, or shorter. This often changes the tick labels along the top of the chart.

Note: If you try to create a sensitivity chart but **Store assumption values forsensitivity analysis** is not selected in the **Run Preferences** dialog, select it, and then reset the simulation and run it again.

One or two assumptions typically have a dominant effect on the uncertainty of a forecast. In Figure 37, the first assumption accounts for approximately 65% of the variance in forecast values and can be considered the most important assumption in the model. A researcher running this model would want to investigate this assumption further in the hopes of reducing its uncertainty and, therefore, its effect on the target forecast. The last assumption contributes the least to forecast variance (about 2%). This assumption has such a small effect, it could be ignored or altogether eliminated by clearing it from the spreadsheet.

Sensitivity Chart Views

To select a sensitivity chart view, in the sensitivity chart menu bar, select **View**, and then one of the following:

• **Contribution to Variance**, the default—This view helps answer questions such as "What percentage of the variance or uncertainty in the target forecast is caused by assumption X?"

The variance contribution percentages are displayed after the respective assumptions. Contribution to variance is calculated by squaring the rank correlation coefficients and normalizing them to 100%. The result is only an approximation and is *not precisely* a variance decomposition.

Note: To ensure appropriate accuracy in Contribution To Variance view, consider running at least 10,000 trials.

- **Rank Correlation**—Crystal Ball calculates sensitivity by computing rank correlation coefficients between every assumption and every forecast while the simulation is running. Positive coefficients indicate that an increase in the assumption is associated with an increase in the forecast. Negative coefficients imply the opposite situation. The larger the absolute value of the correlation coefficient, the stronger the relationship.
- **Sensitivity Data**—This view shows contribution to variance and rank correlation for each assumption in numeric form.

Both **Rank Correlation** view and **Contribution to Variance** view display the direction of each assumption's relationship to the target forecast. Assumptions with a positive relationship have bars on the right side of the zero line. Assumptions with a negative relationship have bars on the left side of the zero line. To show just the absolute magnitude of the relationship, you can change the Chart Type preference setting described in Table 9 to Bar (Magnitude).

Customizing Sensitivity Charts

Subtopics

- Adding and Removing Assumptions
- Grouping Assumptions
- Changing the Target Forecast
- Setting Sensitivity Preferences
- Setting Sensitivity Chart Preferences

You can customize sensitivity charts by adding and removing assumptions, grouping assumptions, changing the target forecast, and by setting sensitivity preferences and chart preferences.

Adding and Removing Assumptions

By default, the sensitivity chart includes all assumptions from the simulation. The total number of assumptions included in the chart affects the calculation of the Contribution to Variance percentages.

- > To change assumptions to include in the sensitivity chart:
- 1 In the Sensitivity Chart window, select Sensitivity, and then Choose Assumptions.

- 2 In the **Choose Assumptions** dialog, select assumptions to add to the sensitivity chart and clear those to remove.
- 3 Click OK.

Grouping Assumptions

Subtopics

- Creating and Modifying Assumption Groups
- Rules for Grouped Assumptions

You can group assumptions in a sensitivity chart to combine similar assumptions, such as grouping Monthly assumptions into a single Year assumption group.

To group assumptions and modify groups, see "Creating and Modifying Assumption Groups" on page 130.

Display criteria and other sensitivity chart features apply to assumption groups as well as individual assumptions. For a summary of rules that apply to assumption groups, see "Rules for Grouped Assumptions" on page 131.

Creating and Modifying Assumption Groups

- ► To group assumptions:
- 1 In the Sensitivity Chart window, select Sensitivity, and then Group Assumptions.
- 2 In the Group Assumptions dialog, click New group.
- 3 Enter the name of the group, and then click **OK**.
- 4 In the **Ungrouped assumption** list, select assumptions to add to the group, and then click the Move Right button (>>).
- 5 When all members of the group are displayed in the Current group column, click OK.

The new group is displayed in the sensitivity chart with a symbol in front of it.

- **Note:** For information about how contribution to variance is calculated for grouped assumptions and the rules that apply to grouped assumptions, see "Rules for Grouped Assumptions" on page 131.
- > To modify members of a group:
- 1 In the Sensitivity Chart window, select Sensitivity, and then Group Assumptions.
- 2 In the Group Assumptions dialog, select the group to modify in the Current group list.
- 3 Use the directional buttons between the lists to move assumptions into or out of the group.
- 4 When all members of the group are displayed in the **Current group** column, click **OK**.

- ► To rename a group:
- 1 In the **Sensitivity Chart** window, select **Sensitivity**, and then **Group Assumptions**.
- 2 In the Group Assumptions dialog, select the group to rename in the Current group list.
- 3 Click Rename group.
- 4 Enter the name of the group, and then click **OK**.
- > To remove a group and ungroup its members::
- 1 In the Sensitivity Chart window, select Sensitivity, and then Group Assumptions.
- 2 In the Group Assumptions dialog, select the group to remove in the Current group list.
- 3 Click **Remove group**, and then click **OK**.

Rules for Grouped Assumptions

The following rules apply to grouped assumptions in sensitivity charts:

- Assumptions can only be included in one group at a time.
- Assumption groups are global; once a group is created, it will affect the grouping of assumptions for all other sensitivity charts.
- If two workbooks have the same group name, the assumptions from both workbooks will be combined into one big group.
- If assumption display criteria are set in the **Criteria** tab of the **Sensitivity Preferences** dialog, these criteria apply to assumption groups as if they were single assumptions. If an entire group is excluded using these criteria, it becomes part of the Others group for display purposes.
- If assumptions are excluded from the sensitivity chart using the **Choose Assumptions** command, they are not available in the **Ungrouped assumptions** list to include in a group. If an assumption is included in a group and later excluded with **Choose Assumptions**, its sensitivity value is not used in calculating the value for its group.
- If the sensitivity chart has a chart type of **Bar (directional)**, assumptions in a group can have positive or negative sensitivities; the charted direction of an assumption group will be the sign that results when the overall sensitivity for the group is calculated.
- **Note:** To work with grouped assumptions in sensitivity charts, see "Creating and Modifying Assumption Groups" on page 130.

Changing the Target Forecast

- > To change the forecast to include in a sensitivity analysis:
- 1 In the Sensitivity Chart window, select Sensitivity, and then Choose Target Forecast.
- 2 In the **Choose Forecasts** dialog, select a new target forecast.

3 Click OK.

Setting Sensitivity Preferences

You can set a number of preferences that determine:

- The sensitivity view that is displayed
- Whether the sensitivity chart opens automatically and whether it is displayed while the simulation is running or after it stops
- How many assumptions are shown in the chart, starting with the most sensitive
- Whether sensitivities are limited to a certain sensitivity value or higher
- > To set sensitivity preferences:
- 1 Select Preferences, and then Sensitivity.

By default, the **Sensitivity Window** tab opens.

- 2 **Optional:** To change how the sensitivities are presented, use the **View** list:
 - **Contribution To Variance** shows sensitivities as values that range from 0% to 100% and indicate relative importance by showing the percentage of the forecast variance contributed by each assumption.
 - **Rank Correlation** shows sensitivities as rank correlations that range from -1 to +1 and indicate both magnitude and direction of the correlation of each assumption with the forecast.
 - **Sensitivity Data** shows a table of contributions to variance (%) and rank correlations for each assumption.

Also see "Sensitivity Chart Views" on page 128.

3 Optional: Use settings in the **Windows** group to determine whether the chart opens automatically.

If **Show Automatically** is selected, you can select whether to display the chart while the simulation is running or after it stops.

4 **Optional:** To limit sensitivities by rank or value, click the **Criteria** tab.

If you have a model with many assumptions, you can select either or both boxes to limit the number of assumptions shown in the chart to a fixed number or to assumptions above a certain sensitivity value. If you select both, the more restrictive of the two criteria is used.

- **5 Optional:** Click **Defaults** at any time to restore original default settings for the **Sensitivity Preferences** dialog.
- 6 When all settings are complete, click **OK**.

You can copy sensitivity charts and paste them into other applications. For more information, see "Copying and Pasting Charts to other Applications" on page 112.

Setting Sensitivity Chart Preferences

- > To control the appearance of a sensitivity chart:
- 1 In the sensitivity chart window, select **Preferences**, and then **Chart**.
- 2 Use the General tab of the Chart Preferences dialog to set the following features:
 - Chart title ("Adding and Formatting Chart Titles" on page 104)
 - Gridlines ("Showing Grid Lines" on page 105)
 - Legend ("Showing the Chart Legend" on page 105)
 - Chart effects ("Setting Special Chart Effects" on page 106)

Except for the disabled **Chart Bins** preferences, the **General** tab settings are the same as those for forecast charts.

3 Optional: On the **Chart Type** tab, select one of these chart types:

 Table 9
 Sensitivity Chart Types

Chart Type	Description	Example
Bar (directional)	The default; horizontal bars to the right and left of the 0 line showing magnitude and direction of sensitivity	65.2% 25.5% -7.2% 2.0%
Bar (magnitude)	Horizontal bars to the right of the 0 line showing magnitude of sensitivity but not direction	65.2% 25.5% 7.2% 2.0%
Pie	A circle divided into proportional wedges showing the magnitude of sensitivity (only available for Contribution To Variance view)	2.0% 7.2% -25.5% 65.2%

4 For bar charts, select whether to use a different color for each assumption (the default), or whether to use the same color for all assumptions.

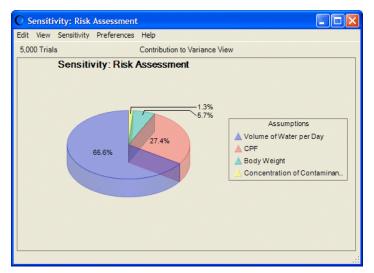
If you clear **Show Multiple Colors**, you can select a specific color to use for all assumptions.

- 5 **Optional:** Select whether to show value labels on the chart (the default), or clear **Show Values On Chart** to show only graphics but no values.
- 6 **Optional:** Select **Defaults** at any time to restore all settings to their original default values.

- 7 **Optional:** To apply the settings to more than one chart, click **Apply To**. Then, specify how they should be applied (see "Applying Settings to Multiple Charts" on page 110 for details) and click **OK**.
- 8 Click **OK** to apply all settings to the active chart.

You can apply different combinations of settings for special effects. For example, Figure 38 shows a sensitivity pie chart with 3D and Transparency chart effects. Assumptions have similar values and ranks to the directional bar chart shown in Figure 37.

Figure 38 Transparent, Three-Dimensional Sensitivity Pie Chart



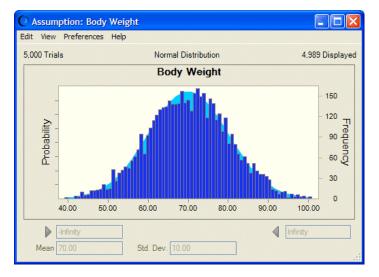
Using Assumption Charts

Subtopics

- Creating and Opening Assumption Charts
- Customizing Assumption Charts

Assumption charts show trial values for a simulation plotted over the ideal probability distribution for that assumption. Assumption charts are created automatically when you run a simulation. They cannot be deleted, only opened or closed (Figure 39).

Figure 39 Assumption Chart



Assumption charts are useful for comparing Run Preferences settings. For example, you can look at charts for the same assumption before and after increasing the number of trials and switching between Monte Carlo and Latin Hypercube sampling. More trials and larger samples usually generate smoother curves that are closer to the ideal distribution. You can add assumption charts to reports or copy them to the clipboard for use in other applications.

Creating and Opening Assumption Charts

- > To open an assumption chart:
- **1** Select **Run**, and then **Run Preferences**.
- 2 Click the **Options** tab and confirm that **Store assumption values for sensitivity analysis** is selected.
- 3 Run a simulation.
- 4 Select Analyze, and then Assumption Charts.

(In Microsoft Excel 2007 or later, select **Analyze**, then **View Charts**, and then **Assumption Charts**.)

5 In the Assumption Charts dialog, select the assumptions to view and click **OK**.

For customization instructions, see "Customizing Assumption Charts" on page 136.

Customizing Assumption Charts

Subtopics

- Setting Assumption Chart Views
- Setting Assumption Preferences
- Setting Assumption Chart Preferences

Because assumption charts look so similar to forecast charts, many of their menu commands and settings are the same. You can change chart views, set assumption preferences, and set chart preferences.

Setting Assumption Chart Views

You can use the **View** menu to select five views: **Probability, Cumulative Probability, Reverse Cumulative Probability, Statistics,** and **Percentiles**. For a description of these views and how to select them, see "Changing the Distribution View and Interpreting Statistics" on page 90.

Setting Assumption Preferences

Assumption preferences, set with **Preferences**, and then **Assumptions**, are similar to those for forecasts, described in "Setting Forecast Preferences" on page 97. By default, assumption charts are not shown when you run a simulation. You can change the **Show Automatically** setting to automatically show assumption charts while a simulation is running or when it stops.

While the **Forecast Preferences** dialog has a button for fitting distributions to forecasts, distribution fitting is not available in the **Assumption Preferences** dialog. Instead, there is a **Run Preferences** button so you can easily change the **Store assumption values for sensitivity analaysis** setting on the **Options** tab of the **Run Preferences** dialog.

Setting Assumption Chart Preferences

Assumption chart preferences are virtually identical to forecast chart preferences. To review or change them, select **Preferences**, and then **Chart** and follow the instructions in "Setting Chart Preferences" on page 101.

Note: As with forecast charts, you can set chart preferences with shortcut keys (Table 6, "Shortcut Keys for Chart Preferences," on page 102).

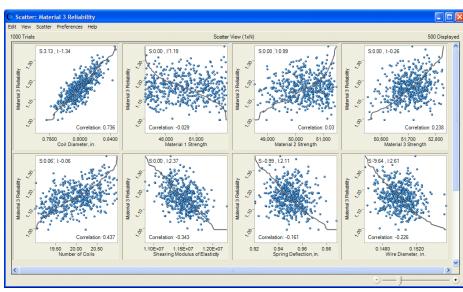
Using Scatter Charts

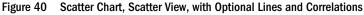
Subtopics

- Creating Scatter Charts
- Customizing Scatter Charts

Scatter charts show correlations, dependencies, and other relationships between pairs of forecasts and assumptions plotted against each other.

In its basic form, a scatter chart contains one or more plots of a target variable mapped against a set of secondary variables. Each plot is displayed as a cloud of points or symbols aligned in a grid within the scatter chart window. Figure 40 shows a set of all model assumptions plotted against a target forecast. In this case, the Material 3 Reliability forecast is the target.



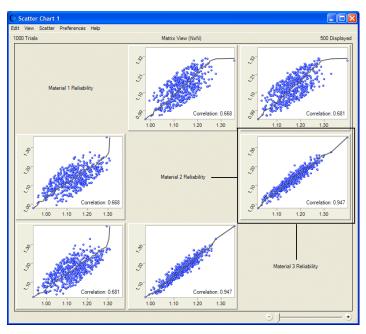


In Figure 40, the line shows where the pairwise points would be displayed if they were sorted in ascending order. The closer the points conform to the line, the closer the relationship among the plotted variables. Lines sloped from lower values to higher (the lower left to the upper right) show positive relationships. If the relationship is negative, the line slopes from higher to lower values (the upper left to the lower right).

Figure 40 shows optional correlations displayed for each plot. Coil Diameter has the highest correlation with Material 3 Reliability, while Material 1 Strength has the lowest correlation.

In another form of scatter chart, the Matrix view, each selected variable is plotted against every other selected variable to show the relationships among them. Figure 41 shows intercorrelations among three forecasts in Matrix view. Material 2 Reliability and Material 3 Reliability have the highest intercorrelation while Material 1 Reliability and Material 2 Reliability have the lowest.

Figure 41 Scatter Chart, Matrix View, with Optional Lines and Correlations



The axis labels are indicated by the text in the diagonal cells. The text is the x-axis label for all plots in the same column as the text. It is the y-axis label for all plots in the same row. For example, in Figure 41, the y-axis label of the highlighted plot is Material 2 Reliability and the x-axis label is Material 3 Reliability.

You can plot scatter charts directly through the **Analyze** menu, or you can create a sensitivity chart and select Sensitivity, and then Open Scatter Chart to create a chart showing an exploded view of the effect each assumption has on the target forecast. The result is similar in form to Figure 40.

Creating Scatter Charts

- To create a scatter chart:
- 1 Select Run, and then Run Preferences.
- 2 Click the Options tab and confirm that Store assumption values for sensitivity analysis is selected.
- 3 Run a simulation in Crystal Ball.
- When the simulation stops, select Analyze, and then Scatter Charts. 4

(In Microsoft Excel 2007 or later, select Analyze, then View Charts, and then Scatter Charts.)

- 5 In the Scatter Charts dialog, click New.
- 6 In the Choose Data dialog, select two or more assumptions or forecasts to include in the scatter chart.

You can include up to 25 variables in a scatter chart. A warning message is displayed if you select more. If you try to create a scatter chart including an assumption but Store Assumption **Values For Sensitivity Analysis** is not selected in the **Run Preferences** dialog, select it, and then reset the simulation and run the simulation again.

7 **Optional:** To create a scatter chart in **Scatter** view, set a single assumption or forecast as the target. You do not need to set a target to display the chart in **Matrix** view.

To set a target, select the box in front of the target assumption or forecast, click its name, and then click **Set As Target**.

8 Click **OK** to create the new scatter chart (Figure 42). In that figure, Material 3 Reliability is set as the target and all assumptions are selected as secondary variables.

Only a portion of the chart is shown in Figure 42. For a view of the complete chart, see Figure 40.

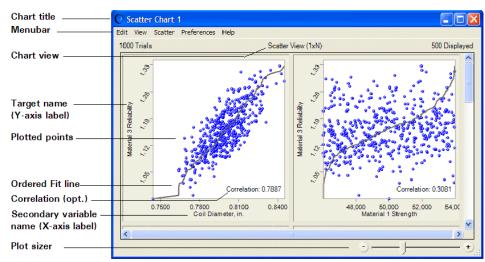


Figure 42 Scatter Chart for the Selected Target, Scatter View

Note: In complex models with many assumptions and forecasts, you may find it helpful to begin by creating a sensitivity chart and then creating a scatter chart from the data included in it. For example, you could open a forecast chart and select **Forecast**, and then **Open Sensitivity Chart** to view a sensitivity chart. Then, in the sensitivity chart, you could choose **Sensitivity**, and then **Open Scatter Chart** to creat a scatter chart using that forecast as the target.

Information about features shown in Figure 42:

- Select **Preferences**, and then **Chart Preferences** to change the chart title.
- To change the number of trials displayed in the plots, select **Preferences**, then **Scatter**, and then **Criteria**.
- The Y-axis labels indicate the scatter chart target. Each X-axis label indicates the secondary variable plotted against the target.
- The Ordered Fit line shows where the pairwise points would be displayed if they were sorted in ascending order. **Optional:** Select **Preferences**, then **Chart Preferences**, and then **Chart**

Type to change it to a Linear Regression line, which uses a least-squares technique to show the linear relationship of the points.

- **Auto** is the default color for all symbols. With color set to **Auto**, plots are colored according to the combination of variables included in them:
 - Assumption vs. assumption = green
 - Forecast vs. forecast = dark blue
 - Assumption vs. forecast = dark teal (blue-green)
- You can use the Plot Sizer to increase or decrease the size of all plots and the amount of detail shown within them. To focus on a single plot, drag the Plot Sizer pointer toward the right to enlarge the plot, and then use the scroll bars to center it.
- In **Scatter** view, plots move to fill available window space when they are resized. In **Matrix** view, plots keep the same NxN configuration. You can scroll to view any plots that are not currently displayed onscreen.
- Frozen forecasts and assumptions are not included in scatter charts.

Customizing Scatter Charts

Subtopics

- Adding and Removing Assumptions and Forecasts
- Setting Scatter Preferences
- Setting Scatter Chart Preferences
- Scatter Charts and Filtered Data

To customize scatter charts, use the menus in the chart window or click portions of the chart:

- Double-click within a plot to open the Chart Preferences dialog.
- Double-click an axis to open the **Axis** dialog.
- Double-click outside a plot or axis to open the Scatter Preferences dialog.

Adding and Removing Assumptions and Forecasts

When you create a new scatter chart, some variables may be closely related to the target or other elements in the matrix and some variables may be completely unrelated.

- Follow these steps to remove or change the variables (forecasts and assumptions) included in a scatter chart:
- 1 In the Scatter Chart window, select Scatter, and then Choose Data.
- 2 In the **Choose Data** dialog, select the assumptions or forecasts to add to the scatter chart and clear those to remove from the chart.
- 3 Optional: To set a different target, click the variable name and then click Set As Target.
- 4 Click **OK** to display the edited chart.

Note: Depending on the edits, the view may change.

Setting Scatter Preferences

You can set a number of preferences that determine how and when the chart is displayed, plot sizes, and the percentage of trials that are plotted.

- > To set scatter preferences:
- **1** Select **Preferences**, and then **Scatter**.

opens.

- 2 Optional: In the Scatter Preferences dialog, you can use the View list to change chart presentation:
 - Scatter View (1xN) shows secondary variables plotted against a target.
 - Matrix View (NxN) shows all selected variables plotted against each other.
- **3 Optional:** Use settings in the **Window** group to determine whether the chart opens automatically and, if so, when it should open.

If **Show Automatically** is selected, you can select whether to display the chart while the simulation is running or after it stops.

- 4 **Optional:** To change the size and amount of detail shown in each plot, slide the **Plot Sizer** left for smaller plots or right for larger plots.
- 5 **Optional:** To determine the number of trials that are plotted relative to the total number of trials in each simulation, click the **Criteria** tab to display it.

Enter a specific number or percentage of trials to display; 100% displays all trials.

- 6 **Optional:** Click **Defaults** at any time to restore original default settings for the **Scatter Preferences** dialog or click **Apply To** to set new defaults, such as plot size.
- 7 When all settings are complete, click **OK**.

You can copy scatter charts and paste them into other applications. For more information, see "Copying and Pasting Charts to other Applications" on page 112.

Setting Scatter Chart Preferences

- > To set scatter chart preferences, which determine chart appearance:
- **1** In the scatter chart window, select **Preferences**, and then **Chart**.

The Chart Preferences dialog opens.

- 2 On the General tab, you can set the following features, described in the sections in parentheses:
 - Chart title ("Adding and Formatting Chart Titles" on page 104)
 - Gridlines ("Showing Grid Lines" on page 105)
 - Legend ("Showing the Chart Legend" on page 105)

• Chart effects ("Setting Special Chart Effects" on page 106)

Except for the disabled **Chart Bins** and **3D Chart** preferences, the **General** tab settings are the same as those for forecast charts.

- **3 Optional:** Click the **Chart Type** tab for more settings:
 - Select whether to draw points, and if selected, to select a symbol, color, and size for them.
 - Select whether to draw a line, and if selected, to select a line type, color and size. The **Ordered Fit** line type shows where pairwise points would be displayed if they were sorted in ascending order. The **Linear Regression** line type uses a least-squares technique to show the linear relationship of the points.
 - Select whether to display correlation coefficients for each plot. These are computed using the Spearman rank correlation method.
 - Select whether to display points that have been filtered out ("Scatter Charts and Filtered Data" on page 142).
- 4 **Optional:** Use the **Axis** tab to select a number format for the chart axes and to indicate whether to round axis values ("Customizing Chart Axes and Axis Labels" on page 109).
- 5 **Optional:** Select **Defaults** at any time to restore all settings to their original default values.
- 6 **Optional**: To apply the settings to more than one chart, click **Apply To** ("Applying Settings to Multiple Charts" on page 110) and click **OK**.
- 7 When settings are complete, click **OK**.

Scatter Charts and Filtered Data

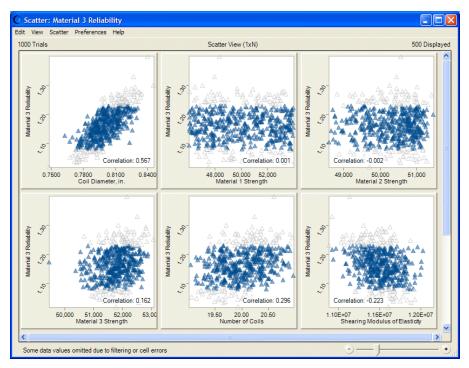
You can use the Filter tab of the Forecast Preferences dialog to include or exclude specific ranges of data from forecast charts ("Filter Tab" on page 63). If you include a filtered forecast in a scatter chart, you can select whether or not to show filtered points in the chart.

- ➤ To change this setting:
- 1 Open the scatter chart and select Preferences, and then Chart.
- 2 Click the Chart Type tab.
- 3 Select or clear Show Points That Have Been Filtered Out to show or hide the filtered points, respectively.
- 4 Click **OK**.

By default, filtered points are displayed in scatter charts as very light (grayed) points or symbols.

Figure 43 shows the same data as Figure 40 except Material 3 Reliability has been filtered to only include data between 1.08 and 1.23. Excluded data shows as very light triangles while included data is plotted normally, in this case as transparent blue triangles, size 4.

Figure 43 Scatter Chart Showing Filtered Points





Creating Reports and Extracting Data

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Creating Reports

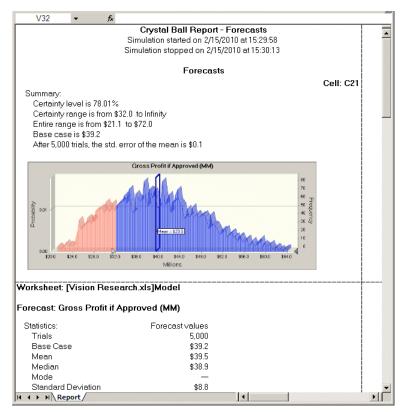
Subtopics

- Basic Steps for Creating Reports
- Setting Report Options
- Defining Custom Reports
- Report Processing Notes

You can generate pre-defined reports for a simulation or you can create a custom report with any or all of the following items, plus data from Predictor or OptQuest (if available): report summary, assumptions, forecasts, decision variables, and charts.

Figure 44 shows part of a forecast report for the Vision Research example model.

Figure 44 Sample Forecast Report



Basic Steps for Creating Reports

> To create a report:

1 Select Analyze, and then Create Report.



(In Microsoft Excel 2007 or later, click the upper half of the **Create Report** icon. If you click the lower half, you can print a pre-defined report with current options. To change options settings, select **Report Preferences** before you select a report.)

- 2 In the **Create Report Preferences** dialog, click an icon to select a report:
 - Assumptions Report summary plus assumption parameters, charts, and correlations
 - Decision Variables Decision variable bounds, variable types, and step size (if discrete)
 - **Forecasts** Report summary plus forecast summaries, charts, statistics, percentiles, and capability metrics if generated
 - Full, the default All sections and details except assumption statistics and percentiles
 - Index Only forecast, assumption, and decision variable summaries
 - **Custom** Displays the Custom Report dialog for report definition
 - OptQuest If you have OptQuest and have active optimization data, displays OptQuest results

- **Predictor** If you have run Predictor and have active time series forecast data, displays Predictor results
- **3 Optional:** Click the **Custom** button and complete the **Custom Report** dialog ("Defining Custom Reports" on page 148).
- 4 Click the **Options** tab to set a location and format for the report ("Setting Report Options" on page 147).

(**Optional:** In Microsoft Excel 2007 or later, if you clicked the lower half of the **Create Report** icon, select **Report Preferences** to set a location and format for the report before you select a report.)

5 When all settings are complete, click **OK**.

Crystal Ball creates the report as a Microsoft Excel worksheet. You can modify, print, or save the report in the same way as any other worksheet. For example, you can select **File**, and then **Print** for the spreadsheet model as you would for a normal spreadsheet.

Note: If ### is displayed in the report instead of a numeric value, try making the column wider to show the entire number.

Setting Report Options

Report options specify the report location and format.

- > To set report options:
- 1 In the Create Report dialog, click the Options tab.

(**Optional:** In Microsoft Excel 2007 or later, if you clicked the lower half of the **Create Report** icon, select **Report Preferences** to set a location and format for the report before you select a report.)

2 In the **Location** group, select whether to create the report in a new Microsoft Excel workbook or the current workbook.

If you select **Current Workbook**, a new sheet is created after the current sheet. You can enter a descriptive name for the new sheet in the **Sheet Name** text box.

3 In the **Formatting** group, indicate whether to include the cell location (workbook, worksheet, and cell address) in report headers and whether to include cell comments.

By default, these settings are selected.

If you choose to include cell comments, only non-Crystal Ball comments are included; Crystal Ball cell comments are redundant and are filtered out.

4 In the **Chart Format** group, select **Image** to create a Crystal Ball chart or select **Microsoft Excel** to create a Microsoft Excel chart.

If you select **Image**, you can format charts using the Crystal Ball Chart Preference settings. Image is the default chart format.

5 When all settings are complete, click **OK**.

Defining Custom Reports

- > To define a custom report:
- 1 Select Analyze, and then Create Report.



(In Microsoft Excel 2007 or later, click the upper half of the **Create Report** icon. If you click the lower half, you can print a pre-defined report with current options. To change options settings, select **Report Preferences** before you select a report.)

- 2 Click the **Custom** button.
- 3 In the **Custom Report** dialog, select one or more items in the **Report Sections** group to include in the report:
 - **Report Summary** The report title, date and time, Run Preferences settings, and run statistics
 - **Forecasts** Forecast information, including the name, charts, percentiles, statistics, and more
 - **Assumptions** Assumption information, including parameters, charts, percentiles, statistics, and correlations
 - **Decision Variables** Decision variable information, including type (continuous or discrete) with step if discrete, plus lower and upper bounds
 - **Charts** (Overlay, Trend, Sensitivity, Scatter) Includes the selected type of chart(s) in the report. You can scale the size of the charts by entering a percentage in the text box.

- **Predictor Series** Available if Predictor data is present; available selections include chart size, forecast information, confidence intervals, statistics, autocorrelation data, and methods
- **OptQuest Results** Available if active OptQuest optimization data is present; displays OptQuest results including summary data, chart size, the best solution, plus constraint, decision variable, and target forecast data.

If you have activated the process capability features and have generated capability metrics, you can include them in the custom report ("Including Capability Metrics in Reports" on page 280).

- 4 As each item is highlighted in the **Report Sections** group, select appropriate settings in the **Details** group:
 - **Report Summary:** Report Title, Date/Time, Run Preferences (Run Preferences settings for the report), Run Statistics
 - Forecasts: Summary, Chart And Size, Statistics, Percentiles, Parameters
 - Assumptions: Chart And Size, Statistics, Percentiles, Correlations

Note: Microsoft Excel charts cannot be created for assumptions defined as custom distributions.

- **Note:** Select **Include unspecified correlations** to show calculated correlations as well as those entered directly.
- Decision Variables: Type, Step Size, Bounds
- **Overlay Charts:** Chart And Size
- Trend Charts: Chart And Size
- Sensitivity Charts: Chart And Size
- Scatter Charts: Chart And Size
- **OptQuest Results:** Summary, Chart (size), Best Solution, Constraints, Decision Variables, Target Forecasts
- Predictor Series: Chart (size), Forecast, Confidence Intervals, Statistics, Autocorrelations, Methods

When no details are selected for a custom report section, only a single row is output with the Crystal Ball item name and the cell reference.

- 5 For each item selected in Report Sections, select whether to display all of that type of item, only selected items, or all open items. **Optional:** If you select **Choose**, a dialog opens so you can select the box in front of each item to display.
- 6 When these settings are complete, click **OK**.
- 7 In the **Create Report** dialog, click the **Options** tab to display it ("Setting Report Options" on page 147).
- 8 When all the report options are set, click **OK**.

Report Processing Notes

The following are special notes concerning Crystal Ball reports:

- No section is created if that section has no Crystal Ball items.
- Statistics follow the chart by default.
- The **Choose**, then **All** options always include restored results if they exist.
- If scroll bars are present in a chart, they are displayed in the report.
- If a Crystal Ball data cell contains a Microsoft Excel comment, it is inserted into the report following the cell name.
- If an assumption has been truncated, you may want to add marker lines to show where the distribution has been truncated. To do this, display the **Chart Type** tab in the **Chart Preferences** dialog and set an appropriate **Value** marker.
- **Sensitivity Charts** and **Scatter Charts** in Scatter view include only the portion of those charts available onscreen at the time the report is requested.

Extracting Data

You can extract assumption and forecast information generated during a Crystal Ball simulation. Crystal Ball places the extracted data in the specified worksheet location. You can only extract data after you run a simulation or restore saved results.

- ➤ To extract data:
- 1 Select Analyze, and then Extract Data.
- 2 In the Extract Data dialog, select the type of data to extract:
 - **Statistics** Descriptive statistics summarizing the assumption and forecast values.
 - **Percentiles** The probability of achieving values below a particular threshold in the selected increments. **Optional:** You can reverse the meaning of the percentiles by changing the setting in the **Run Preferences**, then **Options** panel ("Setting Statistics Preferences" on page 75).
 - Note: If you select **Percentiles**, a dialog opens so you can select which percentiles to use. Optional: Select **Custom** and enter a set of custom percentiles if the set you need is not already available in the dialog.
 - **Chart Bins** For each group interval, or bin, the interval range as well as the probability and frequency of occurrences within the interval for the forecast. This setting is independent of the **Chart Preferences** density setting that controls how many bins or data points are displayed in a graphic chart.
 - **Note:** Optional: If you select **Chart Bins**, the **Chart Bins** dialog opens. You can enter the number of bins to use and can select whether to use the chart range as displayed or the entire chart range, including extreme values excluded from display.
 - Sensitivity Data Sensitivity data (such as the rank correlation coefficient) for all pairs of assumptions and forecasts indicating the strength of the relationship. Optional: If you plan to extract sensitivity data, select Store Assumption Values For Sensitivity Analysis on the Options tab of the Run Preferences dialog before you run a simulation ("Setting Options Preferences" on page 75). Note: Data is extracted for all assumptions regardless of assumptions selected for extraction.
 - Trial Values The generated assumption and forecast values for each simulation trial.
 - **Capability Metrics** Process capability metric values, if available. If you have activated the process capability features and have generated capability metrics, you can extract them ("Extracting Capability Metrics" on page 279).

Data types are extracted in the order they are displayed in the **Select Data To Extract** list. You can use the up and down arrows to rearrange the data types.

- 3 In the **Forecasts** group, select forecasts for data extraction:
 - All includes selected data and restored results for all forecasts in the current simulation.

- **Choose** includes selected data for only selected forecasts. Only forecasts for which data was generated or restored are offered for selection.
- None does not extract any forecast data.
- 4 In the **Assumptions** group, select assumptions for data extraction (**All**, **Choose**, or **None**, as described for forecasts in step 3):
- 5 If you have active OptQuest or Predictor data, make appropriate settings to extract the target data. For details, see the *Crystal Ball Decision Optimizer OptQuest User's Guide* or the *Crystal Ball Predictor User's Guide*.
- 6 Click the **Options** tab to specify a location or formatting for the extracted data.
- 7 In the Location area of the Options tab:
 - To extract data to a new workbook, select New Workbook.
 - To extract data to a new worksheet in the active workbook, select **Current Workbook**, and then **New Sheet**.
 - To extract data to the current sheet, select Current Workbook, and then Current Sheet.
- 8 Specify the name of the sheet and the first cell of the range where the extracted data will be stored.
- 9 Review settings in the **Formatting** group to indicate how to format the extracted data:
 - **Include Labels** adds row and column headers to the data table. Otherwise, just the numeric values are extracted.
 - **Include Cell Locations** adds the workbook, worksheet, and cell address with the object name in the column header. Otherwise, only the object name is displayed.

	Book1	Cell Location labels
	Sheet1!A2	
Statistics	A2	
Trials	1000	

- **AutoFormat** applies the following formats to extracted data:
 - Bold font for column headers
 - Border beside row labels
 - Border beneath column headers
 - Border before first assumption
 - Numeric formatting for values
 - o AutoFit width to columns
- **10 Optional:** Click **Defaults** at any time to restore the original settings to both tabs of the **Extract Data** dialog.
- **11** When the **Data** and **Options** tab settings are complete, click **OK**.

Crystal Ball extracts the simulation data to the specified worksheet location. The extracted data is arranged as columns of forecasts and assumptions and rows of data. You can sort, modify, print, or save the data in the same way as any other spreadsheet.

For examples of extracted data, see "Data Extraction Examples" on page 152.

Data Extraction Examples

The previous section, "Extracting Data" on page 150, describes how to insert simulation data into a worksheet for further analysis. The following figures show samples of different types of data extracted with all Formatting settings selected (forecasts only).

	Α	J	К
1	Statistics	Ending Sales Year 3 - Q1	Ending Sales Year 3 - Q2
2	Trials	5000	5000
3	Base Case	\$17,027,748	\$17,879,136
4	Mean	\$17,043,967	\$17,896,466
5	Median	\$17,025,416	\$17,887,088
6	Mode		
7	Standard Deviation	\$1,116,763	\$1,274,922
8	Variance	\$1,247,160,221,992	\$1,625,427,230,498
9	Skewness	0.1885	0.1794
10	Kurtosis	3.20	3.14
11	Coeff. of Variation	0.0655	0.0712
12	Minimum	\$12,711,586	\$13,574,828
13	Maximum	\$21,337,920	\$23,507,537
14	Range Width	\$8,626,334	\$9,932,709
15	Mean Std. Error	\$15,793	\$18,030

Figure 45 A sample of Extracted Data, Statistics Format

Figure 46 A Sample of Extracted Data, Percentiles Format

	A	В	С
17	Percentiles	Ending Sales Year 3 - Q1	Ending Sales Year 3 - Q2
18	0%	\$13,695,983	\$14,060,365
19	10%	\$15,622,926	\$16,312,876
20	20%	\$16,129,311	\$16,837,542
21	30%	\$16,492,819	\$17,288,938
22	40%	\$16,826,501	\$17,603,671
23	50%	\$17,042,665	\$17,930,927
24	60%	\$17,307,813	\$18,215,054
25	70%	\$17,596,651	\$18,592,965
26	80%	\$17,986,610	\$19,018,804
27	90%	\$18,526,765	\$19,659,121
28	100%	\$21,289,239	\$22,981,379

Figure 47 A Sample of Extracted Data, Chart Bins Format

	A	В	С
31		Ending Sales Year 3 - Q1	
32	Chart Bins	Minimum	Maximum
33	1	\$13,951,523	\$14,076,737
34	2	\$14,076,737	\$14,201,952
35	3	\$14,201,952	\$14,327,166
36	4	\$14,327,166	\$14,452,381
37	5	\$14,452,381	\$14,577,595
38	6	\$14,577,595	\$14,702,809
39	7	\$14,702,809	\$14,828,024
40	8	\$14,828,024	\$14,953,238
41	9	\$14,953,238	\$15,078,453
42	10	\$15,078,453	\$15,203,667
43	11	\$15,203,667	\$15,328,881
44	12	\$15,328,881	\$15,454,096

Figure 48 A Sample of Extracted Data, Sensitivity Data Format

	A	В	С
85	Sensitivity Data		
86	Assumptions	Ending Sales Year 3 - Q1	Ending Sales Year 3 - Q2
87	Growth Year 1 - Q1	0.25	0.22
88	Growth Year 1 - Q2	0.31	0.26
89	Growth Year 1 - Q3	0.23	0.23
90	Growth Year 1 - Q4	0.26	0.24
91	Growth Year 2 - Q1	0.31	0.25
92	Growth Year 2 - Q2	0.22	0.21
93	Growth Year 2 - Q3	0.28	0.28
94	Growth Year 2 - Q4	0.45	0.41
95	Growth Year 3 - Q1	0.46	0.45
96	Growth Year 3 - Q2	0.05	0.43
97	Growth Year 3 - Q3	0.00	-0.03
98	Growth Year 3 - Q4	-0.02	-0.01
99	Coil Diameter, in.		
100	Material 1 Strength		

Figure 49 A Sample of Extracted Data, Trial Values Format

	A	В	С
109	Trial values	Ending Sales Year 3 - Q1	Ending Sales Year 3 - Q2
110	1	\$18,849,027	\$19,620,035
111	2	\$16,454,224	\$16,645,784
112	3	\$16,048,233	\$16,565,879
113		\$14,838,034	\$14,473,412
114	5	\$14,556,109	\$14,399,614
115	6	\$16,234,351	\$16,397,570
116	7	\$16,924,035	\$18,552,808
117	8	\$16,344,792	\$16,678,518

9

Crystal Ball Tools

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Introduction

Crystal Ball tools are features that extend the analytical functionality of Crystal Ball. For a list with summary descriptions, see "Crystal Ball Tools" on page 24.

Fitting Distributions to Assumptions with the Batch Fit Tool

Subtopics

- Starting the Batch Fit Tool
- Using the Batch Fit Welcome Panel
- Setting Batch Fit Input Data Options
- Setting Batch Fit Fitting Options
- Setting Batch Fit Output Options
- Setting Up Batch Fit Reports
- Running the Batch Fit Tool
- Analyzing Batch Fit Results

The Batch Fit tool fits probability distributions to multiple data series. You can select any or all of the probability distributions (binomial, normal, triangular, uniform, and so on) to fit to any number of series limited only by the size of the spreadsheet.

Batch Fit is intended to help you create assumptions when you have historical data for several variables. It selects which distribution best fits each series of historical data, and gives you the distribution and its associated parameters for you to use in the model. This tool also gives you a table of goodness-of-fit statistics for the best fitting distribution and provides a matrix of correlations calculated between multiple data series so you can easily see which series are related and to what degree.

To use the Batch Fit tool, the data series must be contiguous (in adjacent rows or columns) in either rows or columns.

You can select any combination of probability distributions to fit to all the data series.

For an example, see the Oracle Crystal Ball Reference and Examples Guide.

Starting the Batch Fit Tool

- > To start the Batch Fit tool:
- 1 In Microsoft Excel with Crystal Ball loaded, open or build the workbook to analyze.
- 2 Select **Run**, then **More Tools**, then **Batch Fit**. (In Microsoft Excel 2007 or later, select **More Tools** in the **Tools** group.)

If this is the first time you have opened the Batch Fit tool, the **Welcome** panel opens.

Using the Batch Fit Welcome Panel

The Welcome panel opens the first time you use the Batch Fit tool. It describes the tool and its use. The controls for this panel are:

• Next — Opens the Input Data panel for specifying the location of the data series.

- **Run** Runs the Batch Fit tool.
- > To continue with the Batch Fit tool, click **Next**.

The Input Data panel opens.

Setting Batch Fit Input Data Options

The **Input Data** panel of the Batch Fit wizard indicates the location of the data to fit to the distributions selected in the next panel. You can also specify other input-related options.

When you open this panel, the Batch Fit data selector selects possible data for fitting. This information is displayed in the **Location Of Data Series** text box and the illustration. You can select different data if necessary. The text boxes and options in this panel are:

- Location Of Data Series Used to enter or interactively select the cells that contain data to fit. If the data has headers or labels at the beginning of the rows or columns of data, include them in the selection and select the appropriate Headers setting(s). The data must be in adjacent rows or columns.
- **Orientation** Indicates whether the data is in rows or columns. Data In Rows indicates that data is in horizontal rows. Data In Columns indicates that data is in vertical columns.
- **Headers** Indicates whether the data has headers and/or labels and whether they are located in the top (first) row or the left (first) column (varies with orientation). Selected items are used in the output. Top Row Has Headers/Labels, when selected, includes text in the top (first) row in the selection. Left Column Has Labels/Headers, when selected, includes text in the left (first) column in the selection.
- **Back** Returns to the Welcome panel.
- **Next** Advances to the Fitting Options panel.
- **Run** Runs the tool, automatically fitting distributions to the data and creating output of the assumptions and statistics.
- > When all Input Data settings are complete, click **Next** to open the **Fitting Options** panel.

Setting Batch Fit Fitting Options

The Fitting Options panel of the Batch Fit wizard indicates which distributions to fit to each set of data. The Fitting Options panel has these settings:

- Distributions To Fit Indicates the distributions to use for fitting:
 - AutoSelect Crystal Ball selects the best type of distribution for fitting
 - All Continuous Fits the data to all those distributions in which every value in the distribution's range is possible (these distributions are displayed as solid shapes on the Distribution Gallery)

- **All Discrete** Fits the data to all discrete (non-continuous) distributions in the Distribution Gallery (except Yes-No)
- **Choose** Displays another dialog from which you can select a subset of the distributions to include in the fitting.
- **Rank By Goodness-of-Fit Statistic** Indicates which ranking method to use for determining the best fit:
 - **AutoSelect** Crystal Ball selects the best available goodness-of-fit statistic to use for ranking.
 - Anderson-Darling Closely resembles the Kolmogorov-Smirnov method, except that it weights the differences between the two distributions at their tails greater than at their mid-ranges; use this method when you need a better fit at the extreme tails of the distribution.
 - **Kolmogorov-Smirnov** Finds the largest vertical distance between the two cumulative distributions.
 - **Chi-Square** Oldest and most common of the goodness-of-fit tests; gauges the general accuracy of the fit by breaking down the distribution into areas of equal probability and comparing the data points within each area to the number of expected data points.
- Lock Parameters When you select this box or click the Edit Parameters button, opens the Lock Parameters dialog, where you can select parameters to lock during fitting and specify their values.
 - **Note:** If you know location, shape, or other parameter values that may help create a more accurate fit with certain distributions, select **Lock Parameters** and enter appropriate values in the **Lock Parameters** dialog. For details, see "Locking Parameters When Fitting Distributions" on page 44.
- Show comparison chart during fitting When selected, opens a comparison chart that enables you to either accept the selected distribution (based on settings in the Fit Distribution dialog) or select another distribution (see "Confirming the Fitted Distribution" on page 43).
- **Back** Returns to the Input Data panel.
- **Next** Opens the Output Options panel.
- **Run** Runs the tool, automatically fitting distributions to the data and creating output of the assumptions and statistics.
- > When all Fitting Options settings are complete, click **Next** to open the **Output Options** panel.

Setting Batch Fit Output Options

The Output Options panel of the Batch Fit wizard sets output options that control the tool. Available settings and buttons are:

- **Fit Results Location (Assumptions)** Specifies locations of results:
 - **New Workbook** Places results in a new workbook.

- Current Workbook Places results in the current workbook. You can select New Sheet, which places results in a new sheet of the current workbook, or Existing Sheet, which places results in an existing sheet of the current workbook.
- **Sheet Name** The name of a new sheet where the results (assumptions) will be placed.
 - Note: If you select **Current Workbook**, and then **Existing Sheet**, **Sheet Name** is not available. Use the cell selector (^{SSI}) to select the sheet and cell where the results output should start.
- **Starting Cell** The first (upper left) cell of the output range.
- **Direction** Indicates the direction that output data is written, with the starting cell in the upper left of the output range.
 - **Fill Downward** lists data series at the top of each column with data for each series extending below the series label. This is the default.
 - **Fill To The Right** lists data series in the first column with data for each series extending to the right of the series label.
- AutoFormat When selected, uses special cell formatting for the data in the output.
- **Correlations** Specifies whether correlations are generated and defined:
 - Show Correlation Matrix Between Data Series When selected, correlates the data series with each other and displays the results in a matrix.
 - Define Correlations Between Assumptions If The Absolute Value Of The Correlation Is Above

 When selected, defines correlations between assumptions if the absolute value of the correlation is above the indicated level. The default is 0.0, which intercorrelates all assumptions.
 - **Keep Correlations Linked To Matrix** When selected, changes correlations between assumptions if a new matrix is generated.
- **Back** Returns to the **Fitting Options** panel.
- **Next** Opens the **Reports** panel.
- **Run** Runs the tool, automatically fitting distributions to the data and creating output of the assumptions and statistics.

Setting Up Batch Fit Reports

The Reports panel of the Batch Fit wizard indicates which reports to create and their sheet names. Available settings and buttons are:

- **Create Goodness-Of-Fit Report** When selected, creates a goodness-of-fit report on a separate worksheet with the specified sheet name.
- Show All Goodness-of-Fit Statistics When selected, shows all goodness-of-fit statistics, not just the selected type.

- **Create Assumptions Report** When selected creates an assumptions report for all assumptions created by Batch Fit on a separate worksheet with the specified sheet name.
- **Full Statistics** When selected, the assumptions report includes values for all statistics and percentiles (deciles) for each assumption.
- **Back** Returns to the **Output Options** panel.
- **Run** Runs the tool, automatically fitting distributions to the data and creating output of the assumptions and statistics.

Running the Batch Fit Tool

> When all **Output Options** settings are complete, click **Run** to run the Batch Fit tool.

Analyzing Batch Fit Results

The Batch Fit tool analysis example uses a Crystal Ball example model, Magazine Sales.xls. This model (Figure 50) shows the estimated gross profit resulting from newsstand sales of four of the company's most popular magazines.

Figure 50 Magazine Sales Workbook

	B	C	D	E	F
Ma	gazine	Checkou	it Sales		
•					
		Magazine A	Magazine B	Magazine C	Magazine D
Sales	Volume	562	362	646	508
Retail	Price	\$4.95	\$7.95	\$3.95	\$5.95
Cost o	f Goods	\$2.20	\$3.80	\$1.95	\$2.40
Gross	Profit	\$1,546	\$1,502	\$1,292	\$1,805
Total	Gross Profit:	\$6,144			

In this model, cells C5 through F5 are formulas that refer to the first row of data on the Sales Data worksheet. However, the model would be more accurate if these formulas were replaced with assumptions based on the entire range of historical data. The tool can be used to generate an assumption for each data column of the Sales Data worksheet. Then, Crystal Ball commands can be used to copy and paste those assumptions from the output data to the first data row of the Magazine Sales model.

Figure 51 on page 161 shows assumptions and correlations generated by the tool using data on the Sales Data tab of Magazine Sales.xls. When the tool runs, it fits each column of data to each selected distribution. For each fit of a distribution to a set of data, the tool calculates the indicated goodness-of-fit test statistic. The distribution with the best fit is placed in the spreadsheet to create an assumption cell that you can copy to the appropriate location in the model.

Figure 51 Results Below the Model

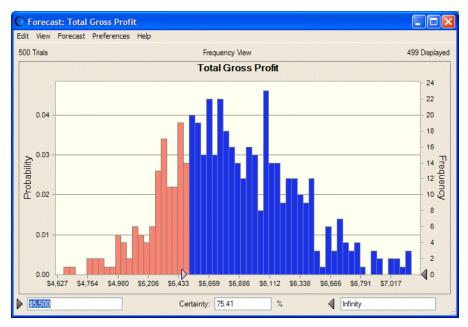
	В	С	D	E	F
Magazin	e Checkout Sal	es			
		Magazine A	Magazine B	Magazine C	Magazine D
Sales Volume		562	362		508
Retail Price		\$4.95	\$7.95	\$3.95	\$5.95
Cost of Goods		\$2.20	\$3.80	\$1.95	\$2.40
Gross Profit		\$1,546	\$1,502	\$1,292	\$1,80
Total Gross Pro	ofit:	\$6,144			
Data Series:		Sales Volume A	Sales Volume B	Sales Volume C	Sales Volume E
Distribution:		499.46			480.7
Best Fit:		Neg Binomial	Binomial	Discrete Uniform	Gamma
Rank Methods:					
	Chi-Square	23.9515	33.3925	33.0667	
	Anderson-Darling				0.089
P-Value:		1.000	0.854	1.000	0.99
Correlations:		Sales Volume A	Sales Volume B	Sales Volume C	Sales Volume [
	Sales Volume A	1.0000	0.0166	-0.0128	-0.012
	Sales Volume B	0.0166	1.0000	-0.0059	0.060
	Sales Volume C	-0.0128	-0.0059	1.0000	-0.039
	Sales Volume D	-0.0124	0.0607	-0.0392	1.000

The tool was set to use all continuous data for curve fitting, to rank fits using the Anderson-Darling method, to define correlations between all assumptions, to show a correlation matrix between all data series, and to place output on the Model tab below existing data.

In this example, the generated assumptions in row 14 are copied into row 5, and then cleared from row 13. The forecast in cell C10 indirectly references all of these Sales Volume assumptions. Then, a Monte Carlo simulation is run, using the same sequence of random numbers with a seed value of 999.

Running the simulation produces a forecast chart of the total gross profit from the Magazine Sales workbook. In the Total Gross Profit forecast chart, if you replace –Infinity with \$5,500, you find that the certainty or probability of making this amount of profit is about 75% (Figure 52).

Figure 52 Magazine Sales Profit from Newsstand Sales



Measuring Variable Effects with the Tornado Analysis Tool

Subtopics

- Tornado Chart
- Spider Chart
- Limitations of the Tornado Analysis Tool
- Starting the Tornado Analysis Tool
- Using the Tornado Analysis Welcome Panel
- Specifying a Tornado Analysis Forecast Target
- Specifying Tornado Analysis Input Variables
- Specifying Tornado Analysis Options
- Running the Tornado Analysis Tool
- Analyzing Tornado Analysis Results

The Tornado Analysis tool measures the impact of each model variable one at a time on a target forecast. The tool displays the results in two ways, described in these sections:

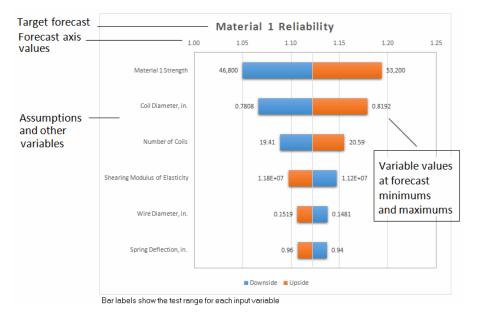
- "Tornado Chart" on page 163
- "Spider Chart" on page 164

This method differs from the correlation-based sensitivity method built into Crystal Ball because this tool tests each assumption, decision variable, or precedent cell independently. While analyzing one variable, the tool freezes the other variables at their base values. This measures the effect of each variable on the forecast cell while removing the effects of the other variables. This method is also known as "one-at-a-time perturbation" or "parametric analysis". The Tornado Analysis tool is useful for:

- Measuring the sensitivity of variables that you have defined in Crystal Ball.
- Quickly pre-screening the variables in the model to determine which ones are good candidates to define as assumptions or decision variables. You can do this by testing the precedent variables of any formula cell.

Tornado Chart

The Tornado Analysis tool tests the range of each variable at percentiles you specify and then calculates the value of the forecast at each point. The tornado chart (Figure 53) illustrates the swing between the maximum and minimum forecast values for each variable. The variable that causes the largest swing is displayed at the top and the variable that causes the smallest swing is displayed at the bottom. The upper variables have the most effect on the forecast, and the lower variables have the least effect on the forecast.



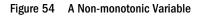


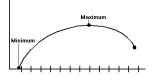
The bars next to each variable represent the forecast value range across the variable tested, as discussed previously. Next to the bars are the values of the variables that produced the greatest swing in the forecast values. The bar colors indicate the direction of the relationship between the variables and the forecast.

For variables that have a positive effect on the forecast, the upside of the variable (shown in blue) is to the right of the base case (the initial value in the cell before running the simulation) and the downside of the variable (shown in red) is to the left side of the base case. For variables that have a reverse relationship with the forecast, the bars are reversed.

When a variable's relationship with the forecast is not strictly increasing or decreasing, it is called non-monotonic. In other words, if the minimum or maximum values of the forecast range do

not occur at the extreme endpoints of the testing range for the variable, the variable has a non-monotonic relationship with the forecast (Figure 54).





If a variable is non-monotonic, an asterisk (*) is displayed before that variable name in the chart and data table.

Spider Chart

The spider chart (Figure 55) illustrates the differences between the minimum and maximum forecast values by graphing a curve through all the variable values tested. Curves with steep slopes, positive or negative, indicate that those variables have a large effect on the forecast, while curves that are almost horizontal have little or no effect on the forecast. The slope of the lines, also called the *elasticity* of the forecast with respect to the input variables, indicates whether a positive change in the variable has a positive or negative effect on the forecast.

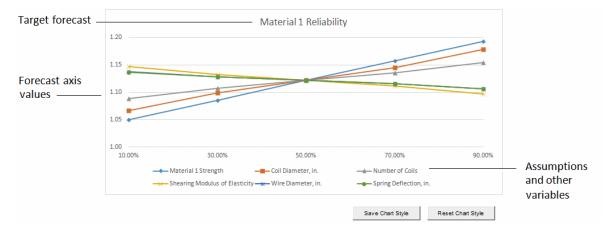


Figure 55 Spider Chart

A maximum of 250 variables can be displayed in these charts.

Limitations of the Tornado Analysis Tool

While tornado and spider charts are useful, they have some limitations:

• Since the tool tests each variable independently of the others, the tool does not consider correlations defined between the variables.

• The results shown in the tornado and spider charts depend significantly on the particular base case used for the variables. To confirm the accuracy of the results, run the tool multiple times with different base cases.

This characteristic makes the one-at-a-time perturbation method less robust than the correlation-based method built into Crystal Ball's sensitivity chart. Hence, the sensitivity chart is preferable, since it computes sensitivity by sampling the variables all together while a simulation is running.

Starting the Tornado Analysis Tool

To start the Tornado Analysis tool, select Run, More Tools, and then select Tornado Analysis. (In Microsoft Excel 2007 or later, select More Tools in the Tools group, and then select Tornado Analysis.)

If this is the first time you have opened the Tornado Analysis tool, the **Welcome** panel opens. Otherwise, the **Target Forecast** panel opens.

Using the Tornado Analysis Welcome Panel

The Welcome panel opens the first time you use the Tornado Analysis tool. It describes the tool and its use. The controls for this panel are:

- **Next** Opens the Target Forecast panel for specifying the analysis target.
- **Run** Runs the Tornado Analysis tool (only available when all required settings are complete).
- > To continue with the Tornado Analysis tool, click **Next**.

The Target Forecast panel opens.

Specifying a Tornado Analysis Forecast Target

The Target Forecast panel in the Tornado Analysis tool indicates whether to select a target forecast or enter a target cell, as follows:

- **Forecast list** Lists all the forecast cells in all open spreadsheets. The first forecast is selected by default. When its button is selected, you can select from the list.
- **Target cell selection box** When its button is selected, you can enter or select a cell containing the target forecast or formula.
- **Back** Opens the **Welcome** panel.
- Next Opens the Input Variables panel.
- **Run** Runs the Tornado Analysis tool.

When settings are complete, click Next to open the Input Variables panel.

Specifying Tornado Analysis Input Variables

The Input Variables panel of the Tornado Analysis tool specifies the assumptions, decision variables, and precedents to include in tornado and spider charts. You can include any value cell in the tornado chart calculations. However, the cells are usually:

- Assumptions Cells defined as assumptions in Crystal Ball.
- Decision variables Cells defined as decision variables in Crystal Ball.
- **Precedents** All cells within open workbooks that are referenced as part of the formula or a sub-formula of the target cell.

The Input Variables panel includes these settings:

- Input variable list Lists all the variables selected for the tornado and spider charts.
- Add Assumptions Adds all assumptions from all open worksheets to the input variable list.
- Add Decision Variables Adds all decision variables from all open worksheets to the input variable list.
- Add Precedents Adds all precedents of the target cell from all open worksheets to the input variable list.
- Add Range Enables you to select a range of cells from the open worksheet to add to the input variable list. If you click this button, an Input panel opens, asking you to enter a cell range or to select a range of cells from the spreadsheet. Click **OK** to accept the selected range.
- **Remove Selected** Removes the selected variable from the input variable list.
- **Remove All** Removes all of the items from the input variable list.
- Back Returns to the Target Forecast panel.
- **Next** Opens the **Options** panel.
- **Run** Runs the Tornado Analysis tool.

When settings are complete, click **Next** to open the **Options** panel.

Specifying Tornado Analysis Options

The Options panel of the Tornado Analysis tool sets options that control the tool. The groups of options in this panel are described in the following sections.

- "Tornado Method Options" on page 167
- "Tornado Input Options" on page 167
- "Tornado Results Location Options" on page 167
- "Tornado Output Options" on page 168

• "Tornado Chart Options" on page 168

Other controls are:

- **Back** Returns to the Input Variables panel.
- **Run** Runs the Tornado Analysis tool.

Tornado Method Options

The **Tornado method** options in this panel are:

- **Percentiles of the variables** Indicates that the tool should test the variables using percentiles of the assumption distributions or percentiles of the decision variable ranges. This is the default.
- **Deviations (by percentage)** Indicates that the tool should test the variables using small changes that are specified percentages away from the base case. This is the only option available if you selected variables other than assumptions or decision variables. The tool treats discrete assumptions and decision variables as continuous for this second method.

Tornado Input Options

The Tornado input options include:

- **Test range** Defines the range in which the tool samples the variables. The choices are either: the percentile range (if the tornado method is **Percentiles of the variables**) or the percent from the base case (if the tornado method is **Deviations (by percentage)**). The default is 10% to 90% for percentiles or -10% to 10% for deviations. You can select **Custom** to define a different range from those listed.
- **Test points** Defines how many values to test in the test range. The test points are evenly distributed across the test range. Testing more points than just end points better detects non-monotonic variable relationships and increases the accuracy of the elasticity calculation. The default is five test points.
- **Customize test ranges by variable** When checked, displays the **Test Ranges** dialog, which enables you to edit the test range minimum or maximum percentile or deviation for each selected input variable. To open this dialog for reiewing or editing values, click **Test Ranges**.
- **Base case for Crystal Ball variables** Indicates whether to define the base case as either the median values or existing cell values for Crystal Ball variables. If the tornado analysis includes simple precedent cells (that is, non-Crystal Ball variables), only **Use existing cell values** is available. The default is **Use median values**.

Tornado Results Location Options

The **Results location** options enable you to select whether analysis results should be output in a **New Workbook** or the **Existing Workbook** (the default).

Tornado Output Options

The Tornado output options are:

- **Tornado chart** When checked, generates a tornado chart showing the sensitivity of the variables using range bars.
- **Spider chart** When checked, generates a spider chart showing the sensitivity of the variables using sloping curves.
- **Show** <u>top variables</u> Indicates the maximum number of variables to include in the tornado charts if many variables exist. The charts can show about 20 variables clearly.
- **Chart Options** Displays the **Chart Options** dialog, which enables you to customize some aspects of how chart labels are displayed ("Tornado Chart Options" on page 168).

Tornado Chart Options

By default, the labels on the tornado chart and spider chart show the absolute values of the input variable's test range (Figure 53 on page 163) In the example figure, the absolute values are 46,800 and 53,200 for the top variable. You can use the **Chart Options** dialog to show the data labels in terms of the forecast's test range, or show a difference amount from the base case (net impact) instead of an absolute amount.

Chart						Option Settings
1.00 Material 1 Strength	1.05	1.10	1.15	1.20 53,200	1.25	Tornado chart variable showing absolute values of the input variable's test range.
1.00 Material 1 Strength	1.05	1.10	1.15	1.20	1.25	Tornado chart variable showing absolute values of the target forecast.
1.00 Material 1 Strength	-3,200	1.10	1.15	1.20	1.25	Tornado chart variable showing difference values of the input variable's tes range.
1.00 Material 1 Strength	-0.07	1.10	1.15	0.07	1.25	Tornado chart variable show difference values of the target forecast.

Table 10 Tornado Chart Option Settings

You can also customize the chart legend labels from **Upside** and **Downside** to labels that suit your data better.

- > To set tornado chart options:
- 1 In the Tornado Analysis wizard, open the **Options** panel.
- 2 Click Chart Options.
- **3** Review and edit chart content as follows:

- Indicate whether to show labels in terms of:
 - The test range of the **Input variables** (the default)
 - The Target forecast or cell

Note: Refer to table above for examples.

- Indicate whether to **show labels as**:
 - **Absolute values** (the default)
 - Differences from base case
- 4 **Optionally:** enter custom legend labels for **Downside** (negative impact on the target) and **Upside** (positive impact).

Running the Tornado Analysis Tool

When all settings are complete, click **Run** to run the Tornado Analysis tool and generate selected charts.

Analyzing Tornado Analysis Results

The following Tornado Analysis example uses a Crystal Ball example model, Reliability.xls. This spreadsheet model predicts the reliability of a spring using three different construction materials.

To generate charts, the Tornado Analysis tool is run against the Material 1 Reliability forecast using the following option settings:

- Tornado method = Percentiles of the variables.
- **Test range** = 10% to 90%.
- Test points = 5.
- Base case for Crystal Ball variables = Use existing cell values.
- Results location = New Workbook
- Tornado output = Tornado chart and Spider chart.
- Show ____ top variables = 20.
- **Chart Options** = defaults ("Tornado Chart Options" on page 168)

For this example, the tool creates the tornado and spider charts in their own workbook with data tables as shown in Figure 56, Figure 57, and Figure 58.

Six assumptions are listed in the tornado chart (Figure 56). The first assumption, Material 1 Strength, has the highest sensitivity ranking and is the most important. A researcher running this model would investigate this assumption further in the hopes of reducing its uncertainty and, therefore, its effect on the target forecast, Material 1 Reliability. The last two assumptions, Wire Diameter and Spring Deflection, are the least influential assumptions. Since their effects on the Material 1 Reliability are very small, you can ignore their uncertainty or eliminate them from the spreadsheet.



Figure 56 Tornado Chart

You can use Microsoft Excel's chart formatting features and the tornado chart options ("Tornado Chart Options" on page 168) to change the appearance of the chart.

Tip: To save the new format as a template, click **Save Chart Style**. Click **Reset Chart Style** to restore original defaults. These settings will only affect future runs of the tool.

Tornado analysis data is displayed below the chart (Figure 57 on page 171). The results table shows the following:

- The input variable names in chart order, starting with the variable with the greatest impact on the target
- The downside difference from the base case
- The upside difference from the base case
- The percent of explained variation in the target, approximately equal to statistical variance (R²), cumulative from the variable with the greatest impact to the least
- The absolute downside value
- The absolute upside value
- The base case value

A list of tool option settings is displayed below the results table.

Figure 57 Tornado Chart Results Data

_							
	Ma	terial 1	Reliabi	lity		Input	
				Explained			
Input Variable	Downside	Upside	Range	Variation ¹	Downside	Upside	Base Case
Material 1 Strength	1.05	1.19	0.14	49.01%	46,800	53,200	50,000
Coil Diameter, in.	1.07	1.18	0.11	79.07%	0.7808	0.8192	0.8000
Number of Coils	1.09	1.15	0.07	89.55%	19.41	20.59	20.00
Shearing Modulus of Elasticity	1.15	1.10	0.05	95.50%	1.12E+07	1.18E+07	1.15E+07
Wire Diameter, in.	1.14	1.11	0.03	97.82%	0.1481	0.1519	0.1500
Spring Deflection, in.	1.14	1.11	0.03	100.00%	0.94	0.96	0.95
¹ Explained Variation is cumulativ	ve						
·							
Run options:							
Tornado method				Percentiles	of the varia	bles	
Testrange				10% to 90%	6		
Test points				5			
Customize test ranges by variat	ole			Off			
Show top variables				20			
Base case for Crystal Ball varia	bles			Existing ce	ll values		
Base save is, orystal Ball talla	2100			chaoling of			

The spider chart shows similar information (Figure 58). Generally, variables that appear at the top of the tornado chart have the steepest slopes in the spider chart. Notice that more forecast values are given in the spider chart than in the tornado chart, one for each of the test points within the test range. An elasticity statistic is displayed in the first column to show the percentage change in output for each percentage change in input. The elasticity statistic is averaged across the entire test range for each variable to present a more robust calculation. The specific formula used is called the "arc elasticity" which results in the same statistic being computed regardless of which test value (upper or lower) is used as the starting point.

Figure 58 Spider Chart with Data



Tornado method	Percentiles of the variables
Test range	10% to 90%
Test points	5
Customize test ranges by variable	Off
Show top variables	20
Base case for Crystal Ball variables	Existing cell values

You can format the chart with Microsoft Excel formatting features and the chart options ("Tornado Chart Options" on page 168). Then, you can use the **Save Chart Style** button to use the current formatting in future spider charts. Use **Restore Chart Style** to use default formatting.

Estimating Data Accuracy with the Bootstrap Tool

Subtopics

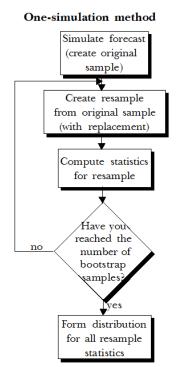
- Starting the Bootstrap Tool
- Using the Bootstrap Welcome Panel
- Specifying Forecasts to Analyze with the Bootstrap Tool
- Specifying a Bootstrap Tool Method
- Setting Bootstrap Options
- Running the Bootstrap Tool
- Analyzing Bootstrap Tool Results

Bootstrapping is a simple technique that estimates the reliability or accuracy of forecast statistics or other sample data. Classical methods rely on mathematical formulas to describe the accuracy of sample statistics. When a statistic's sampling distribution is not normally distributed or easily found, these classical methods are difficult to use or are invalid. Bootstrapping analyzes sample statistics by repeatedly sampling the data and creating distributions of the different statistics from each sampling. The term bootstrap comes from the saying, "to pull oneself up by one's own bootstraps", since this method uses the distribution of statistics itself to analyze the statistics' accuracy.

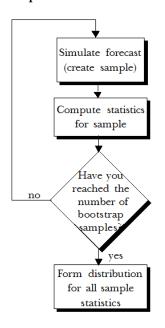
Two bootstrap methods are available with this tool:

- One-simulation method Simulates the model data once (creating the original sample) and then repeatedly resamples those simulation trials (the original sample values). Resampling creates a new sample from the original sample with replacement. That is, it returns the selected value to the sample before selecting another value, letting the selector possibly reselect the same value. It then creates a distribution of the statistics calculated from each resample. This method assumes only that the original simulation data accurately portrays the true forecast distribution, which is likely if the sample is large enough. This method isn't as accurate as the multiple-simulation method, but it takes significantly less time to run.
- Multiple-simulation method Repeatedly simulates the model, and then creates a distribution of the statistics from each simulation. This method is more accurate than the one-simulation method, but it may take a prohibitive amount of time.
- **Note:** When you use the multiple-simulation method, the tool temporarily turns off the **Use Same Sequence Of Random Numbers** option. In statistics literature, the one-simulation method is also called the non-parametric bootstrap, and the multisimulation method is also called the parametric bootstrap.

Figure 59 Bootstrap Simulation Methods



Multiple-simulation method



Since the bootstrap technique does not assume that the sampling distribution is normally distributed, you can use it to estimate the sampling distribution of any statistic, even an unconventional one such as the minimum or maximum value of a forecast. You can also easily estimate complex statistics, such as the correlation coefficient of two data sets, or combinations of statistics, such as the ratio of a mean to a variance.

To estimate the accuracy of Latin Hypercube statistics, you must use the multiple-simulation method.

Starting the Bootstrap Tool

To start the Bootstrap tool, select Run, then More Tools, and then Bootstrap. (In Microsoft Excel 2007 or later, select More Tools in the Tools group.)

The first time you start Bootstrap, the **Welcome** panel opens; otherwise, the **Target Forecast** panel opens.

Using the Bootstrap Welcome Panel

The **Welcome** panel opens the first time you use the Bootstrap tool. It describes the tool and its use. The controls for this panel are:

- Next Opens the Target Forecast panel for choosing a target forecast.
- **Run** Runs the Bootstrap tool and generates results.
- Click Next to continue to the Target Forecast panel.

Specifying Forecasts to Analyze with the Bootstrap Tool

The **Target Forecast** panel of the Bootstrap tool indicates which forecast, formula cell, or cell range to analyze. The controls for this panel are:

- **Forecast list** Lists all the forecast cells in all open spreadsheets. When you select a forecast from the list, its cell information is automatically displayed in the data range text box. The first forecast is selected by default.
- **Data range** Describes the cell location of the selected forecast or formula. If you select a forecast from the forecast list, the cell information is automatically displayed in this text box. You can use this text box to select a formula cell instead of a forecast. If you select a data range, the data must be a single contiguous (connected) block.
- **Back** Opens the Welcome panel.
- Next Opens the Method panel for defining which simulation method to use.
- **Run** Runs the Bootstrap tool and generates results.

> Select a target forecast and then click **Next** to select a simulation method.

Note: If distribution fitting is turned on for the target forecast, it is turned off during the running of simulations within the tool. When simulations finish, distribution fitting is restored.

Specifying a Bootstrap Tool Method

The **Method** panel of the Bootstrap tool specifies a bootstrap method and analysis type. It has the following controls:

- **Bootstrap Method** Selects whether to use the one-simulation or multiple-simulation bootstrap method. For more information on these two methods, see "Estimating Data Accuracy with the Bootstrap Tool" on page 172. The default is the one-simulation method.
- Analyze Distributions Of Selects whether to analyze distributions of statistics, percentiles, or capability metrics. If you select **Percentiles**, you must complete the Percentiles options. The default is **Statistics**.
- **Percentiles** If Percentiles is selected in Analyze Distributions Of, selects which target percentiles to analyze. You can select either: deciles (the 10, 20, 30, 40, 50, 60, 70, 80, and 90 percentiles); 2, 5, 50, 90, and 97.5 percentiles; or a custom list of percentiles you enter in the text box (between 0 and 100, inclusive) separated by commas.
- **Back** Displays the **Target Forecast** panel for specifying a target forecast.
- Next Opens the **Options** panel for defining sample and display options.
- **Run** Runs the Bootstrap tool and generates results.
- > When Method settings are complete, click **Next** to open the **Options** panel.

Setting Bootstrap Options

The **Options** panel of the Bootstrap tool sets sample and display options for Bootstrap. This panel has the following controls:

- **Sample Control** Sets the number of bootstrap samples and the number of trials per sample. The default number of bootstrap samples is 200, and the default number of trials is the number set in the Crystal Ball **Run Preferences** dialog.
- While Running Specifies which forecasts to show while you are running the tool. You can view all the defined forecasts, only the target forecast, or none of the forecasts.
- Back Displays the Method panel for specifying the bootstrap method to use.
- **Run** Runs the Bootstrap tool and generates results.

> When Options settings are complete, click **Run** to run the Bootstrap tool.

Running the Bootstrap Tool

> To run the Bootstrap tool, click **Run** in the Options panel.

Results are generated as described in "Analyzing Bootstrap Tool Results" on page 176.

Analyzing Bootstrap Tool Results

The Bootstrap tool analysis example uses a Crystal Ball example model, Futura Apartments.xls. This spreadsheet model forecasts the profit and loss for an apartment complex.

To generate Bootstrap results, the Bootstrap tool is started with Profit or Loss as the target forecast. The one-simulation method and statistics options are selected on the Method panel. The following are selected on the Options panel:

- Number Of Bootstrap Samples = 200
- Number Of Trials Per Sample = 500
- Show Only Target Forecast is selected

When the analysis is run, the Bootstrap tool displays a forecast chart of the distributions for each statistic and creates a workbook summarizing the data (Figure 60).

Figure 60 Bootstrap Example Results

	A	В	С	D	E	F	G	Н		J
1		Mean	Median	Mode	Standard Deviation	Variance	Skewness	Kurtosis	Coeff. of Variability	Mean Std. Error
2	Profit or Loss	\$2,526.81	\$2,555.39	\$1,669.15	\$1,821.76	\$3,320,949.46	0.00	2.29	0.72	\$81.47
3										
4	Correlations:	4.000	0.777	0.040	0.000	0.000	0.007	0.447	0.775	0.000
5	Mean Median	1.000	0.777	0.246	-0.033 -0.054	-0.033 -0.054	-0.307 -0.571	0.117	-0.775 -0.636	-0.033
7	Mode		1.000	1.000	-0.054	-0.054	-0.571	0.064	-0.636	-0.054
8	Standard Deviation			1.000	1.000	1.000	0.139		0.618	1.000
9	Variance				1.000	1.000	0.139	-0.428	0.618	1.000
10	Skewness					1.000	1.000		0.346	0.139
11	Kurtosis							1.000	-0.357	-0.428
12	Coeff. of Variation								1.000	0.618
13	Me: C Forecast: Mean									1.000
	Edit View Forecast 200 Trials	Preferences	Help	Frequency				200 Dis	played	
	0.06 0.05 0.04 0.02 0.01 0.00 2,360 C		-2.369.51 2.450.00 C	Me		rly Max = 2 680 32 100 2,650 00 2 4 2,650	2,700.00		1	

Notice that the forecast certainty is set to 95%, the precision control confidence level that is displayed on the Trials tab of the Run Preferences dialog.

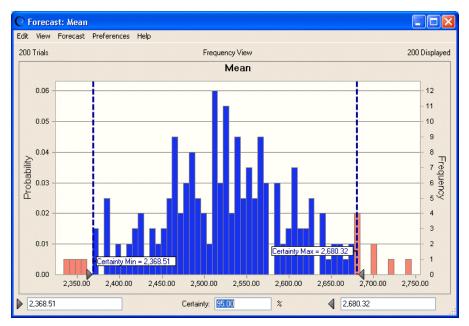
The Bootstrap tool displays sampling distributions in forecast charts for many statistic. Other statistics are also calculated, although they are not displayed.

For percentiles, the Bootstrap tool displays the percentile sampling distributions on the overlay and trend charts. To display the individual percentile forecast charts, select **Analyze**, and then **Forecast Charts**.

Note: If you have the Probability Above A Value option selected in the Run Preferences, then Options panel, the percentiles are reversed in meaning, so that the 1st percentile represents the uppermost 1% and the 99th percentile represents the lowest 1%. For more information on this reversal, "Setting Statistics Preferences" on page 75

The forecast charts visually indicate the accuracy of each statistic (Figure 61). A narrow and symmetrical distribution yields more precise statistics estimates than a wide and skewed distribution.

Figure 61 Bootstrap Forecast Distribution for the Mean



The Statistics view (Figure 62) further lets you analyze the statistics' sampling distribution. If the mean standard error or coefficient of variability is very large, the statistic may not be reliable and may require more samples or more trials. This example has a relatively low standard error and coefficient of variability, so the forecast mean is an accurate estimate of the population mean.

0	0 Trials	Statistics View	BootstrapOutput!B2
.0			BOOKSII APUULPULEZ
	Statistic	Forecast values	
۲	Trials	200	
	Base Case		
	Mean	2,526.81	
	Median	2,526.37	
	Mode		
	Standard Deviation	81.14	
	Variance	6,584.41	
	Skewness	0.0423	
	Kurtosis	2.72	
	Coeff. of Variation	0.0321	
	Minimum	2,334.26	
	Maximum	2,744.15	
	Mean Std. Error	5.74	

Figure 62 Bootstrap Forecast Statistics for the Mean

The results workbook has a correlation matrix showing the correlations between the various statistics. High correlation between certain statistics, such as between the mean and the standard deviation, usually indicates a highly skewed distribution.

You can also use the Bootstrap tool to analyze the distribution of percentiles, but you should run at least 1,000 bootstrap samples and 1,000 trials per sample to obtain good sampling distributions for these statistics (according to Efron and Tibshirani; see the Crystal Ball Bibliography in the *Oracle Crystal Ball Reference and Examples Guide*).

Analyzing Decision Variable Changes with the Decision Table Tool

Subtopics

- Starting the Decision Table Tool
- Using the Decision Table Welcome Panel
- Specifying a Target Forecast for Decision Table Analysis
- Selecting Decision Variables for Decision Table Testing
- Setting Decision Table Tool Options
- Running the Decision Table Tool
- Analyzing Decision Table Results

Decision variables are values that you can control, such as how much to charge for a product or how many wells to drill. But, in situations with uncertainty, it is not always obvious what effect changing a decision variable can have on the forecast results. Crystal Ball decision variables cells enable you to define these variables in spreadsheet models.

The Decision Table tool runs multiple simulations to test different values for one or two decision variables. The tool tests values across the range of the decision variables and puts the results in a table that you can analyze using Crystal Ball forecast, trend, or overlay charts.

The Decision Table tool is useful for investigating how changes in the values of a few decision variable affect the forecast results. For models that contain more than a handful of decision variables, or where you are trying to optimize the forecast results, use OptQuest, available in Crystal Ball Decision Optimizer.

Starting the Decision Table Tool

To start the Decision Table tool, select Run then, More Tools then, Decision Table. (In Microsoft Excel 2007 or later, select More Tools in the Tools group.)

The first time you start the Decision Table tool, the Welcome panel opens. Otherwise, the Target Forecast panel opens.

Using the Decision Table Welcome Panel

The Welcome panel opens the first time you use the Decision Table tool. It describes the tool and its use. The controls for this panel include:

- Next Opens the Target Forecast panel for choosing a target forecast.
- **Run** Runs the **Decision Table** tool and generates results.
- > To continue with the Decision Table tool and define a target forecast, click Next.

The Target Forecast panel opens.

Specifying a Target Forecast for Decision Table Analysis

The Target Forecast panel indicates which forecast to analyze. The controls in this panel include:

- **Forecast list** Lists all forecast cells in all open spreadsheets. The first forecast is selected by default.
- **Back** Opens the **Welcome** panel.
- Next Opens the **Decision Variables** panel.
- **Run** Runs the Decision Table tool and generates results.

> To open the Decision Variables panel and select which decision variables to test, click Next.

The **Decision Variables** panel opens.

Selecting Decision Variables for Decision Table Testing

This panel specifies one or two decision variables to test. The controls in this panel are:

- Available Decision Variables Lists all the defined decision variables in the open spreadsheets.
- **Chosen Decision Variables** Lists one or two decision variables that the tool will test with different values.
- — Moves the selected decision variable in the Available Decision Variables list to the Chosen Decision Variables list.
- — Moves the selected decision variable in the **Chosen Decision Variables** list to the **Available Decision Variables** list.
- **Back** Returns to the **Target Forecast** panel.
- Next Opens the **Options** panel.
- **Run** Runs the Decision Table tool and generates results.
- ➤ To set Decision Table options, click Next

The **Options** panel opens.

Setting Decision Table Tool Options

The Options panel sets options that control the tool. You can set two kinds of options:

- "Simulation Control Options" on page 181
- "While Running Options" on page 181

Other controls include:

• **Back** — Displays the **Decision Variables** panel.

- **Run** Runs the Decision Table tool.
- > When options settings are complete, click **Run** to run the tool.

Simulation Control Options

The **Simulation Control** options in this panel are:

- Number of test values for each decision variable Sets the number of values the tool will test for each selected decision variable. The tool distributes the number of values evenly across the defined decision variable range. If you have one decision variable, the tool runs a simulation for each test value. For two decision variables, the tool runs a simulation for each combination of values.
- Trials per simulation (maximum) Sets the maximum number of trials to run for each simulation. The default is the number set in the Crystal Ball **Run Preferences** dialog.

While Running Options

The While Running options include:

- Show Forecasts As Defined Displays a forecast chart for each defined forecast during the simulation.
- **Show Only Target Forecast** Displays only the forecast chart for the target forecast during the simulation.
- Hide All Forecasts Displays no forecast charts during the simulation.

Running the Decision Table Tool

- > To run the Decision Table tool, click **Run** when all settings are complete.
- **Note:** If distribution fitting is turned on for the target forecast, it is turned off during the running of simulations within the tool. When simulations finish, distribution fitting is restored.

Analyzing Decision Table Results

This Decision Table analysis example uses a Crystal Ball example model, Oil Field Development.xls. This spreadsheet model predicts how best to develop a new oil field by selecting the optimal number of wells to drill, rate of oil production, and size of the refinery to build that will maximize the net present value of the text box.

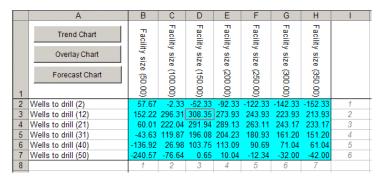
To generate results, Crystal Ball Run Preferences are set to use Monte Carlo simulation with the same sequence of random numbers and a seed value of 999. Then, the Decision Table tool is started. The NPV forecast is selected with Facility Size and Wells To Drill selected as decision variables. The following options are selected:

- Number of values to test for Facility Size = 7.
- Number of values to test for Wells To Drill = 6.
- Maximum trials per simulation = 500.
- Show Only Target Forecast is selected.

When the Decision Table tool is run, it runs a simulation for each combination of decision variable values. Then, it compiles the results in a table of forecast cells indexed by the decision variables.

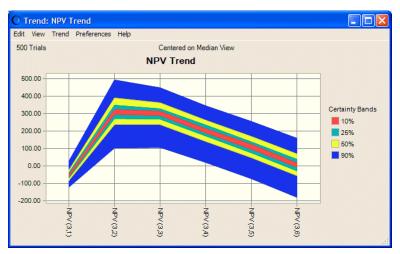
For this example, the Decision Table tool ran 42 simulations, one for each combination of wells to drill and facility sizes. The simulation that resulted in the best mean NPV was the combination of 12 wells and a facility size of 150 mbd (Figure 63).

Figure 63 Decision Table for Oil Field Development Results



To view one or more of the forecasts in the decision table, select the cells and click **Forecast Chart**. To compare one or more forecasts on the same chart, select the cells and click the **Trend Chart** or **Overlay Chart** button in column A (Figure 64).

Figure 64 Trend Chart of 150 Mbd Forecasts



You can create the trend chart shown in Figure 64 by selecting all the forecast cells in the Facility Size (150.00) column of the results table and clicking on Trend Chart. This chart shows that the

forecast with the highest mean NPV also has the largest uncertainty compared to other forecasts with smaller NPVs of the same facility size. This indicates a higher risk that you could avoid with a different number of wells (although the lower risk is accompanied with a lower NPV).

Note: If you have the **Probability Above A Value** option selected in the **Run Preferences**, then **Options** panel, the percentiles will be reversed in meaning, so that the 1st percentile represents the uppermost 1% and the 99th percentile represents the lowest 1%. For more information on this reversal, "Setting Statistics Preferences" on page 75.

Using the Scenario Analysis Tool

Subtopics

- Starting Scenario Analysis
- Specifying a Scenario Analysis Target Forecast
- Specifying Scenario Analysis Options
- Running the Scenario Analysis Tool
- Analyzing Scenario Analysis Results

The Scenario Analysis tool runs a simulation and then sorts and matches all the resulting values of a target forecast with their corresponding assumption values. Then, you can investigate which combination of assumption values gives a particular result.

You can run Scenario Analysis on any Crystal Ball model with at least one assumption and forecast that are not frozen. You select a target forecast to analyze and then the forecast's percentile or value range to examine. The resulting table shows all the values for the target forecast in the designated range, sorted, along with the corresponding assumption values.

Starting Scenario Analysis

- Tip: To help ensure the most accurate Scenario Analysis results, select Run, then RunPreferences, and then Trials and be sure Stop On Calculation Errors is selected before you use Scenario Analysis.
- ► To start Scenario Analysis:
- **1** Select **Run**, then **More Tools**, and then **Scenario Analysis**. (In Microsoft Excel 2007 or later, select **More Tools** in the **Tools** group.)

The first time you start Scenario Analysis, the **Welcome** panel opens. Otherwise, the **Target Forecast** panel is displayed.

2 If Welcome is displayed, click Next to display Target Forecast.

Specifying a Scenario Analysis Target Forecast

The Scenario Analysis tool analyzes the corresponding assumptions for a specified forecast. The Target Forecast panel indicates the forecast to use as the target.

- > To specify a target forecast for analysis:
- 1 In the Target Forecast panel, select a forecast from the list.
- 2 Click Next to open the **Options** panel.

Specifying Scenario Analysis Options

You can use the Options panel to:

- Specify the range of forecast values to analyze
- Indicate which forecast charts to display while running Scenario Analysis
- Set the number of trials to run.
- Include scenarios for non-target forecasts
- > To specify Scenario Analysis Options:
- **1** Display the **Options** panel.
- 2 Review the **Range of forecast results** settings and indicate whether to analyze a range of percentiles or forecast values.

All scenarios resulting in a forecast value that falls within the specified range are displayed in the final table, along with their corresponding assumption values. For the percentile range, enter lower and upper percentiles (both numbers between 0 and 100, or 100 to 0 if **Probability above a value** is selected in the **Run Preferences** dialog). For the forecast value range, enter the lower and upper limits for the values. The default range is –Infinity to +Infinity.

- 3 In the **While running** group, specify which forecasts to show while running Scenario Analysis. You can show all the defined forecasts, only the target forecast, or none of the forecasts (the fastest setting).
- 4 Set Simulation control to select the maximum number of trials to run.
- 5 Optional: Select Include scenarios for non-target forecasts to include all forecasts in the output table.

Running the Scenario Analysis Tool

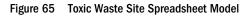
To run the Scenario Analysis tool, click **Run** after a target forecast is selected and appropriate options are set.

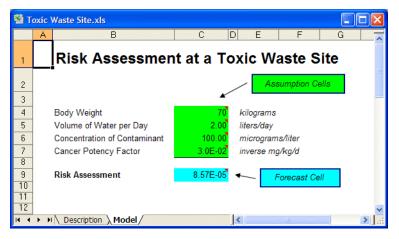
Results are displayed, as described in "Analyzing Scenario Analysis Results" on page 185.

Note: Even if you have not selected **Stop On Calculation Errors** in the **Run Preferences** dialog, the Scenario Analysis tool stops on calculation errors. In that case, reported results are not fully representative and differ from those produced following a complete, error-free simulation. The original setting is restored when the Scenario Analysis tool closes.

Analyzing Scenario Analysis Results

The following Scenario Analysis example uses the Crystal Ball example mode, Toxic Waste Site.xls. This model predicts cancer risk to a nearby population from a toxic waste site. This model has four assumptions and one forecast (Figure 65).





To generate results, the Scenario Analysis tool is run with Risk Assessment as the target forecast and the following Options settings:

- **Range of forecast results** = a percentile range from 95 to 100 percent
- While running = Show only target forecast
- **Simulation control** = 1000 as the maximum number of trials to run

Scenario Analysis creates a table of all the forecast values within the specified range, along with the corresponding value of each assumption (Figure 66).

Figure 66 Scenario Analysis Results for Toxic Waste Site

		-	0		-	-	0	
	А	В	С	D	E	F	G	<u> </u>
	Paste Selected Scenario				Conc		Volume	
	Paste Next Scenario		Risk /	m	entrat			
	Paste Previous Scenario	Trial	Risk Assessmen	Body Weight	Concentration of Conta		of Water per	
1	Reset Original Values	Trial values	sment	veight	Conta	CPF	er Da	
4	95.00%	257	2.03E-04	47.13	116.14	2.4E-02	3.50	
5	95.10%	537	2.04E-04	69.93	111.46	3.6E-02	3.50	
6	95.20%	875	2.04E-04	66.81	107.13	4.9E-02	2.60	
7	95.30%	833	2.06E-04	59.20	118.04	3.1E-02	3.29	
8	95.40%	673	2.06E-04	65.31	109.81	4.6E-02	2.65	
9	95.50%	907	2.06E-04	62.60	112.93	3.4E-02	3.32	
10	95.60%	568	2.08E-04	72.16	104.26	5.2E-02	2.75	
11	95.70%	774	2.10E-04	57.34	100.07	5.0E-02	2.38	
12	95.80%	236	2.11E-04	58.33	111.35	3.9E-02	2.87	
13	95.90%	949	2.12E-04	71.29	106.65	3.1E-02	4.53	
14	96.00%	71	2.13E-04	70.50	114.82	3.3E-02	3.95	
15	96.10%	898	2.13E-04	65.64	110.17	3.2E-02	3.93	
10	► ► ScenarioOutput	400	0.470.04	00.33	00 70	C 0E 00	0.40	

In this example, the simulation generated 1,000 forecast values. Since you selected to analyze the percentiles from 95 to 100, the resulting table lists 51 forecast values, or the top 5% of the forecast range, including the endpoints. The table sorts the forecast values from lowest to highest value along with the assumption values that Crystal Ball generated for each trial.

One way to analyze the Scenario Analysis results is to identify a particular forecast value and see what assumption values created that forecast value.

- ➤ To analyze the 98th percentile:
- 1 Select the row with the 98.00% (assuming percentile display is set to the defaults, **Probability below a value** and **10%**, **90%**, **etc.**).
- 2 Click Paste Selected Scenario.

The scenario of assumption values that produced the 98th percentile value of the target forecast is displayed in the Toxic Waste workbook. Crystal Ball recalculates the workbook and updates the forecast cells.

3 Click Paste Next Scenario.

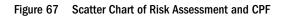
In the workbook, the assumption and forecast values change to the values for the next scenario (for 98.10%).

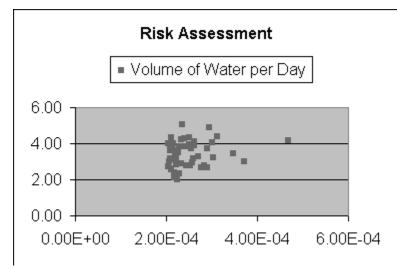
4 Click Reset Original Values.

The original assumption and forecast values are displayed in the workbook.

Note: If you have stochastic elements in the model other than Crystal Ball assumptions—for example a RAND() function, a random value returned by a macro, or even a Crystal Ball probability spreadsheet function such as CB.Normal(), the value for that stochastic element is not pasted into the model with the Paste buttons on the Scenario Analysis tool's output spreadsheet. True scenario analysis cannot be performed in this case; if the target forecast is a function of these other elements, the forecast values do not match.

Another way to analyze the Scenario Analysis results is to generate a scatter chart in Microsoft Excel with the data. For example, you can create a scatter chart comparing the risk assessment with the Cancer Potency Factor (CPF) (Figure 67).





Analyzing Uncertainty and Variability with the 2D Simulation Tool

Subtopics

- Starting the 2D Simulation Tool
- Using the 2D Simulation Welcome Panel
- Specifying a 2D Simulation Target Forecast
- Sorting Assumptions for 2D Simulation Analysis
- Setting 2D Simulation Options
- Running the 2D Simulation Tool
- Analyzing 2D Simulation Results

Risk analysts must often consider two sources of variation in their models:

- Uncertainty Assumptions that are uncertain because you have insufficient information about a true, but unknown, value. Examples of uncertainty include the reserve size of an oil field and the prime interest rate in 12 months. You can describe an uncertainty assumption with a probability distribution. Theoretically, you can eliminate uncertainty by gathering more information. Practically, information can be missing because you haven't gathered it or because it is too costly to gather.
- Variability Assumptions that change because they describe a population with different values. Examples of variability include the individual body weights in a population or the daily number of products sold over a year. You can describe a variability assumption with

a discrete distribution (or approximate one with a continuous distribution). Variability is inherent in the system, and you cannot eliminate it by gathering more information.

For many types of risk assessments, it is important to clearly distinguish between uncertainty and variability (see Hoffman and Hammonds reference in the Bibliography). Separating these concepts in a simulation lets you more accurately detect the variation in a forecast due to lack of knowledge and the variation caused by natural variability in a measurement or population. In the same way that a one-dimensional simulation is generally better than single-point estimates for showing the true probability of risk, a two-dimensional simulation is generally better than a one-dimensional simulation for characterizing risk.

The 2D Simulation tool runs an outer loop to simulate the uncertainty values, and then freezes the uncertainty values while it runs an inner loop (of the whole model) to simulate the variability. This process repeats for some number of outer simulations, providing a portrait of how the forecast distribution varies due to the uncertainty.

The primary output of this process is a chart depicting a series of cumulative frequency distributions. You can interpret this chart as the range of possible risk curves associated with a population.

Note: When using this tool, set the **Seed Value** option in the Crystal Ball **Run Preferences** dialog so that the resulting simulations are more comparable.

Starting the 2D Simulation Tool

To start the 2D Simulation tool, select Run, then More Tools, and then 2D Simulation. (In Microsoft Excel 2007 or later, select More Tools in the Tools group.)

The first time you start 2D Simulation, the **Welcome** panel opens. Otherwise, the Target Forecast panel opens.

Using the 2D Simulation Welcome Panel

The Welcome panel opens the first time you use the 2D Simulation tool. It describes the tool and its use. The controls for this panel include:

- Next Opens the Target Forecast panel for specifying the forecast to analyze.
- Run Runs the 2D Simulation tool if all required settings are complete.
- > If the Welcome panel opens, click **Next** to open the **Target Forecast** panel.

Specifying a 2D Simulation Target Forecast

The Target Forecast panel of the 2D Simulation tool indicates which forecast to analyze. The controls for this panel include:

- **Forecast** list Lists all the forecast cells in all open spreadsheets. The first forecast is selected by default.
- **Back** Opens the **Welcome** panel.
- **Next** Opens the **Assumption Types** panel.
- Run Runs the 2D Simulation tool if all required settings are complete.
- When settings are complete on the Target Forecast panel, click Next to open the Assumption Types panel.

Sorting Assumptions for 2D Simulation Analysis

The Assumption Types panel of the 2D Simulation tool separates the assumptions into uncertainty assumptions and variability assumptions. All the assumptions from all open worksheets start in the Uncertainty list by default. You must have at least one assumption of each type. When you save the spreadsheet model, the tool remembers the assumption types for the next time you run the tool. The controls for this panel include:

- >> Moves any selected assumptions in the list to the **Variability** list.
- << Moves any selected assumptions in the Variability list to the Uncertainty list.
- **Back** Returns to the **Target Forecast** panel.
- **Next** Opens the **Options** panel.
- **Run** Runs the 2D Simulation tool if all required settings are complete.
- When all assumptions have been sorted into the Uncertainty and Variability lists, click Next to open the Options panel.

Setting 2D Simulation Options

The Options panel of the 2D Simulation tool sets simulation control, display, and report options. This panel includes the following controls:

- **Simulation Control** Sets the number of trials for the outer (uncertainty) simulation and inner (variability) simulation. The default number of outer trials is 50 and the default number of inner trials is the number you have set on the **Trials** tab of the **Run Preferences** dialog.
- While Running Specifies which forecasts to show while you are running the tool. You can view the forecasts according to the display setting for each chart, only the target forecast, or none of the forecasts.
- **Report Options** Includes statistics, percentiles, and capability metrics in reports. You can also specify how many simulations to include in accompanying output and overlay charts.
- **Back** Opens the **Assumption Types** panel for identifying uncertainty and variability assumptions.

• **Run** — Runs the 2D Simulation tool if all required settings are complete.

Running the 2D Simulation Tool

To run the 2D Simulation tool, confirm that all required settings are complete and then click Run. Results are generated ("Analyzing 2D Simulation Results" on page 190).

Analyzing 2D Simulation Results

The 2D Simulation analysis example uses a Crystal Ball example model, Toxic Waste Site.xls. This model predicts the cancer risk to the population from a toxic waste site. This spreadsheet has two variability assumptions and two uncertainty assumptions.

To generate results, first the Crystal Ball run preferences are set for Monte Carlo simulation using the same sequence of random numbers with a seed value of 999. Then, the 2D Simulation tool is run with Risk Assessment as the target forecast, Body Weight and Volume of Water per Day included in the Variability list on the Assumption Types panel, and the following Options settings:

- Outer (uncertainty) simulation runs for 100 trials
- Inner (variability) simulation runs for 1,000 trials
- Show Only Target Forecast is selected.
- **Report Options** are set to the defaults.

When run, the 2D Simulation tool first single-steps one trial to generate a new set of values for the uncertainty assumptions. Then it freezes these assumptions and runs a simulation for the variability assumptions in the inner loop.

The tool retrieves the Crystal Ball forecast information after each inner loop runs. The tool then resets the simulation and repeats the process until the outer loop has run for the specified number of simulations.

The results of the simulations are displayed in a table containing the forecast means, the uncertainty assumption values, and the statistics (including percentiles) of the forecast distribution for each simulation (Figure 68).

Figure 68 2D Simulation Results Table

N 1	Book7								X
	А	В	С	D	E	F	G	Н	^
		Summary	Risk Assessment(21)	Risk Assessment(10)	Risk Assessment(85)	Risk Assessment(37)	Risk Assessment(53)	Risk Assessment(14)	
1		nar	121	(10	6	(G)	(5	t(14	
2		¥.						5.55E-05	5
3	Assumptions:				0.002.00	0.022 00	0.002.00	0.002.00	-
4	Concentration of Contaminant in Water		100.70	99.71	94.10	93.13	98.25	93.60	
5	CPF		1.5E-02	1.6E-02	1.8E-02	1.9E-02	1.8E-02	1.9E-02	
6									
7	Statistics:								
8	Mean	9.30E-05	4.55E-05	4.84E-05	5.09E-05	5.32E-05	5.39E-05	5.55E-05	5
9	Median							5.35E-05	-
10	Standard Deviation							2.60E-05	_
11	Variance							6.75E-10	7
12	Skewness	0.56		0.56	0.56	0.56	0.56	0.56	
13	Kurtosis	3.43		3.43	3.43	3.43	3.43	3.43	
14	Coeff. of Variation	0.47	0.47	0.47	0.47	0.47	0.47	0.47	
15	Minimum							5.89E-09	-
16	Maximum							1.59E-04	
17	Range	2.66E-04	1.30E-04	1.38E-04	1.46E-04	1.52E-04	1.54E-04	1.59E-04	1
18									
19	Percentiles:								_
20								5.89E-09	-
21	5%							1.66E-05	
22					2.08E-05	2.18E-05	2.21E-05	2.27E-05	2 🗸
14 4	H TwoDSimulationOutput / Shee	t1 / Sheet	2 / Sheet	3/ <	ш)			J	>

The tool also graphs the results of the two-dimensional simulations on an overlay chart and a trend chart.

The overlay chart preferences can be set to show the risk curves for the simulations for different sets of uncertainty assumption values. To do this, set the **Chart Type** for each series to **Line** and select **Cumulative Frequency** view. It is convenient to use the chart hotkeys — Ctrl+t for the chart type and Ctrl+d for view. Optionally, use Ctrl+n to move or remove the legend and Ctrl+m to cycle through central tendency marker lines.

For this example, Figure 69 shows that most of the risk curves are clustered densely toward the center while a few outlier curves are scattered toward the **Cumulative Frequency** axis, showing the small probability of having a much greater risk.

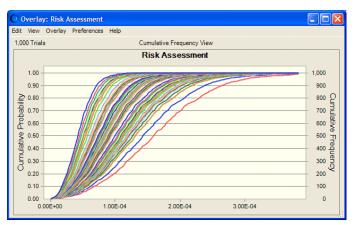


Figure 69 Overlay Chart of Risk Curves

The trend chart (Figure 70) shows certainty bands for the percentiles of the risk curves. The band width shows the amount of uncertainty at each percentile level for all the distributions.

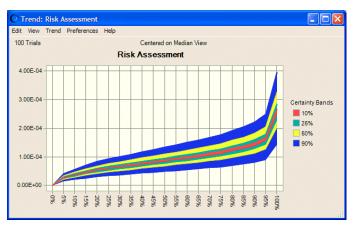


Figure 70 Trend Chart Certainty Bands

You can focus in on a particular percentile level, such as the 95th percentile, by viewing the statistics of the 95th percentile forecast, shown in Figure 71. For example, this figure shows 100 trials, the number of 95th percentiles in the forecast.

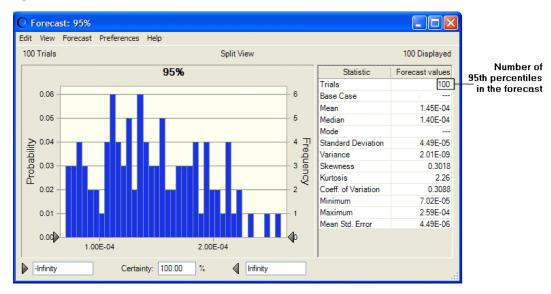
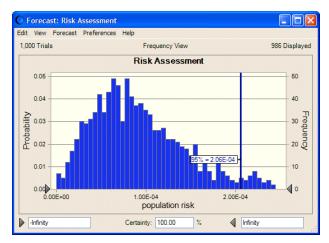


Figure 71 95th Percentile Forecast Statistics

Compare the results of the two-dimensional simulation to a one-dimensional simulation (with both uncertainty and variability co-mingling together) of the same risk model, as in Figure 72.

The mean of the 95th percentiles in Figure 71, 1.45E-4, is lower than the 95th percentile risk of the one-dimensional simulation shown in Figure 72 at 2.06E-4. This indicates the tendency of the one-dimensional simulation results to overestimate the population risk, especially for highly skewed distributions.

Figure 72 Forecast Chart for One-dimensional Simulation



Note: Often, the parameters of assumptions are correlated. For example, you would correlate a higher mean with a higher standard deviation or a lower mean with a lower standard deviation. Defining correlation coefficients between parameter distributions can increase the accuracy of the two-dimensional simulation. With data available, as in sample body weights of a population, you can use the Bootstrap tool to estimate the sampling distributions of the parameters and the correlations between them.

Second-order Assumptions

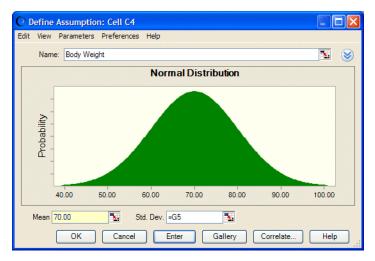
Some assumptions contain elements of both uncertainty and variability. For instance, an assumption may describe the distribution of body weights in a population, but the parameters of the distribution may be uncertain. These types of assumptions are called second-order assumptions (also, second-order random variables; see Burmaster and Wilson, 1996, in the Bibliography). You can model these types of assumptions in Crystal Ball by placing the uncertain parameters of the distribution in separate cells and defining these cells as assumptions. You then link the parameters of the variability assumption to the uncertainty assumptions using cell references.

- > To illustrate this for the Toxic Waste Site.xls spreadsheet:
- 1 Enter the values 70 and 10 into cells G4 and G5, respectively.

These are the mean and standard deviation of the Body Weight assumption in cell C4, which is defined as a normal distribution.

- 2 Define an assumption for cell **G4** using a normal distribution with a mean of 70 and a standard deviation of 2.
- 3 Define an assumption for cell **G5** using a normal distribution with a mean of 10 and a standard deviation of 1.
- 4 Enter references to these cells in the Body Weight assumption (Figure 73).

Figure 73 Assumption Using Cell References for the Mean and Standard Deviation



When you run the tool for second-order assumptions, the uncertainty of the assumptions' parameters is modeled in the outer simulation, and the distribution of the assumption itself is modeled (for different sets of parameters) in the inner simulation.

Importing and Analyzing Data with the Data Analysis Tool

Subtopics

- Starting the Data Analysis tool
- Using the Data Analysis Welcome Panel
- Specifying Data Analysis Input Data
- Setting Data Analysis Options
- Running the Data Analysis Tool
- Analyzing Data Analysis Results

The Data Analysis tool imports and analyzes data in Crystal Ball. The data is imported directly into Crystal Ball forecasts, one for each data series. Then, you can analyze it using any of Crystal Ball's features.

To use the Data Analysis tool, the data series must be contiguous (in adjacent rows or columns) in either rows or columns.

Starting the Data Analysis tool

To start the Data Analysis tool, select Run, then More Tools, then Data Analysis. (In Microsoft Excel 2007 or later, select More Tools in the Tools group.)

The first time you start the Data Analysis tool, the Welcome panel opens. Otherwise, the Input Data panel opens.

Using the Data Analysis Welcome Panel

The Welcome panel opens the first time you use the Data Analysis tool. It describes the tool and its use. The controls for this panel include:

- Next Opens the Input Data panel for specifying the location of the data series.
- **Run** Runs the Data Analysis tool.
- > If the Welcome panel opens, click Next to open the Input Data panel.

Specifying Data Analysis Input Data

The Input Data panel of the Data Analysis tool indicates the location of the data that to analyze. You can also set input-related options. The Data Analysis data selector selects possible data for fitting. This information is displayed in the Location Of Data Series text box and the illustration. You can select different data if necessary. The controls in this panel include:

- Location Of Data Series Indicates the cells that contain data to analyze. If the data has headers or labels at the beginning of the rows or columns of data, include them in the selection and select the appropriate **Headers** setting(s). The data must be in adjacent rows or columns.
- **Orientation** Sets whether the data is in rows or columns: **Data In Rows** indicates that data is in horizontal rows; **Data In Columns** indicates that data is in vertical columns.
- **Headers** Indicates whether the data has headers and/or labels and whether they are located in the first row or the first column (varies with orientation). Selected items are used in the output: **Top Row Has Headers/Labels** includes text in the top (first) row in the selection; **Left Column Has Labels/Headers** includes text in the left (first) column in the selection.
- **Back** Displays the **Welcome** panel.
- **Next** Opens the **Options** panel.
- **Run** Runs the Data Analysis tool, automatically generating forecasts for each selected data series.
- > Click Next to open the Options panel and set Data Analysis options.

Setting Data Analysis Options

The Options panel of the Data Analysis tool sets a variety of preferences for displaying generated forecast charts, fitting probability distributions to generated forecast data, generating correlations between forecast data series, and running simulations on opened models. The Options panel includes these controls:

• Automatically Open Forecast Charts — When selected, automatically opens forecast charts when the Data Analysis tool runs.

- **View** Indicates which forecast chart view to use, similar to the forecast chart View menu commands.
- **Split View** When selected, shows a chart in the first pane and statistics in the second pane.
- **Fit A Probability Distribution To The Data** When selected, calculates and plots a curve for the distribution that best fits the data in each series. Select **Fit Options** to review or change current settings in the **Fit Options** panel.
- **Generate Correlation Matrix Between Data Series** When selected, plots the rank correlation between pairs of forecasts. You can click the **Scatter Chart** button in the results worksheet to show the forecast relationships graphically, along with lines of fit and correlation coefficients.
- **Run Simulation On Opened Models (To Compare Data Simulation Results)** When selected, this setting can be used for validating models. A simulation is run on all open workbooks at the same time the selected data is analyzed. In this case, forecast charts for all opened models are displayed with those generated from the data selected for analysis.
- **Back** Displays the **Input Data** panel.
- Run Runs the tool, automatically generating forecasts for each selected data series.
- When all settings are complete, click **Run** to perform the Data Analysis import and generate forecasts.

Running the Data Analysis Tool

To run the Data Analysis tool, confirm that all required settings are complete and then click Run.

Results are generated as described in "Analyzing Data Analysis Results" on page 196.

Analyzing Data Analysis Results

The analysis example for the Data Analysis tool uses a Crystal Ball example model, Magazine Sales.xls. This model shows the estimated gross profit resulting from newsstand sales of four of the company's most popular magazines (Figure 74). The accompanying Sales Data worksheet contains historical data for each of the four magazines.

Figure 74 Magazine Sales Workbook

B	C	D	E	F
Magazine	Checkou	it Sales		
ſ				
	Magazine A	Magazine B	Magazine C	Magazine [
Sales Volume	562	362	646	50
Retail Price	\$4.95	\$7.95	\$3.95	\$5.95
Cost of Goods	\$2.20	\$3.80	\$1.95	\$2.40
Gross Profit	\$1,546	\$1,502	\$1,292	\$1,80
Total Gross Profit:	\$6,144			

This example shows how to analyze the data by importing the data into the Data Analysis tool, automatically creating a forecast for each magazine, running a simulation, displaying the simulated data as forecast charts, correlating the forecasts for each magazine, and producing other charts using buttons in the DataAnalysisOutput worksheet generated by the tool.

When the workbook is opened to the Sales Data sheet, correct input data is automatically selected when the tool starts. For this example, Options settings are as follows:

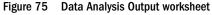
- Select Automatically open forecast charts.
- Set View to Frequency.
- Select Fit a probability distribution to the data.
- Select Generate correlation matrix between data series.
- Select Run simulation on opened models....

AutoSelect defaults are set on the Fit Options panel.

When the Data Analysis tool runs, it creates:

- A series of forecast charts.
- A new workbook with data and buttons on a worksheet named **DataAnalysisOutput**, similar to Figure 75.

	А	B	С	D	E	^
	ForecastChart	ŝ	Ś	Ś	ŝ	
	Trend Chart	Sales V	Sales ∨	Sales ∨	Sales V	
	Overlay Chart	Volume A	Volume	Volume	Volume	
1	Scatter Chart	₽	Φ	0	D	
2		499	355	639	481	_
3	Correlations:					
4	Sales Volume A	1.0000	0.0166	-0.0128	-0.0124	
5	Sales Volume B		1.0000	-0.0059	0.0607	
6	Sales Volume C			1.0000	-0.0392	
7	Sales Volume D				1.0000	
8						~
0	DataAnalysisOutpu	-	<			>



- Cells B2 through E2 contain forecasts, one for each series of magazine data.
- Below that is a correlation matrix, showing the relationship of each forecast to the other three.
- Cell A1 contains four buttons you can use to display forecast, trend, overlay, and scatter charts.

You can use the chart buttons to analyze the newly generated forecasts. For example, select the row of forecasts and click the Forecast Chart button. Then, to see which type of distribution fit best, select a chart and select **View**, and then **Goodness of Fit**.

Working with Smart View Using the Crystal Ball Enterprise Performance Management Connector

- > To use the Crystal Ball Enterprise Performance Management Connector:
- **1** Start Oracle Crystal Ball Enterprise Performance Management.
- 2 In Microsoft Excel 2007 or later, select More Tools, then Integration Tools, and then Enterprise Performance Management from the Tools group in the Crystal Ball ribbon. In Microsoft Excel 2003, select Run, then More Tools, then Integration Tools, and then Enterprise Performance Management.
- 3 In the Enterprise Performance Management Preferences dialog, click Options.
- 4 Select Enable Smart View integration and Preserve Crystal Ball highlighting.
- 5 **Optional:** Click **Calculations** and select a calculation script.
- 6 Within Smart View, select Hyperion, and then Options.
- 7 From the **Display** tab, select **UI Colors**, **Use Microsoft Excel Formatting**, and **Retain Numeric Formatting**, and then click **OK**.
- 8 Within Smart View, connect to a data source and open an Oracle Essbase ad-hoc analysis query or a Planning form as usual (as described in the documentation for Oracle Hyperion Smart View for Office and Oracle Essbase or Oracle Hyperion Planning.
- 9 Arrange the view to suit your analysis, and then use the Crystal Ball toolbar and menus to create Crystal Ball assumptions, forecasts, and decision variables if required. See the *Oracle Crystal Ball User's Guide*.
- 10 Use the Crystal Ball toolbar and menus to run a simulation or time-series forecast.
- **11** View the resulting charts and tables to analyze the results as described in this Guide and related documentation for OptQuest and Predictor.

For more information, see the Oracle Crystal Ball Enterprise Performance Management Integration Guide.

Comparing Extreme and Normal Speed with the Compare Run Modes Tool

If you are concerned about possible differences in model calculations between Extreme and Normal speed in Crystal Ball Decision Optimizer, the Compare Run Modes tool enables you to compare the results between the two run modes.

- ➤ To use the Compare Run Modes tool:
- **1** Open and click the model to test.
- 2 Select Run, then More Tools, and then Compare Run Modes.

The Compare Run Modes dialog opens.

Figure 76 Compare Run Modes Dialog

Compare Run Modes	Modes						
Compare simulation results for dii modes and options for all open w tool will create a new workbook w the differences.	iorkbooks. This						
Run mode Compare results between Extreme speed and Normal speed Compare results between single-threaded calculation and multi- threaded calculation in Microsoft Excel 2007 or later using Normal speed							
Detect <u>d</u> ifferences above: <u>N</u> umber of trials to run:	0.00000000001 Relative						
Compare assumptions in ad	Idition to forecasts Run Comparison Cancel						

- 3 If you are using Crystal Ball with Microsoft Excel 2007 or later, select whether to compare results between Extreme and Normal speed or between single-threaded calculation and multithreaded calculation.
- 4 Indicate the amount of difference to detect, whether that difference is absolute or relative, and the number of trials to run. Optionally, select whether to compare assumptions as well as forecasts.

Depending on the size of the model, differences may not become obvious until after a fairly large number of trials have run. You may want to run 5,000 or more trials for the test.

5 When you are ready, click Run Comparison.

If you are comparing speed results, the simulation runs once in Extreme speed and once in Normal speed. Otherwise, the simulation runs once with single-threaded and once with multithreaded calculations. Results are displayed in a new workbook. The comparison Summary tab is displayed when the comparison is complete. Figure 77 on page 200 shows comparison results for the Tolerance Analysis.xls example file with 5,000 trials. In this case there were no differences in results and the model ran 28.8 times faster in Extreme speed.

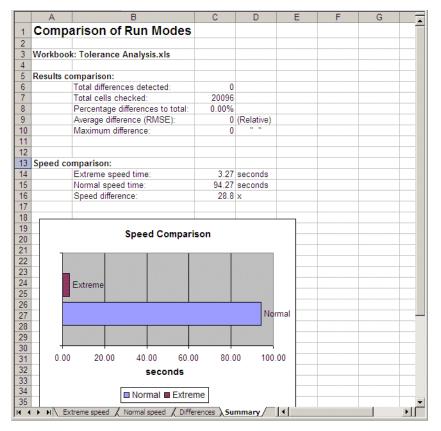


Figure 77 Comparison results for Tolerance Analysis.xls, 5,000 Trials

Note: Because of variations in the random number seeds, you may see differences in comparison results if you use Microsoft Excel's RAND or Crystal Ball's probability functions (such as CB.Uniform) in the model.



Selecting and Using Probability Distributions

In This Appendix

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Truncating Distributions	
Distribution Parameter Summary	236
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Introduction

This appendix explains probability and probability distributions. Understanding these concepts will help you select the most appropriate probability distribution for the spreadsheet model. This section describes in detail the distribution types Crystal Ball uses and demonstrates their use with real-world examples.

Understanding Probability Distributions

For each uncertain variable in a simulation, you define the possible values with a *probability distribution*. The type of distribution you select depends on the conditions surrounding the variable. For example, some common distribution types are shown in Figure 78: normal, triangular, uniform, and lognormal

Figure 78 Common Distribution Types



During a simulation, the value to use for each variable is selected randomly from the defined possibilities.

A simulation calculates numerous scenarios of a model by repeatedly picking values from the probability distribution for the uncertain variables and using those values for the cell. Commonly, a Crystal Ball simulation calculates hundreds or thousands of scenarios in just a few seconds. The following section, "A Probability Example" on page 202, shows how a probability distribution relates to a simple set of employment data.

Crystal Ball works with two types of distributions, described in "Continuous and Discrete Probability Distributions" on page 204. For suggestions about using the best distribution when defining an assumption, see "Selecting Probability Distributions" on page 205. "Probability Distribution Descriptions" on page 207 describes the properties and uses of each distribution available in Crystal Ball.

A Probability Example

To begin to understand probability, consider this example: You want to look at the distribution of non-exempt wages within one department of a large company. First, you gather raw data, in this case the wages of each non-exempt employee in the department. Second, you organize the data into a meaningful format and plot the data as a frequency distribution on a chart. To create a frequency distribution, you divide the wages into groups (also called intervals or bins) and list these intervals on the chart's horizontal axis. Then you list the number or frequency of employees in each interval on the chart's vertical axis. Now you can easily see the distribution of non-exempt wages within the department.

A glance at the chart illustrated in Figure 79 reveals that the most common wage range is \$12.00 to \$15.00.

Approximately 60 employees (out of a total of 180) earn from \$12 to \$15.00 per hour.

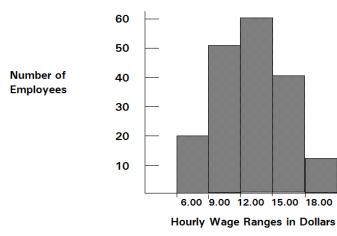
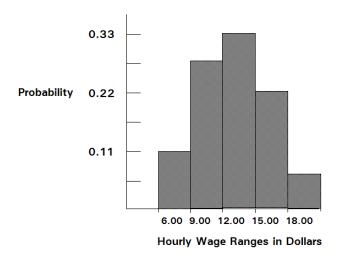
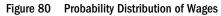


Figure 79 Raw Frequency Data for a Probability Distribution

You can chart this data as a probability distribution. A probability distribution shows the number of employees in each interval as a fraction of the total number of employees. To create a probability distribution, you divide the number of employees in each interval by the total number of employees and list the results on the chart's vertical axis.

The chart illustrated in Figure 80 shows you the number of employees in each wage group as a fraction of all employees; you can estimate the likelihood or probability that an employee drawn at random from the whole group earns a wage within a given interval. For example, assuming the same conditions exist at the time the sample was taken, the probability is 0.33 (a 1 in 3 chance) that an employee drawn at random from the whole group earns between \$12 and \$15 an hour.





Compare the probability distribution in the previous example to the probability distributions in Crystal Ball (Figure 81).

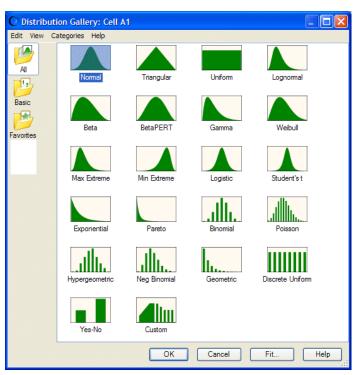


Figure 81 Distribution Gallery Dialog

The probability distribution in the example in Figure 80 has a shape similar to many of the distributions in the Distribution Gallery. This process of plotting data as a frequency distribution and converting it to a probability distribution provides one starting point for selecting a Crystal Ball distribution. Select the distributions in the gallery that is displayed similar to the probability distribution, then read about those distributions in this chapter to find the correct distribution.

Continuous and Discrete Probability Distributions

Notice that the Distribution Gallery shows whether the probability distributions are continuous or discrete.

Continuous probability distributions, such as the normal distribution, describe values over a range or scale and are shown as solid figures in the Distribution Gallery. Continuous distributions are actually mathematical abstractions because they assume the existence of every possible intermediate value between two numbers. That is, a continuous distribution assumes there is an infinite number of values between any two points in the distribution.

Discrete probability distributions describe distinct values, usually integers, with no intermediate values and are shown as a series of vertical columns, such as the binomial distribution at the bottom of Figure 81. A discrete distribution, for example, may describe the number of heads in four flips of a coin as 0, 1, 2, 3, or 4.

However, in many situations, you can effectively use a continuous distribution to approximate a discrete distribution even though the continuous model does not necessarily describe the situation exactly.

In the dialogs for the discrete distributions, Crystal Ball displays the values of the variable on the horizontal axis and the associated probabilities on the vertical axis. For the continuous distributions, Crystal Ball does not display values on the vertical axis since, in this case, probability can only be associated with areas under the curve and not with single values.

Initially, the precision and format of the displayed numbers in the probability and frequency distributions come from the cell itself. To change the format, see "Customizing Chart Axes and Axis Labels" on page 109.

The following sections list continuous and discrete distributions available in Crystal Ball:

- "Continuous Probability Distributions" on page 204
- "Discrete Probability Distributions" on page 205
- **Note:** Custom distributions can be defined as continuous, discrete, or both. For more information, see "Custom Distribution" on page 212.

Continuous Probability Distributions

The following sections describe continuous distributions available in Crystal Ball:

- "Beta Distribution" on page 208
- "BetaPERT Distribution" on page 209

- "Exponential Distribution" on page 213
- "Gamma Distribution" on page 214
- "Logistic Distribution" on page 219
- "Lognormal Distribution" on page 219
- "Maximum Extreme Distribution" on page 221
- "Minimum Extreme Distribution" on page 221
- "Normal Distribution" on page 223
- "Pareto Distribution" on page 224
- "Student's *t* Distribution" on page 226
- "Triangular Distribution" on page 227
- "Uniform Distribution" on page 228
- "Weibull Distribution" on page 229

Discrete Probability Distributions

The following sections describe discrete distributions available in Crystal Ball:

- "Binomial Distribution" on page 210
- "Discrete Uniform Distribution" on page 212
- "Geometric Distribution" on page 216
- "Hypergeometric Distribution" on page 217
- "Negative Binomial Distribution" on page 222
- "Poisson Distribution" on page 225
- "Yes-No Distribution" on page 230
- "Triangular Distribution" on page 227
- "Uniform Distribution" on page 228
- "Weibull Distribution" on page 229

Selecting Probability Distributions

Plotting data is one guide to selecting a probability distribution. The following steps provide another process for selecting probability distributions that best describe the uncertain variables in the spreadsheets.

To select the correct probability distribution:

1. Look at the variable in question. List everything you know about the conditions surrounding this variable.

You may be able to gather valuable information about the uncertain variable from historical data. If historical data are not available, use judgment, based on experience, to list everything you know about the uncertain variable.

For example, look at the variable "patients cured" that is discussed in "Tutorial 2 — Vision Research" on page 254. The company plans to test 100 patients. You know that the patients will either be cured or not cured. And, you know that the drug has shown a cure rate of around 0.25 (25%). These facts are the conditions surrounding the variable.

2. Review the descriptions of the probability distributions.

"Probability Distribution Descriptions" on page 207 describes each distribution in detail, outlining the conditions underlying the distribution and providing real-world examples of each distribution type. As you review the descriptions, look for a distribution that features the conditions you have listed for this variable.

3. Select the distribution that characterizes this variable.

A distribution characterizes a variable when the conditions of the distribution match those of the variable.

The conditions of the variable describe the values for the parameters of the distribution in Crystal Ball. Each distribution type has its own set of parameters, which are explained in the following descriptions.

For example, look at the conditions of the binomial distribution, as described in "Binomial Distribution" on page 210:

- For each trial, only two outcomes are possible: success or failure.
- The trials are independent. What happens on the first trial does not affect the second trial, and so on.
- The probability of success remains the same from trial to trial.

Now compare the "patients cured" variable in "Tutorial 2 — Vision Research" on page 254 with the conditions of the binomial distribution:

- Two possible outcomes exist: the patient is either cured or not cured.
- The trials (100) are independent of each other. What happens to the first patient does not affect the second patient.
- The probability of curing a patient 0.25 (25%) remains the same each time a patient is tested.

Since the conditions of the variable match the conditions of the binomial distribution, the binomial distribution would be the correct distribution type for the variable in question.

4. If historical data are available, use distribution fitting to select the distribution that best describes the data.

Crystal Ball can automatically select the probability distribution that most closely approximates the data's distribution. The feature is described in detail in "Fitting Distributions to Historical Data" on page 41. You can also populate a custom distribution with the historical data.

After you select a distribution type, determine the parameter values for the distribution. Each distribution type has its own set of parameters. For example, the binomial distribution has two parameters: trials and probability. The conditions of a variable contain the values for the parameters. In the example used, the conditions show 100 trials and 0.25 (25%) probability of success.

In addition to the standard parameter set, each continuous distribution (except uniform) also lets you select from alternate parameter sets, which substitute percentiles for one or more of the standard parameters. For more information on alternate parameters, see "Using Alternate Parameter Sets" on page 39. For a summary list of parameters for each probability distribution, see the *Oracle Crystal Ball Reference and Examples Guide*.

Probability Distribution Descriptions

Subtopics

- Beta Distribution
- BetaPERT Distribution
- Binomial Distribution
- Custom Distribution
- Discrete Uniform Distribution
- Exponential Distribution
- Gamma Distribution
- Geometric Distribution
- Hypergeometric Distribution
- Logistic Distribution
- Lognormal Distribution
- Maximum Extreme Distribution
- Minimum Extreme Distribution
- Negative Binomial Distribution
- Normal Distribution
- Pareto Distribution
- Poisson Distribution
- Student's t Distribution
- Triangular Distribution
- Uniform Distribution
- Weibull Distribution
- Yes-No Distribution

This section contains descriptions of all the Crystal Ball probability distributions, listed in alphabetical order.

The following sections list continuous and discrete distributions:

- "Continuous Probability Distributions" on page 204
- "Discrete Probability Distributions" on page 205

See "Custom Distribution" on page 212 for a description of the Custom distribution, which can be continuous, discrete, or both

As you work with the Crystal Ball probability distributions, you can use the Parameters menu found in the distribution menu bar to specify different combinations of parameters. For more information, see "Using Alternate Parameter Sets" on page 39.

Beta Distribution



The beta distribution is continuous. It is commonly used to represent variability over a fixed range. It can represent uncertainty in the probability of occurrence of an event. It is also used to describe empirical data and predict the random behavior of percentages and fractions and can be used to represent the reliability of a company's devices.

Note: Models that use beta distributions will run more slowly because of the inverse CDF and alternate parameter calculations that take place when random numbers are handled as part of beta distributions.

Parameters

Minimum, Maximum, Alpha, Beta

Conditions

The beta distribution is used under these conditions:

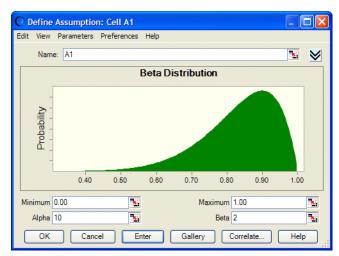
- Minimum and maximum range is between 0 and a positive value.
- Shape can be specified with two positive values, alpha and beta. If the parameters are equal, the distribution is symmetrical. If either parameter is 1 and the other parameter is greater than 1, the distribution is J-shaped. If alpha is less than beta, the distribution is said to be positively skewed (most of the values are near the minimum value). If alpha is greater than beta, the distribution is negatively skewed (most of the values are near the maximum value). Because the beta distribution is complex, the methods for determining the parameters of the distribution are beyond the scope of this manual. For more information about the beta distribution and Bayesian statistics, refer to the texts in the Bibliography.

Beta Distribution Example

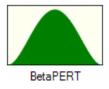
A company that manufactures electrical devices for custom orders wants to model the reliability of devices it produces.

Figure 82 shows the beta distribution with the alpha parameter set to 10, the beta parameter set to 2, and Minimum and Maximum set to 0 and 1. The reliability rate of the devices will be *x*.

Figure 82 Beta Distribution



BetaPERT Distribution



The betaPERT distribution is continuous. It describes a situation where you know the minimum, maximum, and most likely values to occur. It is useful with limited data. For example, you could describe the number of cars sold per week when past sales show the minimum, maximum, and usual number of cars sold. It is similar to the triangular distribution, described in "Triangular Distribution" on page 227, except the curve is smoothed to reduce the peak. The betaPERT distribution is often used in project management models to estimate task and project durations.

Parameters

Minimum, Likeliest, Maximum

Conditions

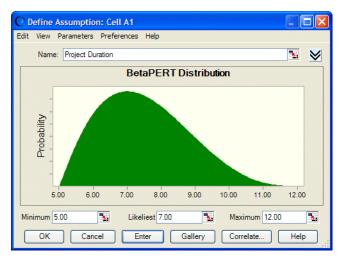
The betaPERT distribution is used under these conditions:

- Minimum and maximum are fixed.
- It has a most likely value in this range, which forms a triangle with the minimum and maximum; betaPERT forms a smoothed curve on the underlying triangle.

BetaPERT Example

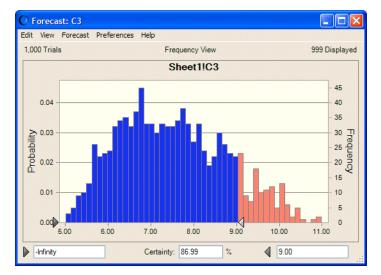
A project manager wants to estimate the probability of finishing a project within 9 days. Similar projects typically take 7 days to finish, but can be finished in 5 days given favorable conditions, and can take as long as 12 days (Figure 83).

Figure 83 BetaPERT Distribution



If that distribution is located in cell A1 and a forecast with formula =A1 is created, simulation results show there is about an 87% probability of the project completing within 9 days (Figure 84 on page 210).

Figure 84 Project Duration Based on BetaPERT Distribution



Binomial Distribution

Subtopics

- Binomial Example
- Binomial Example 2



The binomial distribution is discrete. It describes the number of times a particular event occurs or fails to occur in a fixed number of trials, such as the number of heads in 10 flips of a coin or the number of defective items in 50 items. It can also used for Boolean logic (true/false or on/ off).

Parameters

Probability, Trials

Conditions

The binomial distribution is used under these conditions:

- For each trial, only two outcomes are possible, such as success or failure.
- Trials are independent. Probability is the same from trial to trial.
- The Yes-No distribution is equivalent to the Binomial distribution with one trial.

Binomial Example

You want to describe the number of defective items in a total of 50 manufactured items, 7% of which (on the average) were found to be defective during preliminary testing (Figure 85).

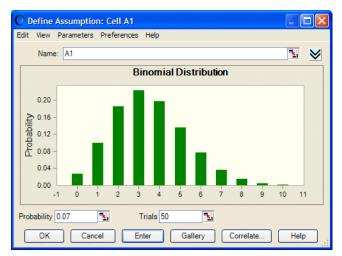


Figure 85 Binomial Distribution

Binomial Example 2

A company's sales manager wants to describe the number of people who prefer the company's product. The manager conducted a survey of 100 consumers (trials) and determined that 60% (0.6, probability of success) prefer the company's product over the competitor's (expressed as a binomial distribution in Crystal Ball.

Custom Distribution



You can use the custom distribution in Crystal Ball to represent a unique situation that cannot be described using other distribution types. It can describe a series of single values, discrete ranges, or continuous ranges.

Parameters

Variable, see "Using the Custom Distribution" on page 231.

Conditions

The custom distribution is used under these conditions:

- It is a flexible distribution, used to represent a situation you cannot describe with other distribution types.
- It can be continuous, discrete, or a combination of both and can be used to input an entire set of data points from a range of cells.

For an example of a custom distribution, see the ClearView tutorial ("Growth Rate Assumption: Custom Distribution" on page 260). Also see "Using the Custom Distribution" on page 231.

Discrete Uniform Distribution



In the discrete uniform distribution, you know the minimum and maximum values and you know that all non-continuous values between the minimum and maximum are equally likely to occur. It can be used to describe a real estate appraisal or a leak in a pipe. It is the discrete equivalent of the continuous uniform distribution ("Uniform Distribution" on page 228).

Parameters

Minimum, Maximum

Conditions

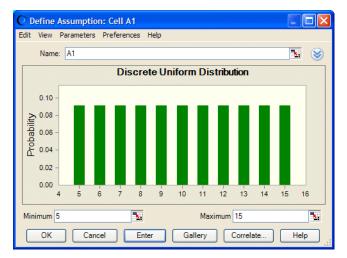
The discrete uniform distribution is used under these conditions:

- Minimum is fixed.
- Maximum is fixed.
- All values in range are equally likely to occur.
- Discrete Uniform is the discrete equivalent of the Uniform distribution.

Discrete Uniform Example

A manufacturer determines that he must receive 10% over production costs—or a minimum of \$5 per unit—to make the manufacturing effort worthwhile. He also wants to set the maximum price for the product at \$15 per unit, so that he can gain a sales advantage by offering the product for less than his nearest competitor. All values between \$5 and \$15 per unit have the same likelihood of being the actual product price, however he wants to limit the price to whole dollars (Figure 86).

Figure 86 Discrete Uniform Distribution



Exponential Distribution

Subtopics

- Exponential Example 1
- Exponential Example 2



The exponential distribution is continuous. It is widely used to describe events recurring at random points in time or space, such as the time between failures of electronic equipment, the time between arrivals at a service booth, incoming phone calls, or repairs needed on a certain stretch of highway. It is related to the Poisson distribution, which describes the number of occurrences of an event in a given interval of time or space.

Parameter

Rate

Conditions

The exponential distribution is used under these conditions:

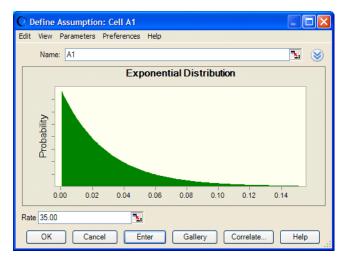
- Distribution describes the time between occurrences.
- Distribution is not affected by previous events.

Exponential Example 1

A travel agency wants to describe the time between incoming telephone calls when the calls are averaging about 35 every 10 minutes, or a rate of 35.

Figure 87 shows a distribution of the probability that *x* number of time units (10 minutes in this case) will pass between calls.

Figure 87 Exponential Distribution



Exponential Example 2

A car dealer needs to know the amount of time between customer drop-ins at his dealership so that he can staff the sales floor more efficiently. The car dealer knows an average of 6 customers visit the dealership every hour. Here, the hourly rate is 6.

Gamma Distribution

Subtopics

- Gamma Example 1
- Chi-square and Erlang Distributions



The gamma distribution is continuous. It applies to a wide range of physical quantities and is related to other distributions: lognormal, exponential, Pascal, Erlang, Poisson, and chi-squared. It is used in meteorological processes to represent pollutant concentrations and precipitation

quantities. The gamma distribution is also used to measure the time between the occurrence of events when the event process is not completely random. Other applications of the gamma distribution include inventory control (such as the demand for an expected number of units sold during the lead time), economics theory, and insurance risk theory.

Parameters

Location, Scale, Shape

Conditions

The gamma distribution is used under these conditions:

- Possible occurrences in any unit of measurement are not limited.
- Occurrences are independent.
- Average numbers of occurrences are constant from unit to unit.

Gamma Example 1

A computer dealership knows that the lead time for re-ordering their most popular computer system is 4 weeks. Based upon an average demand of 1 unit per day, the dealership wants to model the number of business days it will take to sell 20 systems.

The shape parameter is used to specify the *r* th occurrence of the event. In this example, you would enter 20 for the shape parameter (5 units per week times 4 weeks). The result is a distribution showing the probability that *x* number of business days will pass until the 20th system is sold (Figure 88 on page 215).

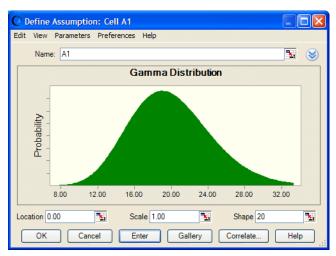


Figure 88 Gamma Distribution

Chi-square and Erlang Distributions

You can model two additional probability distributions, the chi-square and Erlang distributions, by adjusting the parameters entered in the Gamma Distribution dialog. To model the chi-square

distributions with parameters N and S, where N = number of degrees of freedom and S = scale, set the parameters as follows:

Parameter	Symbol
shape =	$\frac{N}{2}$
scale =	$2S^2$

The chi-square distribution is the sum of the squares of *N* normal variates.

The Erlang distribution is identical to the gamma distribution, except the shape parameter is restricted to integer values. Mathematically, the Erlang distribution is a summation of N exponential distributions.

Geometric Distribution

Subtopics

- Geometric Example 1
- Geometric Example 2



The geometric distribution is discrete. It describes the number of trials until the first successful occurrence, such as the number of times you need to spin a roulette wheel before you win or how many wells to drill before you strike oil.

Geometric Parameter

Probability

Geometric Conditions

The geometric distribution is used under these conditions:

- Number of trials is not fixed.
- Trials continue until the first success.
- Probability of success is the same from trial to trial; if there is a 10% probability, this is entered 0.10.

Geometric Example 1

Suppose you are drilling for oil and want to describe the number of dry wells you would drill before the next producing well. Assume that in the past you have hit oil about 10% of the time.

In this example, the value for the Probability parameter is 0.10, representing the 10% probability of discovering oil. You would enter this value as the parameter of the geometric distribution in Crystal Ball (Figure 89) to show the probability of x number of wells drilled before the next producing well.

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	0.02 -		lu.				
	0.00			IIII.			
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Enter

Gallery

Correlate

Figure 89 Geometric Distribution

Geometric Example 2

Cancel

An insurance company wants to describe the number of claims received until a major claim arrives. Records show that 6% of the submitted claims are equal in dollar amount to all the other claims combined.

Help

In this example, the Probability parameter is 0.06 (6%) probability of receiving that major claim.

Hypergeometric Distribution

Subtopics

Probability 0.1

OK

- Hypergeometric Example 1
- Hypergeometric Example 2



The hypergeometric distribution is discrete. It is similar to the binomial distribution. Both describe the number of times a particular event occurs in a fixed number of trials. However, binomial distribution trials are independent, while hypergeometric distribution trials change the success rate for each subsequent trial and are called "trials without replacement". The hypergeometric distribution can be used for sampling problems such as the chance of picking a defective part from a box (without returning parts to the box for the next trial).

Parameters

Success, Trials, Population

Conditions

The hypergeometric distribution is used under these conditions:

- Total number of items (population) is fixed.
- Sample size (number of trials) is a portion of the population.
- Probability of success changes after each trial.

Hypergeometric Example 1

You want to describe the number of consumers in a fixed population who prefer Brand X. You are dealing with a total population of 40 consumers, of which 30 prefer Brand X and 10 prefer Brand Y. You survey 20 of those consumers.

Note: If you have a probability from a different-sized sample instead of a success rate, you can estimate initial success by multiplying the population size by the probability of success. In this example, the probability of success is 75% (.75 x 40 = 30 and 30/40 = .75).

The parameters for this example are a population size of 40, sample size (Trials) of 20, and initial Success of 30 (30 of 40 consumers will prefer Brand X), shown in Figure 90 (the probability that x number of consumers prefer Brand X).

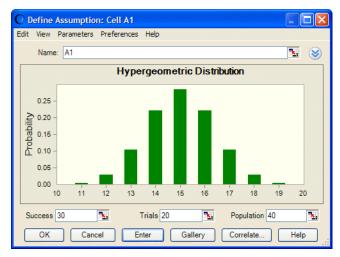


Figure 90 Hypergeometric Distribution

Hypergeometric Example 2

The U.S. Department of the Interior wants to describe the movement of wild horses in Nevada. Researchers in the department travel to a particular area in Nevada to tag 100 horses in a total

population of 1,000. Six months later the researchers return to the same area to find out how many horses remained in the area. The researchers look for tagged horses in a sample of 200.

The parameter values for this hypergeometric distribution are the population size of 1,000, sample size (Trials) of 200, and an initial success rate of 100 out of 1,000 (or a probability of 10% - 0.1 - 0 finding tagged horses. The result would be a distribution showing the probability of observing *x* number of tagged horses.

Logistic Distribution



The logistic distribution is continuous. It is commonly used to describe growth (the size of a population expressed as a function of a time variable). It can also be used to describe chemical reactions and the course of growth for a population or individual.

Parameters

Mean, Scale

Note: The mean parameter is the average value, which for this distribution is the same as the mode, since this is a symmetrical distribution. After you select the mean parameter, you can estimate the scale parameter. The scale parameter is a number greater than 0. The larger the scale parameter, the greater the variance.

Conditions

Conditions and parameters are complex. See: Fishman, G. Springer Series in Operations Research. NY: Springer-Verlag, 1996.

Lognormal Distribution



The lognormal distribution is continuous. It is widely used in situations where values are positively skewed, for example, for determining stock prices, real estate prices, pay scales, and oil reservoir size.

Parameters

Location, Mean, Standard Deviation

By default, the lognormal distribution uses the arithmetic mean and standard deviation. For applications where historical data are available, it is more appropriate to use the logarithmic mean and logarithmic standard deviation or the geometric mean and geometric standard

deviation. These options are available from the Parameters menu in the menu bar. Notice that the location parameter is always in the arithmetic space.

Note: If you have historical data available with which to define a lognormal distribution, it is important to calculate the mean and standard deviation of the logarithms of the data and then enter these log parameters using the Parameters menu (Location, Log Mean, and Log Standard Deviation). Calculating the mean and standard deviation directly on the raw data will not give you the correct lognormal distribution. Alternatively, use the distribution fitting feature described in "Fitting Distributions to Historical Data" on page 41.

For more information on these alternate parameters, see the lognormal distribution section in the *Oracle Crystal Ball Reference and Examples Guide*. For more information about this menu, see "Using Alternate Parameter Sets" on page 39.

Conditions

The lognormal distribution is used under these conditions:

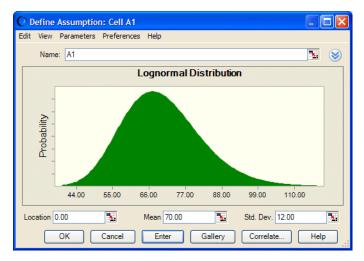
- Upper and lower limits are unlimited, but the uncertain variable cannot fall below the value of the location parameter.
- Distribution is positively skewed, with most values near lower limit.
- Natural logarithm of the distribution is a normal distribution.

Lognormal Example

Suppose you purchase a stock today at \$50. You expect that the stock will be worth \$70 at the end of the year. If the stock price drops at the end of the year, rather than appreciating, you know that the lowest value it can drop to is \$0. On the other hand, the stock could end up with a price much higher than expected, thus implying no upper limit on the rate of return. In summary, the losses are limited to the original investment, but the gains are unlimited. Using historical data, you can determine that the standard deviation of the stock's price is \$12.

Figure 91 shows a lognormal distribution with the mean parameter is set at \$70.00 and the standard deviation set at \$12.00. The default location is 0, which works for this example. This distribution shows the probability that the stock price will be x.

Figure 91 Lognormal Distribution



Maximum Extreme Distribution



The maximum extreme distribution is continuous. It is commonly used to describe the largest value of a response over a period of time: for example, in flood flows, rainfall, and earthquakes. Other applications include the breaking strengths of materials, construction design, and aircraft loads and tolerances. This distribution is also known as the Gumbel distribution. and is closely related to the minimum extreme distribution, its "mirror image".

Parameters

Likeliest, Scale

Note: After you select the Likeliest parameter, you can estimate the Scale parameter. The Scale parameter is a number greater than 0. The larger the Scale parameter, the greater the variance.

Conditions

Conditions and parameters are complex. See: Castillo, Enrique. *Extreme Value Theory in Engineering*. London: Academic Press, 1988.

Minimum Extreme Distribution



The minimum extreme distribution is continuous. It is commonly used to describe the smallest value of a response over a period of time: for example, rainfall during a drought. This distribution is closely related to the maximum extreme distribution.

Parameters

Likeliest, Scale

Note: After you select the Likeliest parameter, you can estimate the Scale parameter. The Scale parameter is a number greater than 0. The larger the Scale parameter, the greater the variance.

Conditions

Conditions and parameters are complex. See: Castillo, Enrique. *Extreme Value Theory in Engineering*. London: Academic Press, 1988.

Negative Binomial Distribution



The negative binomial distribution is discrete. It is useful for modeling the distribution of the number of trials until the *r*th successful occurrence, such as the number of sales calls you need to make to close ten orders. It is essentially a super-distribution of the geometric distribution.

Parameters

Probability, Shape

Conditions

The negative binomial distribution is used under these conditions:

- Number of trials is not fixed.
- Trials continue to the *r*th success (trials never less than *r*).
- Probability of success is the same from trial to trial.

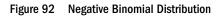
Some characteristics of the negative binomial distribution:

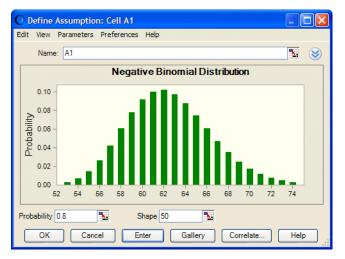
- When Shape = 1, the negative binomial distribution becomes the geometric distribution.
- The sum of any two negative binomial distributed variables is a negative binomial variable.
- Another form of the negative binomial distribution, sometimes found in textbooks, considers only the total number of failures until the r th successful occurrence, not the total number of trials. To model this form of the distribution, subtract out *r* (the value of the shape parameter) from the assumption value using a formula in the worksheet.

Negative Binomial Example

A manufacturer of jet engine turbines has an order to produce 50 turbines. Since about 20% of the turbines do not make it past the high-velocity spin test, the manufacturer will actually have to produce more than 50 turbines.

The negative binomial distribution has two parameters: Probability and Shape. The Shape parameter specifies the *r* th successful occurrence. In this example you would enter 0.8 for the Probability parameter (80% success rate of the spin test) and 50 for the Shape parameter (Figure 92).





Normal Distribution



The normal distribution is continuous It is the most important distribution in probability theory because it describes many natural phenomena, such as people's IQs or heights and the reproductive rates of animals. Decision-makers can use the normal distribution to describe uncertain variables such as the inflation rate or the future price of gasoline.

Parameters

Mean, Standard Deviation

Note: Of the values of a normal distribution, approximately 68% are within 1 standard deviation on either side of the mean. The standard deviation is the square root of the average squared distance of values from the mean.

Conditions

The normal distribution is used under these conditions:

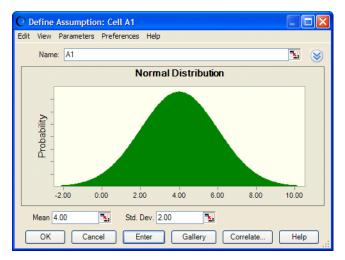
- Mean value is most likely.
- It is symmetrical about the mean.
- More likely to be close to the mean than far away.

Normal Example

The normal distribution can be used to describe future inflation. You believe that 4% is the most likely rate. You are willing to bet that the inflation rate could as likely be above 4% as it could be below. You are also willing to bet that the inflation rate has a 68% chance of falling somewhere within 2% of the 4% rate. That is, you estimate there is approximately a two-thirds chance that the rate of inflation will be between 2% and 6%.

The normal distribution uses two parameters: Mean and Standard Deviation. Figure 93 shows the values from the example entered as parameters of the normal distribution in Crystal Ball: a mean of 0.04 (4%) and a standard deviation of 0.02 (2%). The distribution shows the probability of the inflation rate being a particular percentage.

Figure 93 Normal Distribution



Pareto Distribution



The Pareto distribution is continuous. It is widely used for the investigation of other distributions associated with such empirical phenomena as city population sizes, the occurrence of natural resources, the size of companies, personal incomes, stock price fluctuations, and error clustering in communication circuits.

Parameters

Location, Shape

Note: The Location parameter is the lower bound for the variable. After you select the Location parameter, you can estimate the Shape parameter. The Shape parameter is a number greater than 0, usually greater than 1. The larger the Shape parameter, the smaller the variance and the thicker the right tail of the distribution.

Conditions

Conditions and parameters are complex. See: Fishman, G. Springer Series in Operations Research. NY: Springer-Verlag, 1996.

Poisson Distribution



The Poisson distribution is discrete. It describes the number of times an event occurs in a given interval (usually time), such as the number of telephone calls per minute, the number of errors per page in a document, or the number of defects per 100 yards of material.

Parameter

Rate

Conditions

The Poisson distribution is used under these conditions:

- Number of possible occurrences is not limited.
- Occurrences are independent.
- Average number of occurrences is the same from unit to unit.

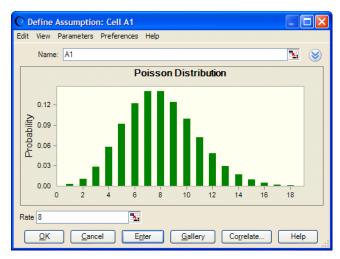
Poisson Example 1

An aerospace company wants to determine the number of defects per 100 square yards of carbon fiber material when the defects occur an average of 8 times per 100 square yards.

The Poisson distribution has only one parameter, Rate, and the value for this parameter is 8 (defects).

Figure 94 shows the probability of observing x number of defects in 100 square yards of the carbon fiber material.

Figure 94 Poisson Distribution



The size of the interval to which the rate applies, 100 square yards in this example, has no bearing on the probability distribution; the rate is the only key factor. If needed for modeling a situation, information on the size of the interval must be encoded in the spreadsheet formulas.

Student's t Distribution



The Student's *t* distribution is continuous. It is used to describe small sets of empirical data that resemble a normal curve, but with thicker tails (more outliers). It is often used for econometric data and exchange rates.

Parameters

Midpoint, Scale, Degrees of Freedom

Note: The Midpoint parameter is the central location of the distribution (also mode), the *x*-axis value where you want to place the peak of the distribution. The Degrees of Freedom parameter controls the shape of the distribution. Smaller values result in thicker tails and less mass in the center. The Scale parameter affects the width of the distribution by increasing the variance without affecting the overall shape and proportions of the curve. Scale can be used to widen the curve for easier reading and interpretation. For example, if the midpoint were a large number, say 5000, the scale could be proportionately larger than if the midpoint were 500.

Conditions

The Student's *t* distribution is used under these conditions:

- Midpoint value is most likely.
- It is symmetrical about the mean.

Note: When degrees of freedom are greater than 30, the normal distribution can be used to approximate the Student's *t* distribution.

Example

For examples, see "Normal Distribution" on page 223. The uses are the same except that the sample degrees of freedom will be < 30 for the Student's *t* distribution.

Triangular Distribution

Subtopics

- Triangular Example 1
- Triangular Example 2



The triangular distribution is continuous. It describes a situation where you know the minimum, maximum, and most likely values to occur. It is useful with limited data in situations such as sales estimates, the number of cars sold in a week, inventory numbers, and marketing costs. For example, you could describe the number of cars sold per week when past sales show the minimum, maximum, and usual number of cars sold.

Parameters

Minimum, Likeliest, Maximum

Conditions

The triangular distribution is used under these conditions:

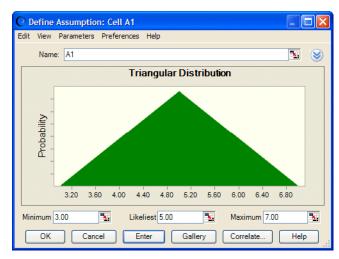
- Minimum and maximum are fixed.
- It has a most likely value in this range, which forms a triangle with the minimum and maximum.

Triangular Example 1

An owner needs to describe the amount of gasoline sold per week by his filling station. Past sales records show that a minimum of 3,000 gallons to a maximum of 7,000 gallons are sold per week, with most weeks showing sales of 5,000 gallons. The triangular distribution in this example has three parameters: 3,000 (Minimum), 5,000 (Likeliest), and 7,000 (Maximum).

Figure 95 on page 228 shows the probability of selling *x* number of gallons per week.

Figure 95 Triangular Distribution



Triangular Example 2

The triangular distribution also could be used to approximate a computer-controlled inventory situation. The computer is programmed to keep an ideal supply of 25 items on the shelf (Likeliest), always keep inventory at 10 items or more (Minimum), and prevent inventory from ever rising above 30 items (Maximum).

The result would be a distribution showing the probability of *x* number of items in inventory.

Uniform Distribution

Uniform

The uniform distribution is continuous. In the uniform distribution, you know the range between the minimum and maximum values and you know that all values in the range are equally likely to occur. It can be used to describe a real estate appraisal or a leak in a pipe.

Parameters

Minimum, Maximum

Conditions

The uniform distribution is used under these conditions:

- Minimum is fixed.
- Maximum is fixed.
- All values in range are equally likely to occur.
- Discrete uniform is the discrete equivalent of the uniform distribution.

Uniform Example

An investment company interested in purchasing a parcel of prime commercial real estate wants to describe the appraised value of the property. The company expects an appraisal of at least \$500,000 but not more than \$900,000. They believe that all values between \$500,000 and \$900,000 have the same likelihood of being the actual appraised value.

This uniform distribution has two parameters: the Minimum (\$500,000) and the Maximum (\$900,000), as in Figure 96. All values between \$500,000 and \$900,000 are equally possible.

Figure 96 Uniform Distribution



Weibull Distribution



The Weibull distribution is continuous. It describes data resulting from fatigue tests and can be used to describe failure time in reliability studies or the breaking strengths of materials in reliability and quality control tests. Weibull distributions are also used to represent various physical quantities, such as wind speed.

Parameters

Location, Scale, Shape

Conditions

This flexible distribution can assume the properties of other distributions. When the shape parameter is equal to 1.0, the Weibull distribution is identical to the exponential distribution. The location parameter lets you set up an exponential distribution to start at a location other than 0.0. When the shape parameter is less than 1.0, the Weibull distribution becomes a steeply declining curve. A manufacturer may find this effect useful in describing part failures during a burn-in period.

When shape parameters equal 1, it is identical to Exponential; when equal to 2, it is identical to Rayleigh.

Weibull Example

A lawn mower company is testing its products. They run 20 mowers, and keep track of how many hours each mower runs until its first breakdown. They use a Weibull distribution to describe the number of hours until the first failure.

Yes-No Distribution



The yes-no distribution, also called the Bernoulli distribution, is a discrete distribution that describes a set of observations that can have only one of two values, such as yes or no, success or failure, true or false, or heads or tails.

The following sections describe the parameters, conditions, and other features of this distribution:

Parameters

Probability of Yes (1)

Conditions

The yes-no distribution is used under these conditions:

- For each trial, only 2 outcomes are possible, such as success or failure; the random variable can have only one of two values, for example, 0 and 1.
- The mean is p, or probability (0 .
- Trials are independent. Probability is the same from trial to trial.
- The Yes-No distribution is equivalent to the Binomial distribution with one trial.

Yes-No Example

A machine shop produces complex high-tolerance parts with a .02 probability of failure and a . 98 probability of success. If a single part is pulled from the line, Figure 97 shows the probability that the part is good.

Figure 97 Probability of Pulling a Good Part

O Define Assu	mption: Cell A1		
Edit View Para	meters Preferences Help		
Name: A1			N
	Yes-No D	istribution	
1.00 -			
0.80 -			
0.60 - 40 - 0.40 -			
원 0.40 -			
0.20 -			
0.00	0	1	2
	, , , , , , , , , , , , , , , , , , ,	· ·	-
Probability of Yes	s(1) 0.98 5		
ОК	Cancel Enter	Gallery Correlate	e Help

Using the Custom Distribution

Subtopics

- Custom Distribution Example 1 Loading Weighted Data
- Custom Distribution Example 2 Loading Mixed Data
- Other Important Custom Distribution Notes



If none of the provided distributions fits the data, you can use the custom distribution to define one. For example, a custom distribution can be especially helpful if different ranges of values have specific probabilities. You can create a distribution of one shape for one range of values and a different distribution for another range. You can describe a series of single values, discrete ranges, or continuous ranges. This section uses real-world examples to describe the custom distribution.

Since it is easier to understand how the custom distribution works with a hands-on example, you may want to start Crystal Ball and use it to follow the examples. To follow the custom distribution examples, first create a new Microsoft Excel workbook then select cells as specified.

For additional information see the listed topics and the *Oracle Crystal Ball Reference and Examples Guide*. Also see "Growth Rate Assumption: Custom Distribution" on page 260.

Custom Distribution Example 1 – Loading Weighted Data

This example describes a special feature in the **Custom Distribution** dialog: the **Load Data** button, which pulls numbers from a specified cell range (grouped data) on the worksheet.

In this example, a company wants to create a custom distribution with six values. Because each value has a different probability of occurring, the values are described as "weighted". The data

is arranged in a two-column table in Microsoft Excel (Figure 98 on page 232). The first column contains values and the second column contains the probability (weight) for each value.

Figure 98 Single Values with Different Probabilities (Weighted Values)

	Α	В		
10	Value	Weight or Probability		
11	2	1		
12	5	6		
13	7	5		
14	8	3		
15	10	8		
16	11	1		

- > To create a custom distribution by loading this data:
- **1** Select a blank cell, and then select **Define Assumption**.
- 2 In the **Distribution Gallery**, select **Custom**.
- 3 In the Define Assumption dialog, select Parameters, and then Weighted Values.
- 4 Click the More button beside the Name text box.

The **Custom Distribution** dialog expands to include a two-column data table.

5 Since the values are already on the worksheet, you can click **Load Data** to enter them into the **Custom Distribution** dialog.

The Load Data dialog opens.

The default settings are appropriate for most purposes, but the following other options are available:

- When loading unlinked data, you can choose to replace the current distribution with the new data or append new data to the existing distribution.
- If probabilities are entered cumulatively into the spreadsheet you are loading, select **Probabilities are cumulative**. Then, Crystal Ball determines the probabilities for each range by subtracting the previous probability from the one entered for the current range. You can select **View**, and then **Cumulative Probability** to display the data cumulatively in the assumption chart.
- 6 Enter a location range for the data, in this case A1:B16. If the range has a name, you can enter the name preceded by an = sign.
- 7 When all settings are correct, click **OK**.

Crystal Ball enters the values from the specified range into the custom distribution and plots the specified ranges, as shown in Figure 99 on page 233.

For more information about entering tables of data into custom distributions, see "Custom Distribution Example 2 — Loading Mixed Data" on page 233 and the probability distribution information in the Oracle Crystal Ball Reference and Examples Guide.

Figure 99 Weighted Values Loaded in a Custom Distribution

	mption: Cell A7		
Edit View Para	meters Preference	es Help	
Name: A7	7		N 😣
		Custom Distribution	
8.000 - 0.00 - 0	3.30 4.40	5.50 6.60 7.70 8.80 9.90	11.00
Value	Probability	Load D	lata
▶ 2.00	1.0		a.a
5.00	6.0	Linked to:	
7.00	5.0	=A11:B16	
8.00	3.0		
10.00	8.0		
11.00	1.0		
ОК	Cancel	Enter Gallery Correlate	Help

Custom Distribution Example 2 – Loading Mixed Data

In this example, a company decides that the unit cost of a new product can vary widely. The company feels it has a 20% chance of being any number between \$10 and \$20, a 10% chance of being any number between \$20 and \$30, a 30% chance of being any number between \$40 and \$50, a 30% chance of being a whole dollar amount between \$60 and \$80, and there is a 5% chance the value will be either \$90 or \$100. All the values have been entered on the worksheet in this order: range minimum value, range maximum value (for all but **Single Value** ranges), total probability, and step (for the **Discrete Range** only) as shown in Figure 100.

📲 Book1 📃 🗖 🗙										
	A	B	С	D	E	F	G	~		
1	Minimum	Maximum	Prob.	Step						
2	\$10	\$20	0.2			Continuous	5			
3	\$20	\$30	0.1			Continuous				
4	\$40	\$50	0.3			Continuous	5			
5	\$60	\$80	0.3	1		Discrete				
6	\$90		0.05			Single Val	ue			
7	\$100		0.05			Single Val	ue			
8								-		
H + H Sheet1 / Sheet2 / Sheet3 / <										

Figure 100 Four-column Custom Data Range

So, you can create an assumption, select **Custom Distribution**, and then select **Parameters**, and then **Discrete Ranges** before loading the data.

- > To complete the data load:
- 1 Create an assumption, select **Custom Distribution**, and then select **Parameters**, and then **Discrete Ranges** before loading the data.

In this example, discrete ranges have the most parameters. so that parameter setting was selected. If the data also included discrete sloping ranges, you could select **Parameters**, and then **Sloping Ranges** before loading the data. The data table would then have five columns and could accommodate all data types.

- 2 Click the More button to expand the Define Assumption dialog and include a data table.
- 3 Since the values are already on the worksheet, you can click **Load Data** to enter them into the **Custom Distribution** dialog.
- 4 Enter a location range for the data, in this case A2 : D7.
- 5 When all settings are correct, click **OK**.

Crystal Ball enters the values from the specified range into the custom distribution and plots the specified ranges, as shown in Figure 101.

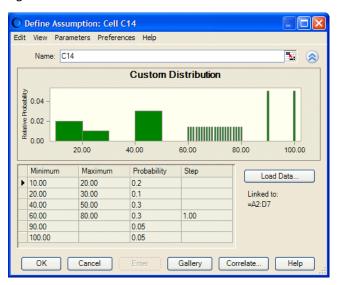


Figure 101 Custom Data from Worksheet

For more additional examples, see the probability distribution information in the *Oracle Crystal Ball Reference and Examples Guide*.

Other Important Custom Distribution Notes

Even if you do not load data from the spreadsheet into the Custom Distribution dialog, you can

still add and edit data using the data table. To do this, click the **More** button, **Solution**, to display the data table. Then, you can:

- Enter a different value in the data table and click **Enter** to change the data.
- Type the minimum, maximum, probability, and step (if discrete data) into a blank row and click **Enter** to add new data.
- To delete a single range of data, select that row of data, right-click, and select **Delete Row**.

- To clear all data rows, right-click within the data table and select **Clear Distribution**.
- •
- •

To delete a single range of data without using the data table, click the range to select it and either:

- Set the Probability or Height of Min. and Height of Max. to 0, or
- Select **Edit**, and then **Delete Row** or right-click and select **Delete Row**.

Truncating Distributions

You can change the bounds or limits of each distribution, except the custom distribution, by dragging the truncation grabbers or by entering different numeric endpoints for the truncation grabbers. This truncates (cuts off) the distribution. You can also exclude a middle area of a distribution by crossing over the truncation grabbers to highlight the portion to exclude.

Note: To display the truncation grabbers, open an assumption in the **Define Assumption** dialog and click the **More** button beside the assumption name text box.

For example, suppose you want to describe the selling price of a house up for auction after foreclosure. The bank that holds the mortgage will not sell for less than \$80,000. They expect the bids to be normally distributed around \$100,000 with a standard deviation of \$15,000. In Crystal Ball, you can specify the mean as 100,000 and the standard deviation as 15,000 and then move the first (left) grabber to set the limit of 80,000. The grabber highlights the portion to exclude, as shown in Figure 102.

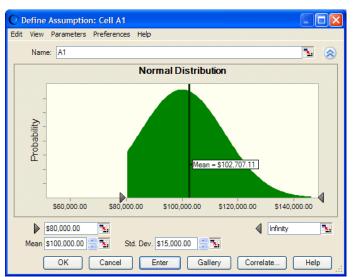


Figure 102 Truncated Distribution Example

Truncation Cautions

Each adjustment changes the characteristics of the probability distribution. For example, the truncated normal distribution in Figure 102 will no longer have an actual mean of \$100,000 and standard deviation of \$15,000. Also, statistics values will be approximate for truncated distributions.

When using alternate percentile parameters, the actual percentiles calculated for a truncated distribution will differ from the specified parameter values. For example, a normal distribution specified with 10th/90th percentiles and truncated on either side of the distribution will have actual 10th/90th percentiles greater or less than the specified percentiles.

Showing the mean line of the distribution is useful when truncating distributions. However, the mean line value may differ from the Mean parameter text box. The mean line shows the actual mean of the truncated distribution while the Mean parameter text box shows the mean of the complete distribution.

Distribution Parameter Summary

The following table lists valid parameter values for each Crystal Ball distribution. Distributions are listed alphabetically by type (continuous or discrete). The *Oracle Crystal Ball Reference and Examples Guide* lists defaults for each parameter value.

Distribution		Туре	Parameter 1	Parameter 2	Parameter 3	Parameter 4
Beta	Beta	continuous	alpha (greater than 0.3, alpha + beta must be less than 1000)	beta (greater than 0.3, alpha + beta must be less than 1000)	maximum value	minimum value
BetaPERT	BetaPERT	continuous	minimum value	likeliest value	maximum value	N/A
Exponential	Exponential	continuous	rate (greater than 0)	N/A	N/A	N/A
Gamma	Gamma	continuous	location	scale (greater than 0)	shape (greater than 0.05 and less than 1000)	N/A
Logistic	Logistic	continuous	mean value	scale (greater than 0)	N/A	N/A
Lognormal	Lognormal	continuous	location	mean value	standard deviation value	N/A

Table 11 Distributions and Their Parameters

Distribution		Туре	Parameter 1	Parameter 2	Parameter 3	Parameter 4
Maximum extreme	Max Extreme	continuous	likeliest	scale (greater than 0)	N/A	N/A
Minimum extreme	Min Extreme	continuous	likeliest	scale (greater than 0)	N/A	N/A
Normal	Normal	continuous	mean value	standard deviation value	N/A	N/A
Pareto	Pareto	continuous	location (greater than 0)	shape (greater than 0. 05)	N/A	N/A
Student's t	Student's t	continuous	midpoint	scale (greater than 0)	degrees of freedom (integer between 1 and 30, inclusive)	N/A
Triangular	Triangular	continuous	minimum value	likeliest value	maximum value	N/A
Uniform	Uniform	continuous	minimum value	maximum value	N/A	N/A
Weibull	Weibull	continuous	location	scale (greater than 0)	shape (greater than 0.05)	N/A
Binomial	Binomial	discrete	probability (between O and 1)	trials (a whole number greater than 0 and less than 1e9)	N/A	N/A
Discrete Uniform	Discrete Uniform	discrete	minimum (integer)	maximum (integer)	N/A	N/A
Geometric	Geometric	discrete	probability (between O and 1)	N/A	N/A	N/A
Hyper- geometric	Hypergeometric	discrete	SUCCESS	trials (whole number less than population)	population (whole number greater than 0 and less than 1000)	N/A

Distribution		Туре	Parameter 1	Parameter 2	Parameter 3	Parameter 4
Negative binomial	Neg Binomial	discrete	probability (between 0 and 1)	shape (whole number greater than 0 and less than 1000)	N/A	N/A
Poisson	Poisson	discrete	rate value (between 0 and 1e9)	N/A	N/A	N/A
Yes-No	Yes-No	discrete	probability (between 0 and 1)	N/A	N/A	N/A
Custom	Custom	custom	See Appendix A of the current Oracle Crystal Ball User's Guide.	N/A	N/A	N/A

Using Probability Functions

For each of the Crystal Ball distributions, there is an equivalent Microsoft Excel function. You can enter these functions in the spreadsheet directly instead of defining distributions using the Define Assumption command. Be aware, though, that these functions have a number of limitations. For details, see "Limitations of Probability Functions" on page 239.

Also see "Probability Functions and Random Seeds" on page 239 for information about setting a random seed so probability functions can have comparable values.

- To view these functions and their parameters, select Insert, and then Function in Microsoft Excel, and then be sure the category is set to Crystal Ball (Figure 103, following).
- (In Microsoft Excel 2007 or later, select **Formulas**, and then **Insert Function**.)

Figure 103 Crystal Ball Functions in Microsoft Excel

Insert Function						
Search for a function:						
Type a brief description of what you want to do and then dick Go						
Or select a <u>c</u> ategory: Crystal Ball						
Select a function:						
CB.Beta CB.Beta2						
CB.BetaPert						
CB.Binomial CB.Custom						
CB.CustomCumul						
CB.DiscreteUniform						
CB.BetaPert(Minimum,Likeliest,Maximum,LowCutoff,) Returns a random number for the BetaPert distribution						
Help on this function OK Cancel						

Parameters and a brief description are displayed below the list of functions. The **Cutoff** parameters indicate truncation values, while **NameOf** is the assumption name. For parameter descriptions and details on each distribution, see the entry for that distribution earlier in this appendix.

Note: The beta distribution is now different from versions earlier than Crystal Ball 7.0. Both the original and revised functions are displayed for compatibility. CB.Beta has three parameters but CB.Beta2 is the current Crystal Ball version with Minimum and Maximum instead of Scale.

Limitations of Probability Functions

Distributions defined with probability functions differ from those entered with the Define Assumption command in these ways:

- You cannot correlate them.
- You cannot view charts or statistics on them.
- You cannot extract data from them or include them in reports.
- They are not included in sensitivity analyses or charts.
- Latin Hypercube sampling is not supported.

Probability Functions and Random Seeds

"Setting Sampling Preferences" on page 73 describes how you can use the Sampling tab of the Run Preferences dialog to use the same sequence of random numbers for each simulation.

If you use **Define**, and then **Define Assumption** or the **Define Assumption** toolbar button to define assumptions, the same sequence of random numbers is used for each simulation, even if you switch from Extreme speed to Normal speed or back to Extreme speed. If you use the probability functions to define assumptions, one sequence of random numbers is used for Extreme speed and a different sequence is used for Normal speed.

Sequential Sampling with Custom Distributions

The probability distributions supplied with Crystal Ball are useful in a variety of modeling situations. Organizations may still want to prepare their own libraries of distributions based on data specific to their applications and situations. One such system involves libraries of stochastic information packets (SIPs), an approach set forth in the article "Probability Management" (see the 2006 reference by S. Savage et al. in the Crystal Ball bibliography in the *Oracle Crystal Ball Reference and Examples Guide*.

A SIP is a list of time- or order-sensitive values for a particular variable. These values are sampled as sequential trials during a Monte Carlo simulation. SIPs are used to preserve the correlation structure between SIP variables without having to explicitly compute and define a matrix of correlation coefficients.

SIPs can be represented by custom distributions in Crystal Ball and can then be published and shared by organizations using Crystal Ball's Publish and Subscribe features in the Distribution Gallery.

For details, see the Oracle Crystal Ball Reference and Examples Guide.



Extreme Speed Compatibility Issues

In This Appendix

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Compatibility Issues	242

Introduction

Extreme speed, available in Crystal Ball Decision Optimizer, runs simulations up to 100 times faster than Normal speed. Extreme speed makes it more practical to run many simulation trials, use Crystal Ball tools that run multisimulations, or seek optimal solutions with OptQuest in a reasonable length of time.

The Extreme Speed feature uses PSI Technology, a high-speed, Microsoft Excel-compatible Polymorphic Spreadsheet Interpreter for running simulations on workbooks. This technology was developed by Frontline Systems, the maker of Microsoft Excel's Solver add-in. PSI Technology supports nearly all of the 320 standard Microsoft Excel functions, including the financial, statistical, and engineering functions that are part of the Analysis Toolpak.

By default, Oracle Crystal Ball Decision Optimizer is set to use Extreme speed when initially loaded. If a model is not compatible with Extreme speed, a dialog offers the opportunity to downshift to Normal speed temporarily for that simulation. "Compatibility Issues" on page 242 explains conditions that cause a model to be incompatible with Extreme speed. The simulation speed can be changed using the Speed tab in the Run Preferences dialogs ("Setting Speed Preferences" on page 73).

Note: Because the Extreme Speed feature uses the Polymorphic Spreadsheet Interpreter, certain Extreme Speed functions may return slightly different results than the corresponding Microsoft Excel function for extreme values of any input arguments. For example, this can occur with statistical and inverse distribution functions.

For a discussion of these differences and other information about Extreme Speed, see the *Oracle Crystal Ball Reference and Examples Guide*.

Compatibility Issues

Subtopics

- Multiple-Workbook Models
- Circular References
- Crystal Ball Microsoft Excel Functions
- User-Defined Functions and Macros
- Special Functions
- Undocumented Behavior of Standard Functions
- Incompatible Range Constructs

While Extreme speed can greatly decrease simulation run times, not all models are compatible with Extreme speed. When you start a simulation, Crystal Ball detects if the spreadsheet is compatible with Extreme speed and warns you if it is incompatible. If you choose, you can run the simulation in Normal speed using standard Microsoft Excel, or you can change the spreadsheet model to correct the incompatibility.

It is important to notice that incompatibilities in functions and formula constructs only concern the cells involved in the calculation of a forecast cell. If cells that are not part of that calculation path have incompatibilities, these are not detected and the simulation is allowed to run.

Multiple-Workbook Models

Extreme speed can now run simulations on multiple workbooks. If you are running in Extreme speed and the workbook contains external references to cells in other closed workbooks, Crystal Ball obtains the current value from those workbooks. References to cells in other open workbooks are dynamically updated if those cells depend on one or more assumptions. If the external reference is part of a formula (not a simple external reference), this is not compatible with Extreme speed:

- Example message: "Unable to interpret formula at cell location [Book1.xls]Sheet1!A1. (Code #5524 Complex external reference)"
- Workaround: If possible, consolidate all of the variables and formulas from a multipleworkbook model containing Crystal Ball data into a single workbook.

Circular References

Circular references within a model are supported as long as Iteration is selected on the Tools, then Options, then Calculation tab in Microsoft Excel.

(In Microsoft Excel 2007 or later, click the Office button and select Microsoft Excel Options, then Formulas, and then select Enable Iterative Calculation in the Calculation Options group.)

If Crystal Ball detects a circular reference and Iteration is not selected, this error is displayed:

• Example message: "Circular reference detected at cell [Book1.xls]Sheet1! A1. (Code #5523)"

• Workaround: Stop the simulation and select Iteration on the Tools, then Options, then Calculation tab.

In Extreme speed, circular references with short Iteration setting may not match Microsoft Excel's values because of differences in calculation algorithms. For most consistent results, set Iteration to at least 1,000.

However, if a circular reference is non-converging, its results can differ greatly when run at both Extreme and Normal speed, regardless of the Iteration setting. If a circular reference is non-converging, this error message is displayed:

- Example message: "Unable to run in Extreme speed for the following reason: Circular references do not converge, results cannot be guaranteed to match Normal speed. To bypass this message, turn off "Stop on calculation errors" in the Run Preferences dialog. (Code #5545)"
- Workaround: There is no workaround. Review the formulas in the workbook that have created this circular reference and look for a problem that keeps this circular reference from converging to a single value.

Simulations with circular references run in non-vectorized mode. For this reason, they will probably run more slowly than simulations without circular references.

Crystal Ball Microsoft Excel Functions

The following Crystal Ball spreadsheet functions are handled normally:

- CB.IterationsFN
- distribution functions (such as CB.Binomial)

These functions are not supported in Extreme speed during a simulation:

- CB.GetForeStatFN
- CB.GetForePercentFN
- CB.GetRunPrefsFN
- CB.GetAssumPercentFN
- CB.GetCertaintyFN

While running in Extreme speed, all values for these functions return #VALUE. At the end of the simulation, Crystal Ball performs a final recalculation on the model so these functions are evaluated properly. Normally, this should not present a problem unless one of these functions was defined as a forecast and you are expecting a valid value to be computed during the simulation. If one of these Get functions feeds into a forecast during a simulation, this is not compatible with Extreme speed:

• Example message: "Unsupported Microsoft Excel or Crystal Ball function at cell location [Book1.xls]Sheet1!A1. (Code #5539)"

• Workaround: Defining forecasts on statistical functions that are dependent on other forecasts is generally not a good modeling practice. If you need to have a forecast cell defined on a statistical result from another forecast, use the Auto Extract feature for the dependent forecast instead of using one of the above Crystal Ball functions.

User-Defined Functions and Macros

Calls to user-defined or third-party functions are allowed. The functions may be written in Visual Basic or they may be in XLL or COM Automation DLL libraries that have been opened in Microsoft Excel. To be compatible with Extreme Speed, user-defined functions must be "pure". A pure function is one that computes its value solely on the basis of values passed to it as arguments. Range arguments in user-defined functions are only compatible with Extreme Speed when they are handled as Variant types. User-defined functions whose arguments are static (their values do not change during a simulation) are not called by Extreme Speed unless the Volatile property of the function has been set.

User-defined macros cannot be run during a simulation in Extreme speed, only before or after.

For details on these issues and more information about using user-defined functions and macros with Extreme speed, see the *Oracle Crystal Ball Reference and Examples Guide*.

Special Functions

A small group of Microsoft Excel functions are not supported in Extreme speed: CALL, CELL, GETPIVOTDATA, INFO, HYPERLINK, REGISTER.ID, and the CUBE functions added in Microsoft Excel 2007 or later (CUBEMEMBER, CUBEVALUE, CUBESET, CUBESETCOUNT, CUBERANKEDMEMBER, CUBEMEMBERPROPERTY, CUBEKPIMEMBER). Any forecast formulas that contain one or more of these functions will be flagged as incompatible:

- Example message: "Unsupported Microsoft Excel or Crystal Ball function at cell location [Book1.xls]Sheet1!A1. (Code #5539)"
- Workaround: Avoid using these functions if you want to run the model in Extreme speed.

Undocumented Behavior of Standard Functions

Microsoft Excel allows certain undocumented argument constructs for standard functions. Some of these constructs that were previously unsupported in Extreme speed are now allowed, for example:

```
=SUMPRODUCT(A1:A10*B1:B10)
=SUMPRODUCT(A1:A10/B1:B10)
```

However, some of these argument constructs are still not supported in Extreme speed and will be flagged as incompatible:

- Example message: "Unsupported Microsoft Excel or Crystal Ball function at cell location [Book1.xls]Sheet1!A1. (Code #5539)"
- Workaround: For best results, always use standard syntax with fully valid arguments.

Incompatible Range Constructs

The following sections discuss Microsoft Excel range constructs that are not supported in Extreme speed:

- "Dynamic Ranges" on page 245
- "Labels in Formulas That Are Not Defined Names" on page 245
- "Multiple Area References" on page 245
- "3-D References" on page 246

Dynamic Ranges

Extreme speed does not support dynamic ranges, where the OFFSET function is used on one or both sides of the range constructor. For example, =AVERAGE(Cellname1:OFFSET(Cellname2, x, y)).

- Example message: "Unable to interpret formula at cell location [Book1.xls]Sheet1!A1. (Code #5504 Invalid token)"
- Workaround: Avoid using the OFFSET function to construct dynamic ranges.

Labels in Formulas That Are Not Defined Names

Extreme speed supports defined names and their use in formulas, but not the Microsoft Excel **Accept labels in formulas** option which allows cell labels to be used in formulas without defining them as names:

- Example message: "Unable to interpret formula at cell location [Book1.xls]Sheet1!A1. (Code #5514 Undefined identifier)"
- Workaround: For best results, use defined names instead of cell labels in formulas.

Multiple Area References

Extreme speed does not support multiple-area references such as (A1:A5,B1,C1:E1) except as used in standard functions such as SUM that accept a variable-length argument list of cell ranges. The only supported use of the comma is as the separator in the argument list of a standard function, not as a cell-range union operator. A defined name whose value is a multiple-area reference is not accepted:

- Example message: "Multi-area reference not supported at cell location [Book1.xls]Sheet1!A1. (Code #5525)"
- Workaround: For best results, avoid using multiple-area references when defining names or as arguments to any functions except those that accept a variable-length, comma-separated list of cell ranges.

3-D References

Extreme speed does not support 3-D references, where a cell range – used as an argument in a function call, for example – spans multiple workbooks:

- Example message: "Unable to interpret formula at cell location [Book1.xls]Sheet1!A1. ("Code #5514 Undefined identifier")"
- Workaround: For best results, avoid using 3-D cell references.

С

Crystal Ball Tutorials

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Tutorial 2 – Vision Research	254

Introduction

This appendix presents the basics you need to understand how Crystal Ball can be used to analyze uncertainty in two financial settings, a process improvement setting, and a product design setting.

- "Tutorial 1 Futura Apartments" on page 247 is ready to run so you can quickly see how Crystal Ball works. If you work regularly with statistics and forecasting techniques, this may be all the introduction you need before running spreadsheets with Crystal Ball.
- "Tutorial 2 Vision Research" on page 254 teaches more about defining and running simulations and interpreting their results.

The Oracle Crystal Ball Reference and Examples Guide has two additional tutorials showing how Crystal Ball supports process quality.

Tutorial 1 – Futura Apartments

This tutorial contains the following sections:

- "Starting Crystal Ball" on page 248
- "Opening the Example Model" on page 248
- "Running Simulations" on page 249
- "Results Analysis Determining Profit" on page 250
- "Take a Look Behind the Scenes" on page 251
- "Resetting and Single-Stepping" on page 253
- "Tutorial Review" on page 254

Starting Crystal Ball

▶ Start Crystal Ball as described in "Starting and Closing Crystal Ball" on page 26..

If the Crystal Ball Welcome screen opens, click Use Crystal Ball.

Crystal Ball opens and launches Microsoft Excel. If Microsoft Excel is already open, Crystal Ball opens in a new Microsoft Excel window.

For a description of the Crystal Ball menus and toolbar or ribbon, see "Crystal Ball Menus, Toolbar, and Ribbon" on page 28.

Opening the Example Model

Open the Futura Apartments workbook (Futura Apartments.xls) from the Crystal Ball Examples folder.

To find this folder, select **Help**, then **Crystal Ball**, and then **Examples Guide**. You can also select **Start**, then **All Programs**, then **Oracle Crystal Ball**, and then **Examples** in the Windows taskbar.

(In Microsoft Excel 2007 or later, select **Resources**, and then **Examples Guide** in the **Help** group.)

The Futura Apartments workbook opens as shown in Figure 104.

Figure 104 Futura Apartments Workbook

🗐 F	utura Apa	irtments.xls				
	A	В	С	D	E F	G 🗖
1	F	utura Apartm	ents			
2						
4						
5	Nu	mber of Rental Units	35		First Assumption	
6	Re	nt per Unit	\$500.00			
7	Mo	onthly Expenses	\$15,000.00			
8						
9	Pr	ofit or Loss	\$2,500.00		Second Assumption	
10			t			
11						
12			I			_
13			Forecast Cell			
14 15						
15						~
14 4	► H\D	escription \ Model /		<		

All example models included with Crystal Ball include these two worksheets:

- A **Model** tab with the spreadsheet model
- A **Description** tab with information about the model

For a list of the models included with Crystal Ball, open the Examples Guide as described earlier in this section.

Futura Apartments Model Scenario

In this example, you are a potential purchaser of the Futura Apartments complex. You have created Futura Apartments.xls to reflect the following assumptions:

- \$500 per month is the going rent for the area.
- The number of units rented during any given month will be somewhere between 30 and 40.
- Operating costs will average around \$15,000 per month for the entire complex, but may vary slightly from month to month.

You want to know how profitable the apartment complex will be for various combinations of rented units and operating costs. This is difficult to determine with a traditional spreadsheet model, but with Crystal Ball, this kind of analysis is easy.

For this tutorial, the simulation is already set up for you. You just need to run it using the Crystal Ball default settings.

Running Simulations

▶ To run the simulation, select **Run**, and then **Start [Simulation]**. ▶

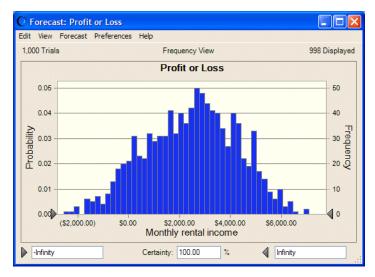
Crystal Ball runs a simulation for the situation in the Futura Apartments workbook and displays a forecast chart as it calculates the results.



By default, the simulation stops automatically after it has run for 1,000 trials. For larger models, you can use the **Stop** button or select **Run**, and then **Stop [Simulation]** if you need to stop the simulation before all trials have run.

When the simulation stops, the forecast window opens, as in Figure 105. The numbers will vary slightly each time the simulation is run, but the forecast window should look similar to this illustration.

Figure 105 Futura Apartments Profit/Loss Forecast



The forecast chart shows the total range of profit or loss outcomes predicted for the Futura Apartments scenario. Each bar on the chart represents the likelihood, or probability, of earning a given income. The cluster of columns near the center indicates that the most likely income level is between \$2000 and \$4000 per month. Notice that there is also a small chance of losing almost \$2000 per month (the lower-value end of the display range) and a small chance of making about a \$7,000 gain.

Notice that the probability, or certainty, of a value falling within the range of negative infinity and positive infinity is 100 percent. Notice too that the chart shows 1000 trials were run but only 998 are displayed. The excluded values, if any, are extreme values that are included in calculations but are not included in the forecast chart.

Note: If the forecast window disappears behind Microsoft Excel's window during a simulation, you can bring it back to the front by clicking the Crystal Ball icon in the Windows task

bar, Crystal Ball . In Microsoft Excel 2007 or later, you can select Analyze, then View Charts, then Forecast Charts.

Results Analysis – Determining Profit

Now, you can use Crystal Ball to determine the likelihood of making a profit.

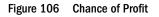
- > To determine the statistical likelihood of making a profit:
- 1 Select the first (left) Certainty text box in the forecast window.
- 2 Type **0** in the text box.

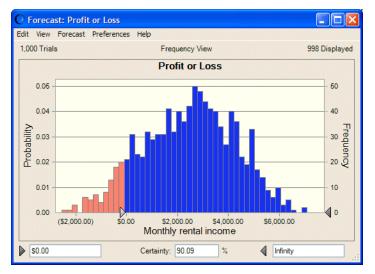


3 Press Enter.

The value in the Certainty text box changes to reflect the probability of making a profit — reaching an income level ranging from \$0 to positive infinity. This information puts you in

a much better position to decide whether to purchase the Futura Apartments. Figure 106 shows the chance of making a profit is about 90%.





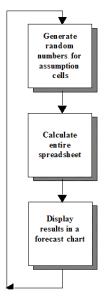
Take a Look Behind the Scenes

While powerful results are displayed in this example with virtually no effort, obviously there must be some drivers in the process. Crystal Ball cannot generate the same results for any typical spreadsheet without some help.

The key is using Crystal Ball to define certain input cells of the spreadsheet as assumptions and certain output cells of interest as forecasts.

After these cells are defined, Crystal Ball uses Monte Carlo simulation to model the complexity of a real-world scenario.

For each trial of a simulation, Crystal Ball repeats the following three steps:



- 1. For every assumption cell, a random number is generated according to the range you defined and then is placed into the spreadsheet.
- 2. The spreadsheet is recalculated.
- 3. A value is retrieved from every forecast cell and added to the chart in the forecast windows.

This is an iterative process that continues until either:

- The simulation reaches a stopping criterion
- You stop the simulation manually

The final forecast chart reflects the combined uncertainty of the assumption cells on the model's output. Keep in mind that Monte Carlo simulation can only approximate a real-world situation. When you build and simulate spreadsheet models, you need to carefully examine the nature of the problem and continually refine the models until they approximate the situation as closely as possible. See "Crystal Ball Cells in the Example Model" on page 252 for an example.

Crystal Ball Cells in the Example Model

The Futura Apartments model has two assumption cells and a forecast cell. They were already defined before you ran the simulation:

- Cell C5 defines the assumption about occupancy that units rented each month will vary between 30 and 40.
- Cell C7 defines the assumption about operating costs that they will average around \$15,000 per month but may vary slightly.
- Cell C9 defines the simulation forecast (the results). If you highlight cell C9, you can see it contains a formula that references cells C5 and C7.

By default, assumption cells are green and forecast cells are blue. For each trial of the simulation, the values within these cells change as the worksheet is recalculated.

To see this process close-up, reset the model and run it again in single-step mode. You can use the Crystal Ball Control Panel for these procedures.

Resetting and Single-Stepping

When you first run a simulation, the Crystal Ball Control Panel opens. After it opens, you will find it convenient to use for managing simulations and analyzing results.

Note: If the Control Panel or any other Crystal Ball windows disappear behind Microsoft Excel, click the Crystal Ball icon in the Windows task bar to display them again,

🜔 Crystal Ball

Figure 107 Crystal Ball Control Panel



For information about the Crystal Ball Control Panel menus, see "The Crystal Ball Control Panel menu bar" in Chapter 4 of the *Oracle Crystal Ball User's Guide*.

- \blacktriangleright To reset the simulation and clear all previous calculations, click the **Reset** button, \P .
- To single-step through the simulation one trial at a time, click the Single-step button,

Notice that the values in the assumption and forecast cells change each time you click the **Single-step** button.

Closing Crystal Ball

This completes Tutorial 1. You can save and close Crystal Ball models the same as any other Microsoft Excel workbook.

If you want, you can click the **Reset** button or select **Run**, and then **Reset [Simulation]** to reset the model before you close Crystal Ball.

- ➤ To close Crystal Ball, either:
- Right-click the Crystal Ball icon in the Windows taskbar and select **Close**, Crystal Ball, or

Close Microsoft Excel.

Tutorial Review

In this tutorial, you have:

- Opened Crystal Ball.
- Used the Crystal Ball menus, toolbar, and Control Panel to run an example model.
- Observed how Crystal Ball assumption and forecast cells change while a simulation runs.
- Closed Crystal Ball.

For background information about risk, risk analysis, models, and Monte Carlo simulation, see Chapter 2.

"Tutorial 2 — Vision Research" on page 254, shows how to define assumption and forecast cells and gives more suggestions for analyzing the results.

Tutorial 2 – Vision Research

This tutorial contains the following sections for review and instruction:

- "Starting Crystal Ball and Opening the Example Model" on page 254
- "Reviewing the Vision Research Scenario" on page 255
- "Defining Assumptions" on page 255
- "Defining Forecasts" on page 265
- "Running Simulations" on page 267
- "Interpreting the Results" on page 268
- "Closing Crystal Ball" on page 272

Starting Crystal Ball and Opening the Example Model

If Crystal Ball is not already started, follow the instructions in "Starting Crystal Ball" on page 248.

Then, open the Vision Research workbook (Vision Research.xls) from the Crystal Ball Examples Guide.

► To open the Examples Guide, see "Opening the Example Model" on page 248.

The Vision Research workbook for the ClearView project opens, as in Figure 108.

Figure 108 Vision Research's ClearView Project Workbook

Vision	n Research.xls		
Α	В	С	D E F
1	Pharmaceutical Researcl	h - Cl	earView Project
2	-		Suggested Assumptions:
3	Costs (in millions)		
4	Development Cost of ClearView to Date	\$10.0	
5	Testing Costs	\$4.0	Uniform
6	Marketing Costs	\$16.0	Triangular
7	Total Costs	\$30.0	
3			
Э	Drug Test (sample of 100 patients)		
0	Patients Cured	100	Binomial
11	FDA Approved if 20 or More Patients Cured	TRUE	
2			,
13	Market Study (in millions)		
4	Persons in U.S. with Nearsightedness Today	40.0	
5	Growth Rate of Nearsightedness	2.00%	Custom
6	Persons with Nearsightedness After One Year	40.8	
7			,
8	Gross Profit on Dosages Sold		
9	Market Penetration	8.00%	Normal
20	Profit Per Customer in Dollars	\$12.00	
21	Gross Profit if Approved (MM)	\$39.2	
22			Forecasts
23	Net Profit (MM)	\$9.2	
24			
4 +	Description Model	<	

This spreadsheet models the problem that Vision Research is trying to solve.

Reviewing the Vision Research Scenario

The Vision Research spreadsheet models a business situation filled with uncertainty. Vision Research has completed preliminary development of a new drug, code-named ClearView, that corrects nearsightedness. This revolutionary new product could be completely developed and tested in time for release next year if the FDA approves the product. Although the drug works well for some patients, the overall success rate is marginal, and Vision Research is uncertain whether the FDA will approve the product.

You begin the analysis by defining assumption cells to support this scenario.

Defining Assumptions

In Crystal Ball, you define an assumption for a value cell by choosing a probability distribution that describes the uncertainty of the data in the cell. To do this, you select a distribution type in the Distribution Gallery (see Figure 109).

This part of the tutorial helps you understand how to select a distribution type. For more information about choosing distributions, see Appendix A, "Selecting and Using Probability Distributions."

You need to define or review these assumptions:

• "Testing Costs Assumption: Uniform Distribution" on page 256

- "Marketing Costs Assumption: Triangular Distribution" on page 258
- "Patients Cured Assumption: Binomial Distribution" on page 259
- "Growth Rate Assumption: Custom Distribution" on page 260
- "Market Penetration Assumption: Normal Distribution" on page 263

Testing Costs Assumption: Uniform Distribution

So far, Vision Research has spent \$10,000,000 developing ClearView and expects to spend an additional \$3,000,000 to \$5,000,000 to test it based on the cost of previous tests. For this variable, "testing costs," Vision Research thinks that any value between \$3,000,000 and \$5,000,000 has an equal chance of being the actual cost of testing.

The uniform distribution describes a situation where all values between the minimum and maximum values are equally likely to occur, so this distribution best describes the cost of testing ClearView.

- > To define the assumption cell for testing costs:
- 1 Click cell C5.
- 2 Select Define, and then Define Assumption.

Because an assumption has not yet been defined in cell C5, the **Distribution Gallery** dialog opens as shown in Figure 109.

By default, the **Basic** distributions are displayed. These are six of the most frequently used continuous and discrete distributions. When you click a distribution to select it, information about that distribution is displayed at the bottom of the **Distribution Gallery**.

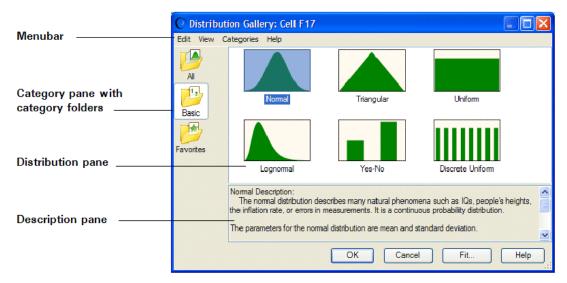


Figure 109 Distribution Gallery Dialog

- **Note:** In Microsoft Excel 2007 or later, if you click the upper half of the **Define Assumption** icon or if the assumption has already been defined, the **Distribution Gallery** opens. If you click the lower half of the **Define Assumption** icon, a list of **All**, **Basic**, or **Favorite** distributions opens, depending on the active category in the **Distribution Gallery**.
- **3** Click the **Uniform** distribution.
- 4 Click OK.

The Uniform Distribution dialog opens (Figure 110).

Since cell C5 already has label text beside it on the worksheet, that text is displayed in the **Assumption Name** text box. Use this name, rather than typing a new one. Also, notice that Crystal Ball assigns default values to the distribution parameters, **Minimum** and **Maximum**.

	Define Assumption: Cell C5		
Menubar	Edit View Parameters Preferences Help		
Assumption name	Name: Testing Costs	. 🛛 –	More button
Assumption distribution type	Uniform Distribution		
Distribution chart	53.6 53.7 53.8 53.9 54.0 54.1 54.2 54.3	34.4	
Parameters	Minimum \$3.6 Si Maximum \$4.4 OK Cancel Enter Gallery Correlate	Help	

Figure 110 Uniform Distribution for C5

Vision Research expects to spend a minimum of \$3,000,000 and a maximum of \$5,000,000 on testing. Use these values in place of the defaults to specify the parameters of the uniform distribution in Crystal Ball, as described in the following steps.

> To specify parameters:

1 Type 3 in the **Minimum** text box (remember that the numbers on the worksheet represent millions of dollars).

This represents \$3,000,000, the minimum amount Vision Research estimates for testing costs.

- 2 Press Tab.
- **3** Type 5 in the Maximum text box.

This represents \$5,000,000, the maximum estimate for testing costs.

4 Click Enter.

The distribution changes to reflect the values you entered, as shown in Figure 111.

Figure 111 Changed Distribution Values

O Define Assumption: Cell C5	
Edit View Parameters Preferences Help	
Name: Testing Costs	N
Uniform Distribution	
<u>≩</u>	
Probability	
<u>ዲ</u> -	
-	
\$3.0 \$3.2 \$3.4 \$3.6 \$3.8 \$4.0 \$4.2 \$4.4 \$4.6	\$4.8 \$5.0
Minimum \$3.0 The Maximum \$5.0	
OK Cancel Enter Gallery Correlate	. Help

With the values from step 1 and step 3 entered correctly, the distribution looks like Figure 111. Later, when you run the simulation, Crystal Ball generates random values for cell C5 that are evenly spread between 3 and 5 million dollars.

5 Click **OK** to return to the worksheet.

The assumption cell is now green.

Marketing Costs Assumption: Triangular Distribution

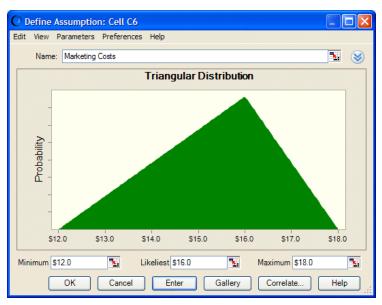
Vision Research plans to spend a sizeable amount marketing ClearView if the FDA approves it. Including sales commissions and advertising costs, Vision Research expects to spend between \$12,000,000 and \$18,000,000, with a most likely amount of \$16,000,000.

Vision Research selects the triangular distribution to describe marketing costs because the triangular distribution describes a situation where you can estimate the minimum, maximum, and most likely values to occur. This assumption is already defined for you.

- > To examine the assumption cell for marketing costs:
- 1 Click cell C6.
- 2 Select **Define**, and then **Define Assumption**.

The Triangular Distribution dialog (Figure 112) opens for cell C6.





The triangular distribution has three parameters — **Minimum** (\$12 million), **Likeliest** (\$16 million), and **Maximum** (\$18 million).

When you run the simulation, Crystal Ball generates random values that fall around 16, with fewer values near 12 and 18.

3 Click **OK** to return to the worksheet.

Patients Cured Assumption: Binomial Distribution

For FDA approval of ClearView, Vision Research must conduct a controlled test on a sample of 100 patients for one year. Vision Research expects that the FDA will grant an approval if 20% or more of the patients tested are cured (show corrected vision) after taking ClearView for one year. Vision Research is encouraged by their preliminary testing, which shows a success rate of around 25%.

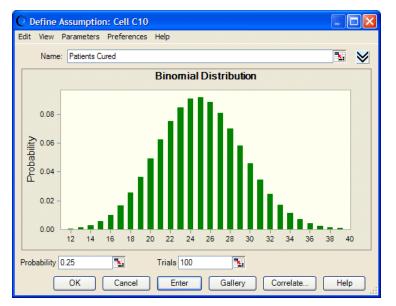
Vision Research selects the binomial distribution to describe the uncertainties in this situation because the binomial distribution describes the random number of successes (25) in a fixed number of trials (100).

This assumption is already defined.

- > To examine the assumption cell for patients cured, use the following steps:
- 1 Click cell C10.
- 2 Select Define, and then Define Assumption.

The Binomial Distribution dialog opens as shown in Figure 113.

Figure 113 Binomial Distribution Dialog



The binomial distribution has two parameters: **Probability** and **Trials**. Because Vision Research experienced a 25% success rate during preliminary testing, the Probability parameter is set to 0.25 to show the likelihood of success.

Note: You can express probabilities either as decimals between 0 and 1, such as 0.03, or as whole numbers followed by the percent sign, such as 3%.

Because the FDA expects Vision Research to test 100 people, the **Trials** parameter is set to 100. When you run the simulation, Crystal Ball generates random integers between 0 and 100, simulating the number of patients that would be cured in the FDA test.

3 Click **OK** to return to the worksheet.

Growth Rate Assumption: Custom Distribution

Vision Research has determined that nearsightedness afflicts nearly 40 million people in the United States, and an additional 0% to 5% of these people will develop this condition during the year in which ClearView is tested.

However, the marketing department has learned that a 25% chance exists that a competing product will be released on the market soon. This product would decrease ClearView's potential market by 5% to 15%.

Since the uncertainties in this situation require a unique approach, Vision Research selects Crystal Ball's custom distribution to define the growth rate.

The method for specifying parameters in the custom distribution is quite unlike the other distribution types, so follow the directions carefully. If you make a mistake, click Gallery to return to the distribution gallery, then start again at step 4.

Use the custom distribution to plot both the potential increase and decrease of ClearView's market.

- > To define the assumption cell for the growth rate of nearsightedness:
- 1 Select cell C15.
- Select Define, and then Define Assumption. 2

(In Microsoft Excel 2007 or later, click the upper half of the **Define Assumption** icon.)

The **Distribution Gallery** dialog opens.

- 3 Click All in the navigation pane of the Distribution Gallery to show all distributions shipped with Crystal Ball.
- 4 Scroll down to the end of the Distribution Gallery and click the Custom distribution.
- Click OK. 5

The **Custom Distribution** dialog opens.

Notice in Figure 114 that the chart area remains empty until you specify the **Parameters** type and enter the values for the distribution.

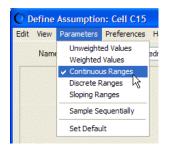
Figure 114 Custom Distribution Dialog

	Q	efine Assumption: Cell C15		
	Edit	View Parameters Preferences Help		
		Name: Growth Rate of Nearsightedness	1 .	۲
The area remains empty until you — enter values.	En	No Data Available ter one or more values with probabilities: Value Probability OK Cancel Enter Gallery Correlate	Help	

You know that you will be working with two distribution ranges: one showing growth in nearsightedness and one showing the effects of competition. Both ranges are continuous.

Open the **Parameters** menu (Figure 115). 6

Figure 115 Custom Distribution Parameters Menu



7 Select Continuous Ranges in the Parameters menu.

The **Custom Distribution** dialog now has three parameters: **Minimum**, **Maximum**, and **Probability**.

- 8 Enter the first range of values to show the growth of nearsightedness with low probability of competitive effects:
 - a. Type 0% in the Minimum text box.

This represents a 0% increase in the potential market.

b. Type 5% in the Maximum text box.

This represents a 5% increase in the potential market.

c. Type 75% or . 75 in the **Probability** text box.

This represents the 75% chance that Vision Research's competitor will not enter the market and reduce Vision Research's share.

d. Click Enter.

A uniform distribution for the range 0% to 5% is displayed (Figure 116.

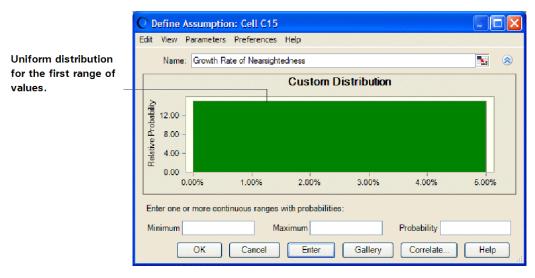


Figure 116 Uniform Distribution Range

Notice that the total area of the range is equal to the probability: 5% wide by 15 units high equals 75%.

9 Now, enter a second range of values to show the effect of competition:

a. Type -15% in the **Minimum** text box.

This represents a 15% decrease in the potential market.

b. Type -5% in the **Maximum** text box.

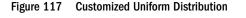
This represents a 5% decrease in the potential market.

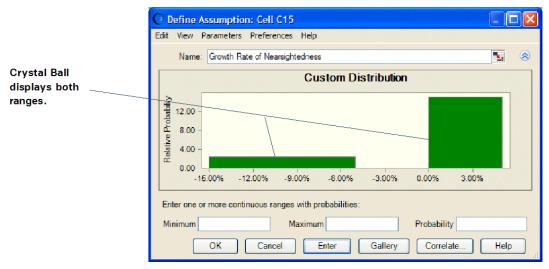
c. Type 25% in the **Probability** text box.

This represents the 25% chance that Vision Research's competitor will enter the market place and decrease Vision Research's share by 5% to 15%.

d. Click Enter.

A uniform distribution for the range -15% to -5% is displayed. Both ranges are now displayed in the Custom Distribution dialog (Figure 117).





Notice that the area of the second range is also equal to its probability: $2.5 \times 10\% = 25\%$.

10 Click **OK** to return to the worksheet.

When you run the simulation, Crystal Ball generates random values within the two ranges according to the probabilities you specified.

Market Penetration Assumption: Normal Distribution

The marketing department estimates that Vision Research's eventual share of the total market for the product will be normally distributed around a mean value of 8% with a standard deviation of 2%. "Normally distributed" means that Vision Research expects to see the familiar bell-shaped curve with about 68% of all possible values for market penetration falling between one standard deviation below the mean value and one standard deviation above the mean value, or between 6% and 10%.

In addition, the marketing department estimates a minimum market of 5%, given the interest shown in the product during preliminary testing.

Vision Research selects the normal distribution to describe the variable "market penetration."

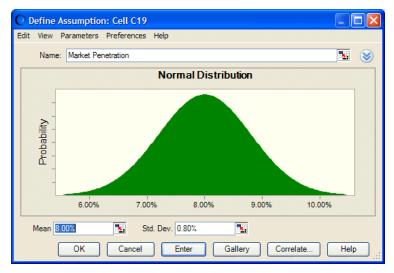
- > To define the assumption cell for market penetration:
- 1 Click cell C19.
- 2 Select **Define**, and then **Define Assumption**.
- 3 In the Distribution Gallery, click the normal distribution.

(Scroll up to the top of the All category or click Basic to immediately display the normal distribution.)

4 Click OK.

The Normal Distribution dialog opens (Figure 118).





- 5 Specify the parameters for the normal distribution: the mean and the standard deviation.
 - a. If the Mean text box doesn't contain 8.00%, type 8% in the Mean text box.

This represents an estimated average for market penetration of 8%.

b. Type 2% in the **Std. Dev.** text box.

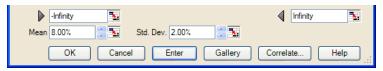
This represents an estimated 2% standard deviation from the mean.

6 Click Enter.

The normal distribution scales to fit the chart area, so the shape of the distribution does not change. However, the scale of percentages on the chart axis does change.

7 Click the More button, 💜, to display additional text boxes (Figure 119).

Figure 119 Assumption Truncation Text Boxes



These text boxes, marked by gray arrows, display the minimum and maximum values of the assumption range. If values are entered into them, they cut or truncate the range. These text boxes are then called the truncation minimum and maximum.

8 Type 5% in the minimum truncation text box (the first or left text box).

This represents 5%, the minimum market for the product.

9 Click Enter.

The distribution changes to reflect the values you entered (Figure 120).

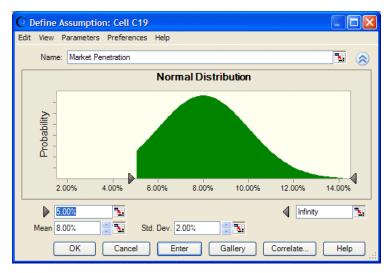


Figure 120 Changed Distribution for the Truncated Values

When you run the simulation, Crystal Ball generates random values that follow a normal distribution around the mean value of 8%, and with no values generated below the 5% minimum limit.

10 Click **OK** to return to the worksheet.

Defining Forecasts

Now that you have defined the assumption cells in the model, you are ready to define the forecast cells. Forecast cells contain formulas that refer to one or more assumption cells.

The president of Vision Research would like to know both the likelihood of achieving a profit on the product and the most likely profit, regardless of cost. These forecasts are displayed in the gross profit (cell C21) and net profit (cell C23) for the ClearView project.

You can define both the gross profit and net profit formulas as forecast cells, described in the following sections:

- "Gross Profit Forecast" on page 266
- "Net Profit Forecast" on page 266

Gross Profit Forecast

- > First, look at the contents of the cell for gross profit:
- 1 Click cell C21.

The cell contents are displayed in the formula bar near the top of the worksheet. The contents are C16*C19*C20. Crystal Ball uses this formula to calculate gross profit by multiplying Persons With Nearsightedness After One Year (C16) by Market Penetration (C19) by Profit Per Customer (C20).

Now that you understand the gross profit formula, you are ready to define the forecast cell for gross profit.

To define this forecast cell:

2 Select Define, and then Define Forecast.

The **Define Forecast** dialog opens as shown in Figure 121. You can enter a name for the forecast. By default, the forecast cell label is displayed as the forecast name.

Figure 121 Define Forecast Dialog–Gross Profit If Approved

Define Fore	cast: Cell C21		X
Name:	Gross Profit if Approved (MM)		<u></u>
Units:			1
		OK Cancel	Help

Use the forecast name that is displayed, rather than typing a new name.

- 3 Since the spreadsheet model involves millions of dollars, type Millions in the Units text box.
- 4 Click **OK** to return to the worksheet.

Net Profit Forecast

- Before defining the forecast cell formula for net profit, look at the contents of the cell for net profit:
- 1 Click cell C23.

The contents are displayed in the Microsoft Excel formula bar. The contents are IF (C11, C21-C7, -C4-C5).

The formula translates as follows:

If the FDA approves the drug (C11 is true), then calculate net profit by subtracting total costs (C7) from gross profit (C21). However, if the FDA does not approve the drug, (C11 is false), then calculate net profit by deducting both development costs (C4) and testing costs (C5) incurred to date.

To define the forecast cell for net profit:

Select Define, and then Define Forecast. 2



The Define Forecast dialog opens.

Again, use the forecast name that is displayed in the Forecast Name text box and specify Millions in the **Units** text box.

3 Click **OK** to return to the worksheet.

You have defined assumptions and forecast cells for the Vision Research spreadsheet, and are now ready to run a simulation.

Setting Run Preferences

- > To specify the number of trials and initial seed value (so the charts will look like this tutorial):
- Select Run, then Run Preferences, then Trials. 1

The Run Preferences Trials dialog opens. For this example, running more trials will help achieve more accurate forecast results.

- 2 In the Number Of Trials To Run text box, type 5000.
- 3 Click Sampling.
- 4 Select Use Same Sequence Of Random Numbers.
- 5 In the Initial Seed Value text box, type 999.
- 6 Notice that the Sampling Methods group has two choices: Monte Carlo and Latin Hypercube. Latin Hypercube is less random and produces a smoother, more even results chart. For now, though, select the default - Monte Carlo.
- 7 Click OK.

Running Simulations

When you run a simulation in Crystal Ball, you have the freedom to stop and then continue the simulation at any time. Buttons for Run, Stop, and Continue are displayed on the Crystal Ball toolbar and, after you have started to run a simulation, they are displayed on the Crystal Ball Control Panel.

➤ To run the simulation, click **Run**, 🚩

Interpreting the Results

Now that you have run the simulation, you are ready to interpret the forecast results. Should Vision Research scrap the ClearView project or proceed to develop and market this revolutionary new drug? For the answer, review the forecast charts.

The following sections describe how to analyze results for this scenario:

- "Reviewing the Net Profit Forecast Chart" on page 268
- "Determining the Net Profit Certainty Level" on page 269
- "Customizing Forecast Charts" on page 271
- **Note:** Crystal Ball windows are separate from Microsoft Excel windows. If Crystal Ball's windows or charts disappear from the screen, they usually are behind the main Microsoft Excel window. To bring them to the front, click the Crystal Ball icon in the Windows taskbar

or press Alt+Tab and select Crystal Ball, C Crystal Ball

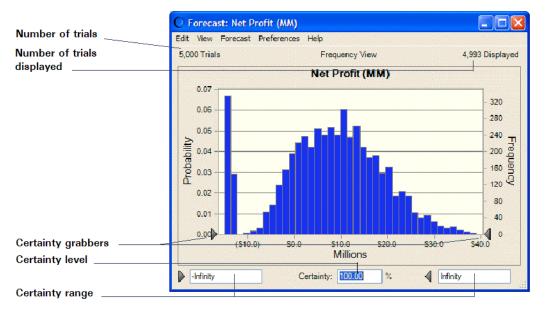
Note: To display forecast charts in Microsoft Excel 2007 or later, select **Analyze**, then **View Charts**, and then **Forecast Charts**.

Reviewing the Net Profit Forecast Chart

Forecast charts are frequency distributions. They show the number or frequency of values occurring in a given bin or group interval and show how the frequencies are distributed. In Figure 122, the bin that contains the most values has a frequency of about 280.

Crystal Ball forecasts the entire range of results for the Vision Research project. However, the forecast charts do not display the most extreme values. Here, the display range includes values from approximately –\$15 million to \$38 million.

Figure 122 Net Profit Forecast



The forecast chart also shows the certainty range for the forecast. By default, the certainty range includes all values from negative infinity to positive infinity.

Crystal Ball compares the number of values in the certainty range with the number of values in the entire range to calculate the certainty level.

The previous example shows a certainty level of 100%, since the initial certainty range includes all possible values. Remember that the certainty level is an approximation, since a simulation can only approximate the elements of the real world.

Determining the Net Profit Certainty Level

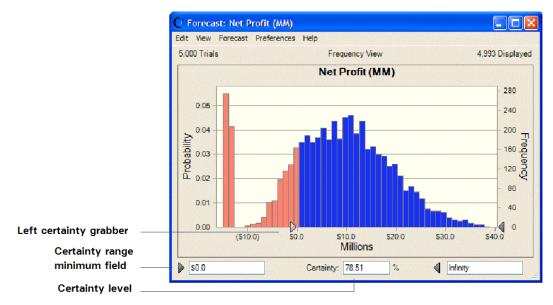
The Vision Research president wants to know how certain Vision Research can be of achieving a profit and what are the chances of a loss.

- > To determine the certainty level of a specific value range:
- 1 In the Net Profit forecast chart, type 0 in the certainty range minimum text box.
- 2 Press Enter.

Crystal Ball moves the lower-value (left) certainty grabber to the break-even value of \$0.0 and recalculates the certainty level.

Analyzing the Net Profit forecast chart again (Figure 123), you can see that the value range between the certainty grabbers shows a certainty level of about 79%. That means that Vision Research can be 79% certain of achieving a net profit. You can therefore calculate a 21% chance of suffering a net loss (100% minus 79%).

Figure 123 Net Profit Forecast—\$0 Minimum



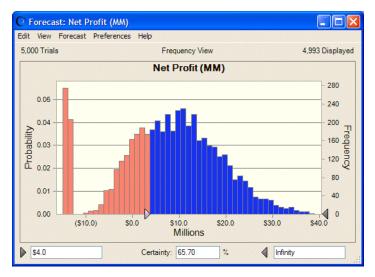
Now, the president of Vision Research would like to know the certainty of achieving a minimum profit of \$4,000,000. If Crystal Ball shows that Vision Research can be at least two-thirds certain of a \$4,000,000 net profit, the president is ready to go ahead with the ClearView project.

- > Again, Crystal Ball can easily answer this question:
- **1** Type 4 in the range minimum text box.
- 2 Press Enter.

Crystal Ball moves the lower-value (left) certainty grabber to \$4.0 and recalculates the certainty level.

The Net Profit forecast chart in Figure 124 shows a certainty level of almost 66%. With virtually two-thirds certainty of a minimum net profit of \$4,000,000, Vision Research decides to go ahead with the ClearView project and proceed to develop and market this revolutionary new drug.

Figure 124 Net Profit Forecast-\$4.0 Million Minimum



You can work with the Gross Profit chart in similar ways.

Customizing Forecast Charts

Crystal Ball charts are useful for presenting results as well as analyzing them. A variety of chart preferences are available to show different chart views, types, colors, and more.

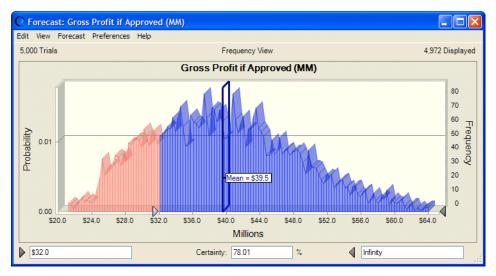
To display the chart preferences, select **Preferences**, and then **Chart** in the forecast chart window.

You can also use keyboard shortcuts to customize the appearance of charts without using the Chart Preferences dialog.

- > Select a forecast chart and try these shortcuts now:
- Press Ctrl+t to cycle through chart types (area, line, and column).
- Press Ctrl+d to change the chart views (frequency, cumulative frequency, reverse cumulative frequency).
- Press Ctrl+m to cycle through a series of markers that show the mean and other measures of central tendency.
- Press Ctrl+p to cycle through a series of percentile markers.
- Press Ctrl+b to change the density of the chart by varying the number of bins.
- Press Ctrl+w to display the chart in 3D.
- Drag the edges of the chart window until the proportions and size suit the presentation plans.

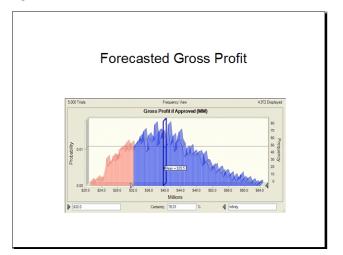
For example, Figure 125 on page 272 shows the ClearView gross profit forecast presented as a 3-D area chart with a mean marker, stretched to show more detail in the *x*-axis. The chart is also set for 50% transparency. The Certainty text boxes have been set to show that the certainty of a gross profit greater than \$32 million is about 78%.

Figure 125 Customized Gross Profit Chart



You can select Edit, then Copy Chart in the chart menu bar to copy a chart to the clipboard for pasting into Microsoft Excel or another application. Figure 126 shows the ClearView gross profit chart pasted into a presentation slide.

Figure 126 Gross Profit Chart Pasted into a Presentation Slide



Closing Crystal Ball

> To close Crystal Ball, exit Microsoft Excel.

Summary

In this tutorial, you started Crystal Ball, opened the tutorial example model, defined assumptions and forecasts, ran the simulation, and reviewed and customized forecast charts. By experimenting with certainty values, you explored a few questions that Vision Research executives may ask as they analyzed the results of the simulation.

Crystal Ball keeps the assumption and forecast definitions (but not the forecast values) with the spreadsheet. When you save the spreadsheet, the definitions are saved with it. To learn about saving and restoring forecast results, see "Saving and Restoring Simulation Results" on page 80.



Using the Process Capability Features

This Appendix		
	Introduction	275
	Preparing to Use Process Capability Features	275
	Analyzing Process Capability Results	277

Introduction

In

If you use Six Sigma or other quality methodologies, the process capability features of Crystal Ball can help you improve quality in your organization. This appendix describes Crystal Ball's process capability features, which support quality improvement methodologies such as Six Sigma, DFSS (Design for Six Sigma), and Lean principles.

For additional information, including tutorials and descriptions of each metric, see the *Oracle Crystal Ball Reference and Examples Guide*.

Preparing to Use Process Capability Features

Subtopics

- Activating the Process Capability Features
- Setting Capability Calculation Options
- Setting Specification Limits and Targets

Before you can use the process capability features, you must activate them, set options, and enter limits and target values for at least one forecast.

Activating the Process Capability Features

- > To activate Crystal Ball's process capability features:
- 1 Select Run, and then Run Preferences to display the Run Preferences dialog.
- 2 Click the **Statistics** tab.
- 3 Select Calculate Capability Metrics.
- 4 Click **Options** to set the capability calculation options, described in the next section.

5 Click OK.

Setting Capability Calculation Options

After you activate the process capability features, you can set a variety of options to further customize these features for the situation.

- > To set the process capability options:
- 1 Display the Statistics tab of the Run Preferences dialog.
- 2 Click Options.

The Capability Options panel opens.

- 3 Indicate whether metrics should use short-term or long-term formulas, depending on the time-span of the model.
- 4 **Optional:** Specify a Z-score shift value to be used in long-term formulas.

You can specify a value from 0 to 100.

The default is 1.5. If don't want to use a Z-score shift value, enter 0 in the box or delete the current value and leave it empty.

- 5 Indicate whether metrics should be calculated from a fitted distribution or directly from the forecast values ("Calculation Method" on page 276).
- 6 When settings are complete, click OK.

Calculation Method

By default, Crystal Ball tries to fit a normal distribution to the forecast values. You can enter a significance level to specify the threshold below which the assumption of normality is rejected. The default level of 0.05 translates into a 95% confidence that a rejection of normality will be correct. Other significance levels typically used are 0.01, 0.025, and 0.1, which translate into 99%, 97.5%, and 90% confidences, respectively.

If normality is rejected, Crystal Ball will then either calculate the metrics directly from the forecast values (the default) or, if you choose, perform a best fit to select the most appropriate continuous probability distribution from which to calculate the metrics.

The normality test and non-normal best fit (if normality is rejected) use the goodness-of-fit test and distribution selection that is set in the Forecast Window tab of the Forecast Preferences dialog (opened by choosing Preferences, then Forecast in the forecast window).

Before you choose to calculate from the best fitting distribution if the distribution is not normal, consider that:

- You are not guaranteed of attaining a good fit to the forecast values, and
- The fitting process may take a long time depending on how many simulation trials you are running.

Note: In unusual circumstances, it is possible for the normality test to fail and the best fitting distribution still be a normal distribution, or for the normality test to pass and the best fitting distribution be non-normal.

Alternatively, you can select the second main setting, Calculate Metrics From Forecast Values, to bypass the normality test and always calculate the metrics directly from the forecast data.

Setting Specification Limits and Targets

The capability metrics only display if you specify either an upper or lower specification limit (or both) for the forecast. You can also specify an optional target.

➤ To specify these limits:

1 Either define a new forecast or select an existing forecast and select **Define**, and then **Define Forecast**.

The **Define Forecast** dialog opens. With process capability features activated, it includes **Name**, **Units**, **LSL**, **USL**, and **Target** text boxes.

2 Enter specification limits and target values for this forecast into the appropriate text boxes.

LSL = lower specification limit, **USL** = upper specification limit, and **Target** = target value for this forecast. If you prefer, you can enter cell references by typing or browsing.

All of these text boxes are optional, but Crystal Ball only calculates capability metrics if a value is entered for one or both of the specification limits.

- 3 To set forecast preferences at the same time, click the More button, \bigotimes , beside the Name text box.
- 4 When all settings are complete, click **OK**.

For information about the relationship of the LSL and USL to the certainty range, see "Viewing LSL, USL, and Target Marker Lines" on page 278.

Analyzing Process Capability Results

Subtopics

- Viewing Capability Metrics
- Viewing LSL, USL, and Target Marker Lines
- Extracting Capability Metrics
- Including Capability Metrics in Reports

When capability metrics have been activated and appropriate information entered, run a Crystal Ball simulation as usual. Then, you can view and extract the metrics and include them in reports.

Viewing Capability Metrics

After you have defined a forecast with at least one specification limit (and, optionally, a target), you can run a simulation and display capability metrics for the forecast.

- > To display capability metrics:
- 1 Define a forecast with LSL, USL, and Target values as described in "Setting Specification Limits and Targets" on page 277.
- 2 Run the simulation and display the chart for that forecast.
- 3 In the forecast window, select View, and then Capability Metrics.

A table of metrics opens, similar to Figure 127.

Figure 127 Capability Metrics View

.0	000 Trials Capa	bility Metrics View	Model!K
1	ormality test passed (p-value =	0 199)	
	Metric	Fit: Normal	
	Mean	49.2546	
	Standard Deviation	1.2764	
	Ср	0.8705	
	Cpk-lower	0.5204	
	Cpk-upper	1.22	
	Cpk	0.5204	
	Cpm	0.6003	
	Z-LSL	1.56	
	Z-USL	3.66	
	Zst-total	1.56	
	Zlt	0.0603	
	p(N/C)-below	0.0592	
	p(N/C)-above	1.2527e-04	
	p(N/C)-total	0.0593	
	PPM-below	59,222.22	
	PPM-above	125.27	
	PPM-total	59,347.49	
	LSL	47.2617	
	USL	53.9283	
	Target	50.5950	
	Z-score shift	1.50	

For a description of each statistic, see the capability metrics list in the Oracle Crystal Ball Reference and Examples Guide.

It can be helpful to view a forecast chart and its capability metrics side by side in Split View. This is now the default view when capability metrics are activated. For instructions, see "Using Split View" on page 95.

Viewing LSL, USL, and Target Marker Lines

By default, after you add specification limits and a target to a forecast, markers for these values are displayed on the forecast chart.

The certainty range on the forecast chart changes to match the LSL and USL values. The certainty indicates the probability of falling within those specification limits. To show the certainty of different values, type them into the Minimum and Maximum text boxes or click the certainty grabbers and drag them to a new position.

- > To add specification limit and target marker lines manually or to remove them:
- 1 Select **Preferences**, and then **Chart Preferences** in a forecast chart window, or double-click the chart.
- 2 Click the Chart Type tab in the Chart Preferences dialog.
- 3 Scroll down to the bottom of the Marker Lines list.
- 4 Be sure LSL, USL, Target is selected to display the specification limit and target marker lines on that forecast chart.

To hide the markers, clear LSL, USL, Target.

5 When all settings are complete, click **OK**.

Notice that you can display the mean and other marker lines in addition to the specification limit and target markers.

Extracting Capability Metrics

Subtopics

- Extracting Capability Metrics Automatically
- Extracting Capability Metrics Manually

You can extract capability metrics automatically or manually.

Extracting Capability Metrics Automatically

- You can automatically extract capability metrics whenever a simulation runs. To extract metrics automatically:
- 1 In a forecast window, select **Preferences**, and then **Forecast** and display the **Auto Extract** tab of the **Forecast Preferences** dialog.
- 2 Select Extract Forecast Statistics Automatically... and scroll down to the bottom of the data selection list.
- **3** Select Capability Metrics, enter a Starting Cell, and then click OK.

Now, when you run a simulation, capability metrics are written to the specified area of the worksheet, along with any other data you have requested.

Note: For more information about the Auto Extract feature, see "Auto Extract Tab" on page 63. IMPORTANT! Be sure to select an open area of the worksheet as the Starting Cell to avoid overwriting the model.

Extracting Capability Metrics Manually

- > To extract capability metrics manually after a simulation runs:
- 1 Select Analyze, and then Extract Data to display the Extract Data Preferences dialog.
- 2 Select Capability Metrics at the bottom of the Select Data To Extract list.
- **3** Select appropriate **Forecasts** and **Assumptions** settings and specify locations and other preferences on the **Options** tab. For more information, see "Extracting Data" on page 150.
- 4 Click **OK** to extract the data.

Capability metrics are written to the specified location, along with any other data you have requested. See Figure 128 for an example.

Figure 128 Manually Extracted Capability Metrics

	А	В	С	
1	Capability metrics	FLOW RATE FORECAST (ml / sec)	TOTAL COST FORECAST (\$)	
2	Mean	49.2453	\$26.73	
3	Standard Deviation	1.2122	\$0.00	
4	Ср	0.92		
5	Cpk-lower	0.55		
6	Cpk-upper	1.29		
7	Cpk	0.55		
8	Cpm	0.61		
9	Z-LSL	1.64		
10	Z-USL	3.86		
11	Zst-total	1.64		
12	Zlt	0.14		
13	p(N/C)-below	0.05		
14	p(N/C)-above	0.00		
15	p(N/C)-total	0.05		
16	PPM-below	50,879.49		
17	PPM-above	55.92		-
14 4	▶ N Description / I	Model Data		

Including Capability Metrics in Reports

- > To include capability metrics in full, forecast, or custom reports:
- **1** Select Analyze, and then Create Report to display the Create Report dialog.
- 2 Click a report type: Full, Forecast, or Custom.

If you select **Full** or **Forecast**, the capability metrics are displayed in a block for each forecast following the statistics and percentiles for that forecast. Additional process capability information is displayed in the summary and all selected marker lines are displayed in forecast and overlay charts.

If you select Custom, the Custom Report dialog opens.

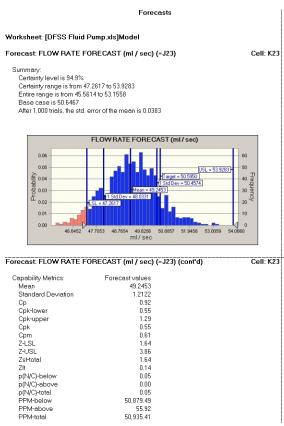
3 If it is not already highlighted, highlight Forecasts in the Report Sections list.

The **Forecasts Details** list is displayed. With the process capability features activated, **Capability Metrics** is selecteded by default.

- 4 If you do not want to include the capability metrics for some reason, clear that setting in the **Forecasts Details** list. Otherwise, leave it selected and follow the instructions in "Defining Custom Reports" on page 148 to finish defining the custom report.
- 5 When all settings are complete, click **OK** to generate the report.

Capability metrics are displayed with other forecast data, similar to Figure 129.





Glossary

algorithm A rule that specifies how to solve a particular problem.

assumption An estimated value or input to a spreadsheet model.

assumption cell A value cell in a spreadsheet model that has been defined as a probability distribution.

base case The value in a Crystal Ball assumption, decision variable, or forecast cell at the start of a simulation.

CDF Cumulative distribution function that represents the probability that a variable will fall at or below a given value.

certainty bands In a trend chart, a graphic depiction of a particular certainty range for each forecast.

certainty level The percentage of values in the certainty range compared to the number of values in the entire range.

certainty range The linear distance for the set of values between the certainty grabbers on the forecast chart.

coefficient of variation, also **coefficient of variance or coefficient of variability** A measure of relative variation that relates the standard deviation to the mean. Results can be represented in percentages for comparison purposes.

continuous probability distribution A probability distribution that describes a set of uninterrupted values over a range. In contrast to the discrete distribution, the continuous distribution assumes there is an infinite number of possible values.

correlation In Crystal Ball, a dependency that exists between *assumption cells*.

correlation coefficient A number between -1 and 1 that specifies mathematically the degree of positive or negative correlation between *assumption cells*. A *correlation* of 1 indicates a perfect positive correlation, minus 1 indicates a perfect negative correlation, and 0 indicates there is no correlation.

cumulative frequency distribution A chart that shows the number or proportion (or percentage) of values less than or equal to a given amount.

decision variable A Crystal Ball variable in the model that you can control.

decision variable cell Cells that contain the values or variables that are within the control to change. The decision variable cells must contain simple numeric values, not formulas or text.

deterministic model Another name for a *spreadsheet model* which yields single-valued results.

discrete probability distribution A *probability distribution* that describes distinct values, usually integers, with no intermediate values. In contrast, the continuous distribution assumes there is an infinite number of possible values.

display range The linear distance for the set of values displayed on the forecast chart.

dominant A relationship between distributions in which one distribution's values for all percentile levels are higher than another's. *See also subordinate*.

entire range The linear distance from the minimum *forecast value* to the maximum forecast value.

forecast A statistical summary of the assumptions in a spreadsheet model, output graphically or numerically.

forecast cell Cells that contain formulas that refer to one or more assumption and decision variable cells and combine the values in the assumption, decision, and other cells to calculate a result.

forecast definition The forecast name and parameters assigned to a cell in a Crystal Ball dialog.

forecast filtering A process by which Crystal Ball discards forecast values outside or inside a specified range.

forecast formula A formula that has been defined as a forecast cell.

forecast value also trial A value calculated by the forecast formula during an iteration. These values are kept in a list for each forecast, and are summarized graphically in the forecast chart and numerically in the descriptive statistics.

 $\ensuremath{\textit{formula cell}}$ A cell that contains a mathematical formula.

frequency also frequency count The number of times a value recurs in a group interval.

frequency distribution A chart that graphically summarizes a list of values by subdividing them into groups and displaying their frequency counts.

goodness-of-fit A set of mathematical tests performed to find the best fit between a standard probability distribution and a data set.

grabber also certainty grabber or truncation grabber A control that lets you use the mouse to change values and settings.

group interval A subrange of a distribution that allows similar values to be grouped together and given a frequency count.

iteration also trial A three-step process in which Crystal Ball generates random numbers for assumption cells, recalculates the spreadsheet model or models, and displays the results in a forecast chart.

kurtosis The measure of the degree of peakedness of a curve. The higher the kurtosis, the closer the points of the curve lie to the mode of the curve. A normal distribution curve has a kurtosis of 3. Latin Hypercube sampling In Crystal Ball, a sampling method that divides an assumption's probability distribution into intervals of equal probability. The number of intervals corresponds to the Minimum Sample Size option available in the Run Preferences dialog. A random number is then generated for each interval.

Compared with conventional Monte Carlo sampling, Latin Hypercube sampling is more precise because the entire range of the distribution is sampled in a more even, consistent manner. The increased accuracy of this method comes at the expense of added memory requirements to hold the full Latin Hypercube sample for each assumption. (See "Setting Sampling Preferences" on page 73.)

mean The familiar arithmetic average of a set of numeric observations: the sum of the observations divided by the number of observations.

mean standard error The Standard Deviation of the distribution of possible sample means. This statistic gives one indication of how accurate the simulation is.

median The value midway (in terms of order) between the smallest possible value and the largest possible value.

mode That value which, if it exists, occurs most often in a data set.

model sensitivity The overall effect that a change in an assumption cell produces in a forecast cell. This effect is solely determined by the formulas in the spreadsheet model.

Monte Carlo simulation A system which uses random numbers to measure the effects of uncertainty in a spreadsheet model.

outlying values Values generated during a simulation on the extreme end of a distribution that are excluded from the display range.

PDF Probability density function that represents the probability that an infinitely small variable interval will fall at a given value.

probabilistic model A system whose output is a distribution of possible values. In Crystal Ball, this system includes a spreadsheet model (containing mathematical relationships), probability distributions, and a mechanism for determining the combined effect of the probability distributions on the model's output (Monte Carlo simulation).

probability (Classical Theory) The likelihood of an event.

probability distribution also distribution A set of all possible events and their associated probabilities.

random number A mathematically selected value which is generated (by a formula or selected from a table) to conform to a probability distribution.

random number generator A method implemented in a computer program that is capable of producing a series of independent, random numbers.

range The difference between the largest and smallest values in a data set.

rank correlation also Spearman's rank correlation A method whereby assumption values are replaced with their ranking from lowest value to highest value using the integers 1 to N prior to computing the correlation coefficient. This method allows the distribution types to be ignored when correlating assumptions.

relative probability also relative frequency A value, not necessarily between 0 and 1, that indicates probability when used in a proportion.

reverse cumulative frequency distribution A chart that shows the number or proportion (or percentage) of values greater than or equal to a given amount.

risk The uncertainty or variability in the outcome of some event or decision.

seed value The first number in a sequence of random numbers. A given seed value produces the same sequence of random numbers every time you run a simulation.

sensitivity The amount of uncertainty in a forecast cell that is a result of both the uncertainty (probability distribution) and model sensitivity of an assumption cell.

sensitivity analysis The computation of a forecast cell's sensitivity with respect to the assumption cells.

skewed An asymmetrical distribution.

skewed, **negatively** A distribution in which most of the values occur at the upper end of the range.

skewed, **positively** A distribution in which most of the values occur at the lower end of the range.

skewness The amount a curve differs from a normal, symmetrical distribution. The greater the degree of *skewness*, the more points of the curve lie to either side of the peak of the curve. A normal distribution curve, having no *skewness*, is symmetrical. Skewness is computed by finding the third moment about the mean and dividing by the cube of the standard deviation.

spreadsheet model Any spreadsheet that represents an actual or hypothetical system or set of relationships.

standard deviation The square root of the variance for a distribution. A measurement of the variability of a distribution, i.e., the dispersion of values around the mean. (See formulas in the discussion of standard deviation in the *Oracle Crystal Ball Reference and Examples Guide.*)

subordinate A relationship between distributions in which one distribution's values for all percentile levels are lower than another's. *See also dominant*.

trial also iteration A three-step process in which Oracle Crystal Ball generates random numbers for assumption cells, recalculates the spreadsheet model or models, and displays the results in a forecast chart.

trial as used to describe a parameter in certain probability distributions The number of times a given experiment is repeated.

value cell A cell that contains a simple numeric value.

variable A quantity that can assume any one of a set of values and is usually referenced by a formula.

variance The square of the standard deviation; i.e., the average of the squares of the deviations of a number of observations from their mean value.

Variance can also be defined as a measure of the dispersion, or spread, of a set of values about a mean. When values are close to the mean, the variance is small. When values are widely scattered about the mean, the variance is large. (See formulas in the discussion of variance in the Oracle Crystal Ball Reference and Examples Guide.)

virtual memory Memory which uses the hard drive space to store information after you run out of random access memory. Virtual memory supplements the random access memory.

workbook a Microsoft Excel file composed of at least one worksheet.

worksheet a Microsoft Excel file in which you work and store the data. A worksheet is part of a workbook.

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