

ORACLE® CRYSTAL BALL, FUSION EDITION

RELEASE 11.1.1.3.00

USER'S GUIDE

ORACLE®
ENTERPRISE PERFORMANCE
MANAGEMENT SYSTEM

Crystal Ball User's Guide, 11.1.1.3.00

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Contents

Chapter 1. Welcome	13
Introduction	13
Who Should Use This Program	14
What You Will Need	14
About the Crystal Ball Documentation Set	14
Screen Capture Notes	16
Getting Help	16
Technical Support and More	16
Chapter 2. Crystal Ball Overview	17
Introduction	17
Model Building and Risk Analysis Overview	17
What is a Model?	18
Risk and Certainty	18
How Crystal Ball Differs from Traditional Analysis Tools	19
Monte Carlo Simulation and Crystal Ball	20
Crystal Ball Feature Overview	22
Charts and Analysis Tools	22
Other Crystal Ball Tools	29
Process Capability Features	31
Trend Analysis with Predictor	31
Optimizing Decision Variable Values with OptQuest	31
Steps for Using Crystal Ball	31
Resources for Learning Crystal Ball	32
Starting and Closing Crystal Ball	32
Starting Crystal Ball Manually	32
Starting Crystal Ball Automatically	33
Crystal Ball Welcome Screen	33
Closing Crystal Ball	34
Crystal Ball Menus and Toolbar	34
The Crystal Ball Menus	34
The Crystal Ball Toolbar	35

Crystal Ball Tutorials	35
Chapter 3. Defining Model Assumptions	37
Introduction	37
Types of Data Cells	37
About Assumptions and Probability Distributions	38
Defining Assumptions	38
Entering Assumptions	38
Additional Assumption Features	41
Entering Cell References and Formulas	42
Alternate Parameter Sets	43
Fitting Distributions to Data	44
Specifying Correlations Between Assumptions	47
Setting Assumption Preferences	50
Using the Crystal Ball Distribution Gallery	51
Displaying the Distribution Gallery	51
Distribution Gallery Window	51
Managing Distributions	53
Managing Categories	57
Chapter 4. Defining Other Model Elements	63
Introduction	63
Defining Decision Variable Cells	63
Defining Forecasts	64
Setting Forecast Preferences	65
Working with Crystal Ball Data	68
Editing Crystal Ball Data	68
Selecting and Reviewing Data	70
Setting Cell Preferences	72
Saving and Restoring Models	73
Chapter 5. Running Simulations	75
Introduction	75
About Crystal Ball Simulations	75
Setting Run Preferences	76
Setting Trials Preferences	76
Setting Sampling Preferences	77
Setting Speed Preferences	78
Setting Options Preferences	79
Setting Statistics Preferences	80

Freezing Crystal Ball Data Cells	80
Running Simulations	81
Starting Simulations	81
Stopping Simulations	82
Continuing Simulations	82
Resetting and Rerunning Simulations	82
Single-Stepping	82
The Crystal Ball Control Panel	83
Managing Chart Windows	84
Single Windows	84
Multiple Windows	84
Saving and Restoring Simulation Results	86
Saving Crystal Ball Simulation Results	86
Restoring Crystal Ball Simulation Results	87
Using Restored Results	87
Restored Results with Capability Metrics	87
Functions for Use in Excel Models	88
Running User-Defined Macros	88
User-Defined Macro Interfaces	89
Priority Rules	91
Global Macros	91
Toolbar Macros	92
Chapter 6. Analyzing Forecast Charts	93
Introduction	93
Guidelines for Analyzing Simulation Results	93
Understanding and Using Forecast Charts	95
Determining the Certainty Level	96
Focusing On the Display Range	100
Formatting Chart Numbers	101
Changing the Distribution View and Interpreting Statistics	102
Setting Forecast Preferences	110
Setting Forecast Chart Preferences	111
Setting Chart Preferences	112
Setting Preferences with Shortcut Keys	112
Basic Customization Instructions	113
Specific Customization Instructions	114
Managing Existing Charts	121
Opening Charts	121

Copying and Pasting Charts to Other Applications	122
Printing Charts	123
Closing Charts	123
Deleting Charts	124
Chapter 7. Analyzing Other Charts	125
Overview	125
Selecting Assumptions, Forecasts, and other Data Types	126
Understanding and Using Overlay Charts	126
Creating Overlay Charts	127
Customizing Overlay Charts	130
Using Distribution Fitting with Overlay Charts	130
Understanding and Using Trend Charts	131
Creating Trend Charts	133
Customizing Trend Charts	133
Understanding and Using Sensitivity Charts	138
About Sensitivity Charts	139
Creating Sensitivity Charts	139
How Crystal Ball Calculates Sensitivity	141
Limitations of Sensitivity Charts	142
Customizing Sensitivity Charts	143
Understanding and Using Assumption Charts	147
Customizing Assumption Charts	148
Understanding and Using Scatter Charts	149
Creating Scatter Charts	150
Customizing Scatter Charts	152
Chapter 8. Creating Reports and Extracting Data	157
Introduction	157
Creating Reports	157
Basic Steps for Creating Reports	158
Setting Report Options	159
Defining Custom Reports	160
Report Processing Notes	161
Extracting Data	161
Data Extraction Examples	164
Chapter 9. Crystal Ball Tools	167
Introduction	167
Overview	167

Setup Tools	168
Analysis Tools	168
Integration Tools	168
Tools and Run Preferences	168
Batch Fit Tool	169
Using the Batch Fit Tool	169
Batch Fit Example	172
Correlation Matrix Tool	177
About Correlations	177
About the Correlation Matrix Tool	178
Using the Correlation Matrix Tool	178
Correlation Matrix Example	180
Tornado Chart Tool	183
Tornado Chart	183
Spider Chart	185
Using the Tornado Chart Tool	185
Tornado Chart Example	188
Limitations of the Tornado Chart Tool	191
Bootstrap Tool	191
Using the Bootstrap Tool	193
Bootstrap Example	195
Decision Table Tool	199
Using the Decision Table Tool	200
Decision Table Example	202
Scenario Analysis Tool	205
Using the Scenario Analysis Tool	206
Scenario Analysis Example	207
2D Simulation Tool	210
Using the 2D Simulation Tool	211
2D Simulation Example	213
Second-Order Assumptions	218
Data Analysis Tool	219
Using the Data Analysis Tool	219
Data Analysis Example	221
Appendix A. Selecting and Using Probability Distributions	225
Introduction	225
Understanding Probability Distributions	225
A Probability Example	226

Continuous and Discrete Probability Distributions	228
Selecting Probability Distributions	229
Probability Distribution Descriptions	231
Beta Distribution	231
BetaPERT Distribution	233
Binomial Distribution	235
Custom Distribution	236
Discrete Uniform Distribution	237
Exponential Distribution	238
Gamma Distribution	240
Geometric Distribution	243
Hypergeometric Distribution	245
Logistic Distribution	247
Lognormal Distribution	248
Maximum Extreme Distribution	250
Minimum Extreme Distribution	251
Negative Binomial Distribution	252
Normal Distribution	253
Pareto Distribution	255
Poisson Distribution	256
Student's t Distribution	258
Triangular Distribution	259
Uniform Distribution	261
Weibull Distribution	262
Yes-No Distribution	264
Using the Custom Distribution	265
Custom Distribution Example 1	266
Custom Distribution Example 2	268
Custom Distribution Example 3 — Loading Data	271
Entering Tables of Data into Custom Distributions	274
Changes from Crystal Ball 2000.x (5.x)	279
Other Important Custom Distribution Notes	279
Truncating Distributions	280
Be Aware...	280
Comparing Distributions	281
Distribution Parameter Summary	282
Using Probability Functions	284
Limitations of Probability Functions	285
Probability Functions and Random Seeds	285

Sequential Sampling with Custom Distributions	285
Creating Custom SIP Distributions	286
Running Simulations with SIPs	287
Appendix B. Accessibility	289
Introduction	289
Enabling Accessibility for Crystal Ball	289
Using the Tab and Arrow Keys in the Crystal Ball User Interface	289
Toolbar and Menu Commands: Excel 2003 or Earlier	290
Crystal Ball Toolbar	290
Crystal Ball Menus	290
Shortcut key Combinations in Excel 2003 or Earlier	291
Distribution Gallery Shortcut Keys	299
Chart Preference Shortcut Keys	300
Using Crystal Ball in Excel 2007	301
Introduction	301
Crystal Ball Ribbon in Excel 2007	301
Shortcut Key Combinations in Excel 2007	302
Distribution Gallery Shortcut Keys	308
Chart Preference Shortcut Keys	308
Compatibility and File Conversion Issues	308
Appendix C. Using the Extreme Speed Feature	311
Overview	311
Compatibility Issues	312
Multiple-Workbook Models	312
Circular References	313
Crystal Ball Excel Functions	313
User-Defined Functions	314
Running User-Defined Macros	316
Special Functions	316
Undocumented Behavior of Standard Functions	316
Incompatible Range Constructs	316
Data Tables	318
Numerical Differences and the Compare Run Modes Tool	318
Other Important Differences	319
OptQuest and other Crystal Ball Tools	320
Precision Control and Cell Error Checking	320
Spreadsheet Updating	320
Very Large Models	320

Memory Usage	321
Spreadsheets with No Crystal Ball Data	321
Maximizing the Benefits of Extreme Speed	321
String Intermediate Results in Formulas	322
Calls to User-Defined Functions	322
Dynamic Assumptions	322
Excel Functions	323
Appendix D. Crystal Ball Tutorials	325
Introduction	325
Tutorial 1 — Futura Apartments	325
Starting Crystal Ball	326
Opening the Example Model	327
Running Simulations	328
Results Analysis — Determining Profit	329
Take a Look Behind the Scenes	330
Resetting and Single-Stepping	331
Closing Crystal Ball	332
Tutorial Review	332
Tutorial 2 — Vision Research	333
Starting Crystal Ball	333
Opening the Example Model	333
Reviewing the Vision Research Scenario	334
Defining Assumptions	334
Improving Process Quality — Tutorial 3	352
Overall Approach	353
Using the Loan Processing Model	355
Packaging Pump Design — Tutorial 4	366
Overall Approach	366
Using the DFSS Liquid Pump model	369
Using OptQuest to Optimize Quality and Cost	377
Appendix E. Using the Process Capability Features	381
Introduction	381
About Crystal Ball’s Process Capability Features	381
About Quality Improvement Methodologies	382
Methodologies for Improving Processes — Six Sigma	382
Methodologies for Improving Design — DFSS	383
Methodologies for Adding Value — Lean Principles	383
How Crystal Ball Supports Quality	384

Working Through Process Capability Tutorials	386
Preparing to Use Process Capability Features	386
Activating the Process Capability Features	386
Setting Capability Calculation Options	386
Setting Specification Limits and Targets	387
Analyzing Process Capability Results	388
Viewing Capability Metrics	388
Extracting Capability Metrics	391
Including Capability Metrics in Reports	392
Capability Metrics List	393
Appendix F. Bibliography	399
Bootstrap	399
Monte Carlo Simulation	399
Probability Theory and Statistics	400
Random Variate Generation Methods	400
Specific Distributions	401
Extreme Value Distribution	401
Lognormal Distribution	401
Weibull Distribution	401
Tornado Charts and Sensitivity Analysis	401
Two-Dimensional Simulation	402
Uncertainty Analysis	402
Sequential Sampling with SIPs	402
Glossary	403
Index	407

1

Welcome

In This Chapter

Introduction.....	13
Who Should Use This Program.....	14
What You Will Need.....	14
About the Crystal Ball Documentation Set.....	14
Getting Help.....	16
Technical Support and More.....	16

Introduction

This Guide describes how to use all three current releases of Oracle Crystal Ball:

- Oracle Crystal Ball, Fusion Edition
- Oracle Crystal Ball Decision Optimizer, Fusion Edition
- Oracle Crystal Ball Enterprise Performance Management, Fusion Edition

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

Crystal Ball is a graphically oriented forecasting and risk analysis program that takes the uncertainty out of decision-making.

Through the power of simulation, Crystal Ball becomes an effective tool in the hands of decision-makers. You can 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?" With Crystal Ball, you will become a more confident, efficient, and accurate decision-maker.

Crystal Ball is easy to learn and easy to use. 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.

The following sections explain more about Crystal Ball and how it works:

- [“Who Should Use This Program” on page 14](#)
- [“What You Will Need” on page 14](#)
- [“About the Crystal Ball Documentation Set” on page 14](#)
- [“Getting Help” on page 16](#)
- [“Technical Support and More” on page 16](#)

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 your 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:

- Crystal Ball
- Crystal Ball Decision Optimizer
- Crystal Ball EPM

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

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, see the *Oracle Crystal Ball Statistical 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. Note 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 Ball 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 your 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 Chart 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, “Accessibility”](#)

Describes Crystal Ball accessibility features including command equivalents and descriptions for each Crystal Ball toolbar button (Excel 2003 and earlier) or Crystal Ball ribbon icon (Excel 2007) and provides more information about using Crystal Ball with Excel 2007 and Windows Vista.
- [Appendix C, “Using the Extreme Speed Feature”](#)

Discusses the optional Extreme Speed feature available with Crystal Ball and describes its benefits and compatibility issues.
- [Appendix D, “Crystal Ball Tutorials”](#)

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

- [Appendix E, “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.

- [Appendix F, “Bibliography”](#)

Lists related publications, including statistics textbooks.

- Glossary

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


Screen Capture Notes

All the screen captures in this document were taken in Excel 2003 for Windows XP Professional and Excel 2003 for Windows XP, using a Crystal Ball Run Preferences random seed setting of 999, unless otherwise noted.

Due to round-off differences between various system configurations, you might 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, , in a dialog.
- Click the Help tool in the Crystal Ball toolbar or ribbon in Excel.
- In the Excel menubar, choose **Help**, then **Crystal Ball**, then **Crystal Ball Help**.
- In the Distribution Gallery and other dialogs, press F1.

Note: In Excel 2007, click Help at the right end of the Crystal Ball ribbon. Note that if you press F1 in Excel 2007, 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.

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

In This Chapter

Introduction.....	17
Model Building and Risk Analysis Overview	17
Crystal Ball Feature Overview	22
Steps for Using Crystal Ball	31
Starting and Closing Crystal Ball	32
Crystal Ball Menus and Toolbar.....	34
Crystal Ball Tutorials	35

Introduction

This chapter presents the basics you need to understand, start, review the menus and toolbars, and close Crystal Ball. Now, spend a few moments learning how Crystal Ball can help you make better decisions under conditions of uncertainty.

Chapters 2 through 7 of this *Oracle Crystal Ball User's Guide* describe how to build, run, analyze, and present your own Crystal Ball model simulations.

Model Building and Risk Analysis Overview

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.
2. Run a simulation on it.
3. Analyze the results.

The following sections give a brief overview of risk analysis and modeling. They build a foundation for understanding the many ways Crystal Ball and related products can help you minimize risk and maximize success in virtually any decision-making environment.

What is a Model?

Crystal Ball works with spreadsheet models, specifically Excel spreadsheet models. Your spreadsheet might already contain a model, depending on what type of information you have in your spreadsheet and how you use it.

If you only use spreadsheets to hold data — sales data, inventory data, account data, and so on — then you do not have a model. Even if you have formulas that total or subtotal the data, you might not have a model that is useful for simulation.

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 a combination of functions, formulas, and data. As you add more cells to the model, your spreadsheet begins to portray the behavior of a real-world system or situation.

Risk and Certainty

The following sections describe risk and how Crystal Ball helps handle it:

- [“About Risk” on page 18](#)
- [“Quantifying Risks with Spreadsheet Models” on page 18](#)
- [“Assumption Ranges” on page 19](#)
- [“Forecast Ranges” on page 19](#)
- [“Analyzing Certainty” on page 19](#)

About Risk

Risk is usually associated with uncertainty, where risk includes the possibility of an undesirable event coupled with severity. For example, if sales for next month are above a certain amount (a desirable event), then orders will reduce the inventory. If the reduction in inventory is large enough, there will be a delay in shipping orders (an undesirable event). If a delay in shipping means losing orders (severity), then that possibility presents a risk. As uncertainty and risk increase, decision-making becomes more difficult.

There are two points to keep in mind when analyzing risk:

- Where is the risk?
- How significant is the risk?

Quantifying Risks with Spreadsheet Models

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 out of your own pocket, that might 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 might 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:

- Help end "analysis paralysis" and 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

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 38](#).

Forecast Ranges

Since all those 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

The forecast results show the different result values for each forecast and also the probability of obtaining any value. Crystal Ball normalizes these probabilities to calculate another important number: the certainty.

The chance of any forecast value falling between $-\infty$ and $+\infty$ is always 100%. However, the chance — or certainty — of that same forecast being at least zero (which you might want to calculate to make sure that you make a profit) might be only 45%. For any range you define, Crystal Ball calculates the resulting certainty. This way, not only do you know that your 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 might, therefore, decide to skip).

How Crystal Ball Differs from Traditional Analysis Tools

When risk and uncertainty exist, traditional spreadsheet analysis tries to analyze this uncertainty using:

- [“Point Estimates” on page 20](#)
- [“Range Estimates” on page 20](#)
- [“What-if Scenarios” on page 20](#)

Point Estimates

Point estimates are when you use what you think are the most likely values (technically referred to as the mode) for the uncertain variables. These estimates are the easiest, but can return misleading results. For example, try crossing a river with an average depth of three feet. Or, if it takes you an average of 25 minutes to get to the airport, leave 25 minutes before your flight takes off. You will miss your plane 50% of the time.

Range Estimates

Range estimates typically calculate three scenarios: the best case, the worst case, and the most likely case. These types of estimates can show you the range of outcomes, but not the probability of any of these outcomes.

What-if Scenarios

What-if scenarios are usually based on range estimates, and are often constructed informally. What is the worst case for sales? What if sales are best case but expenses are the worst case? What if sales are average, but expenses are the best case? What if sales are average, expenses are average, but sales for the next month are flat?

These traditional methods 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 might tell you what is possible, they do not tell you what is probable.

This is where simulation with Crystal Ball comes in. Crystal Ball uses Monte Carlo simulation to generate a range of values for assumptions 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 and Crystal Ball

Spreadsheet risk analysis uses both a spreadsheet model and simulation to analyze the effect of varying inputs on outputs of the modeled system. One type of spreadsheet simulation is Monte Carlo simulation, which randomly generates values for uncertain variables over and over to simulate a model.

Monte Carlo simulation was named for Monte Carlo, Monaco, where the primary attractions are casinos containing games of chance. Games of chance such as roulette wheels, dice, and slot machines exhibit random behavior.

The random behavior in games of chance 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).

The following sections describe the benefits of Monte Carlo simulation and how it works in Crystal Ball:

- [“Benefits of Monte Carlo Simulation” on page 21](#)
- [“How Crystal Ball Uses Monte Carlo Simulation” on page 21](#)

Benefits of Monte Carlo Simulation

Crystal Ball uses Monte Carlo simulation to overcome both of the spreadsheet limitations encountered with traditional spreadsheet analysis ([“How Crystal Ball Differs from Traditional Analysis Tools” on page 19](#)):

- You can describe a range of possible values for each uncertain cell in your spreadsheet. Everything you know about each assumption is expressed all at once. For example, you can define your 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.

How Crystal Ball Uses Monte Carlo Simulation

Crystal Ball implements Monte Carlo simulation in a repetitive three-step process. For each trial of a simulation, Crystal Ball repeats the following three steps:

1. For every assumption cell, Crystal Ball generates a random number according to the probability distribution you defined and places it into the spreadsheet.
2. Crystal Ball recalculates the spreadsheet.
3. Crystal Ball then retrieves a value from every forecast cell and adds it 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 your own spreadsheet models, you need to carefully examine the nature of the problem and continually refine the models until they approximate your situation as closely as possible.

Crystal Ball Feature Overview

The following sections introduce the main features of Crystal Ball:

- [“Charts and Analysis Tools” on page 22](#)
- [“Other Crystal Ball Tools” on page 29](#)
- [“Process Capability Features” on page 31](#)
- [“Trend Analysis with Predictor” on page 31](#)
- [“Optimizing Decision Variable Values with OptQuest” on page 31](#)

Charts and Analysis Tools

Crystal Ball offers several types of charts and reports, introduced in these sections:

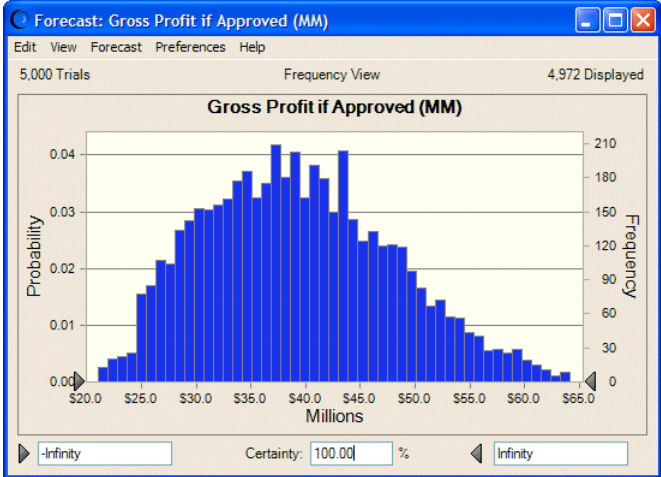
- [“Forecast Charts” on page 22](#)
- [“Overlay Charts” on page 23](#)
- [“Trend Charts” on page 24](#)
- [“Sensitivity Charts” on page 24](#)
- [“Scatter Charts” on page 25](#)
- [“Assumption Charts” on page 26](#)
- [“OptQuest Charts” on page 27](#)
- [“Reports” on page 27](#)
- [“Extracting and Pasting Data” on page 28](#)

These graphical analysis tools are all accessed through the Analyze menu. They are discussed in [Chapter 6, “Analyzing Forecast Charts,”](#) [Chapter 7, “Analyzing Other Charts,”](#) and [Chapter 8, “Creating Reports and Extracting Data.”](#)

Forecast Charts

Forecast charts are the basic tool for Crystal Ball results analysis. They use frequency distributions to show the number of values occurring in a given interval. The result is a range of values representing possible and probable values for a given forecast formula based on input assumption definitions. You can use forecast charts to evaluate the certainty of obtaining a particular value or range of forecast values. For more information on forecast charts, see [Chapter 6, “Analyzing Forecast Charts.”](#)

Figure 1 Forecast Chart Showing Gross Profit

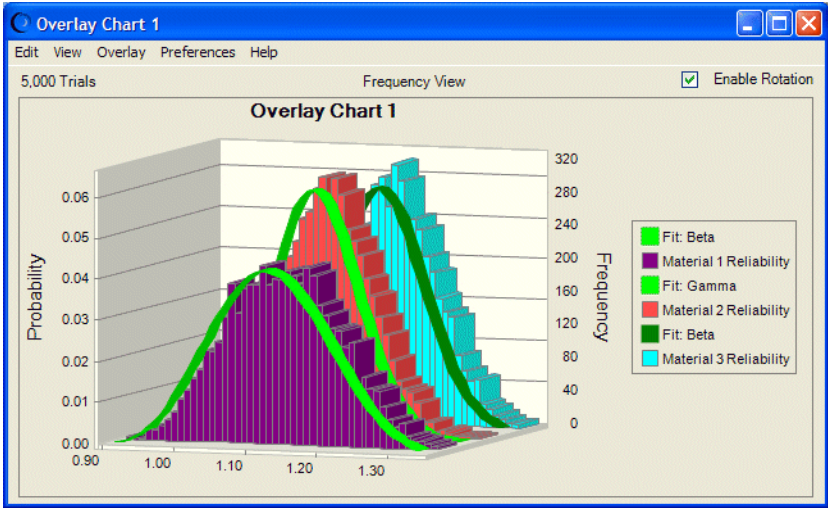


Overlay Charts

After completing a simulation with multiple related forecasts, you can create an overlay chart to view the frequency data from selected forecasts in one location. Then, you can compare differences or similarities that otherwise might not be apparent. You can customize the overlay chart to accentuate these characteristics. You can also use the overlay chart to fit standard distributions to forecasts.

The chart in [Figure 2](#) shows reliabilities of three kinds of manufacturing material with lines of best fit for each type of distribution.

Figure 2 Overlay Chart with Forecasts and Lines of Best Fit



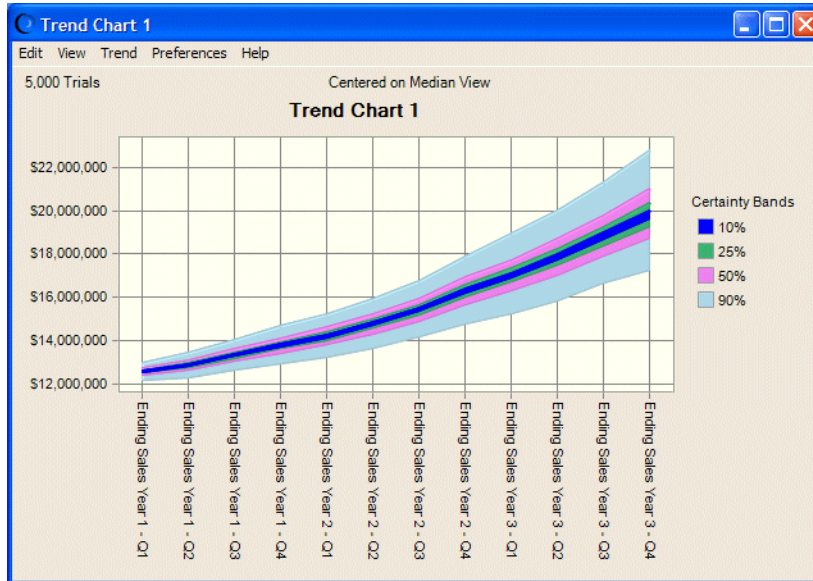
Note: This overlay chart is shown in 3D, rotated view with legend to the right.

Trend Charts

After completing a simulation with multiple related forecasts, you can create a trend chart to view the certainty ranges of all the forecasts on a single chart. The ranges are displayed as a series of patterned bands. Each band represents the certainty range into which the actual values of your forecasts fall. For example, the band which represents the 90% certainty range shows the range of values into which your forecast has a 90% chance of falling.

The chart in [Figure 3](#) shows increases in sales over time.

Figure 3 Upward trending sales figures, by quarter



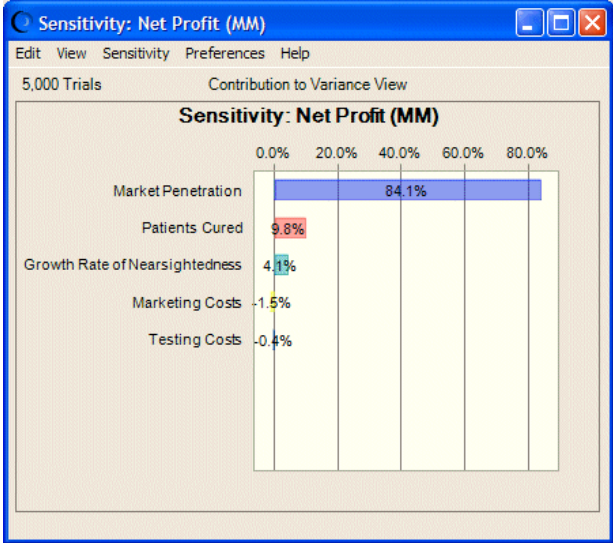
If you have cyclical or seasonal time-series data, you can use Predictor for data trend analysis. For more information, see [“Trend Analysis with Predictor”](#) on page 31.

Sensitivity Charts

Sensitivity charts show the influence of each assumption cell on a particular forecast cell. During a simulation, Crystal Ball ranks the assumptions according to their correlation (or sensitivity) to each forecast cell. The sensitivity chart displays these rankings as a bar chart, indicating which assumptions are the most or least important in the model. You can print the sensitivity chart or copy it to the clipboard.

The chart in [Figure 4](#), following, shows the effects of several assumptions on forecasted net profits for the pharmaceutical company discussed in [“Tutorial 2 — Vision Research”](#) on page 333. Market penetration accounts for about 84% of variation of net profits for a new product under consideration.

Figure 4 Effects of Assumptions on Net Profit



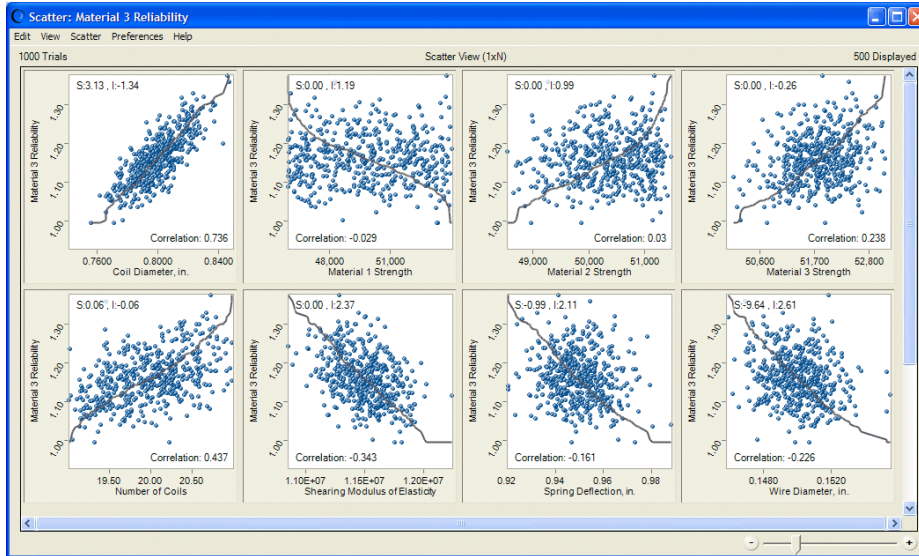
The Tornado Chart tool provides alternate ways to measure and chart sensitivity. For more information, see [“Tornado Chart” on page 30](#).

Scatter Charts

Scatter charts show correlations, dependencies, and other relationships between pairs of forecasts and assumptions plotted against each other. You can plot scatter charts directly through the Analyze menu, or you can create a sensitivity chart and choose Sensitivity, then Open Scatter Chart to create a chart showing how the assumptions with the greatest impact relate to the target forecast.

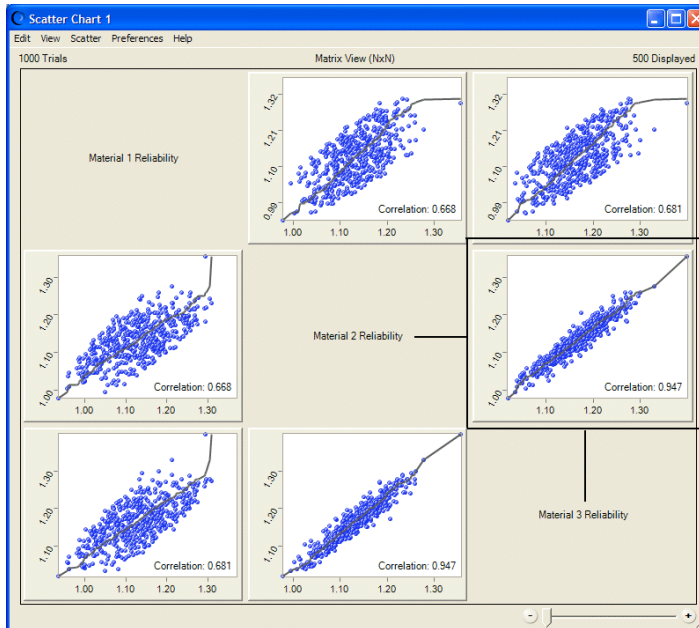
In its basic form, a scatter chart (Figure 5) contains one or more plots of a target variable mapped against a set of secondary variables. Each plot is displayed as a cloud of points or symbols aligned in a grid within the scatter chart window. Optional correlation coefficients indicate the strength of the relationship.

Figure 5 Scatter Chart with Correlations Displayed



In another form of scatter chart, called the Matrix view, each selected variable is plotted against the other selected variables to show the relationships among them, as shown in Figure 6.

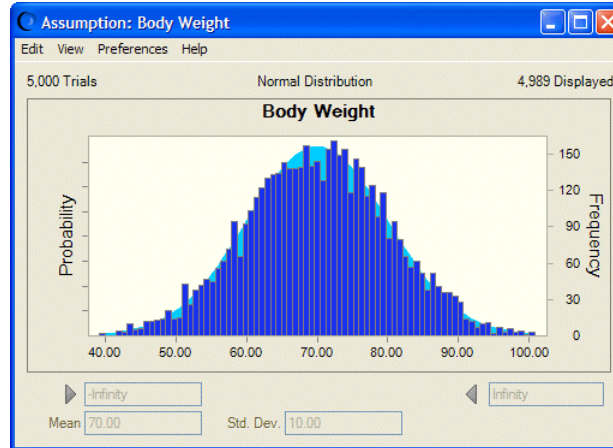
Figure 6 Scatter Chart in Matrix View



Assumption Charts

Assumption charts show trial values (that is, random numbers) for the current simulation layered over the assumption's ideal probability distribution. They are generated automatically each time a simulation runs.

Figure 7 Assumption chart for Body Weight



OptQuest Charts

You can use OptQuest, included in Crystal Ball Decision Optimizer, to optimize certain forecast statistics or process capability metrics using variable inputs provided by Crystal Ball decision variables. Optimization results are displayed in OptQuest charts. For more information, see [“Optimizing Decision Variable Values with OptQuest” on page 31](#),

Predictor Charts

You can use Predictor to perform time series forecasts based on seasonal and non-seasonal historical data. Time series forecasts are displayed in Predictor charts. For more information, see [“Trend Analysis with Predictor” on page 31](#).

Reports

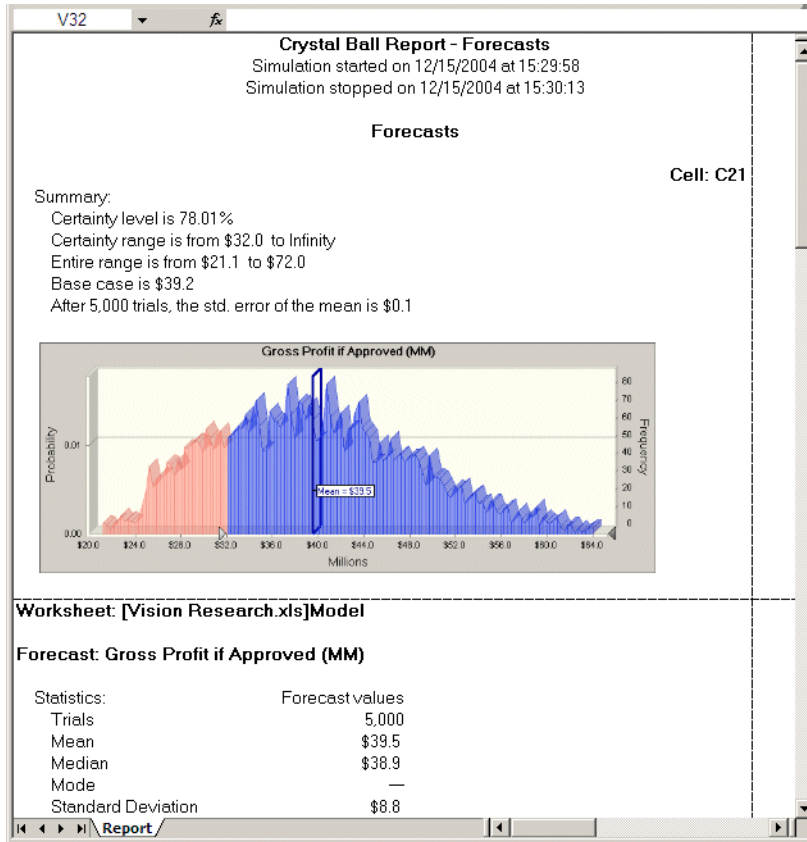
Crystal Ball has powerful reporting capabilities. You can customize reports to include the following charts and data:

- 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 Excel workbooks. You can modify, print, or save the report in the same way as any other workbook.

Figure 8 shows part of a forecast report for the Vision Research model.

Figure 8 Sample Forecast Report



Extracting and Pasting Data

You can select Analyze, then Extract Data to extract forecast information generated by a simulation and place it in a new Excel workbook. You can extract these types of data: statistics, percentiles, chart bins, sensitivity data, and trial values.

Figure 9 shows statistics data extracted from a sales spreadsheet.

Figure 9 Extracted Statistics Data

	A	B	C
1	Statistics	Ending Sales Year 3 - Q1	Ending Sales Year 3 - Q2
2	Trials	1000	1000
3	Mean	\$17,081,883	\$17,950,914
4	Median	\$17,042,665	\$17,930,927
5	Mode	---	---
6	Standard Deviation	\$1,117,986	\$1,297,577
7	Variance	\$1,249,891,924,272	\$1,683,706,187,431
8	Skewness	0.19	0.15
9	Kurtosis	3.22	3.19
10	Coeff. of Variability	0.07	0.07
11	Minimum	\$13,695,983	\$14,060,365
12	Maximum	\$21,289,239	\$22,981,379
13	Range Width	\$7,593,255	\$8,921,013
14	Mean Std. Error	\$35,354	\$41,033

Other Crystal Ball Tools

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

- [“Batch Fit” on page 29](#)
- [“Bootstrap” on page 29](#)
- [“Correlation Matrix” on page 29](#)
- [“Data Analysis” on page 30](#)
- [“Decision Table” on page 30](#)
- [“Scenario Analysis” on page 30](#)
- [“Tornado Chart” on page 30](#)
- [“2D Simulation” on page 30](#)
- [“Integration Tools” on page 30](#)
- [“Compare Run Modes” on page 31](#)

All of these except the integration tools are discussed in [Chapter 9, “Crystal Ball Tools.”](#) The integration tools are only available in Crystal Ball EPM and are described in the *Oracle Crystal Ball Enterprise Performance Management Integration Guide*.

Additional tools, Predictor and OptQuest, may also appear on the Run menu (or the Tools group in Microsoft Excel 2007) in certain editions of Crystal Ball. For a description of these features, see [“Trend Analysis with Predictor” on page 31](#) and [“Optimizing Decision Variable Values with OptQuest” on page 31](#).

Batch Fit

The Batch Fit tool fits probability distributions to multiple data series. It helps create assumptions when you have historical data for several variables. Inputs are rows or columns of data. Outputs include fitted assumptions (probability distributions), tables of goodness-of-fit statistics and correlation coefficients calculated from the data series.

Bootstrap

The Bootstrap tool estimates the reliability or accuracy of statistics or percentiles for forecasts or other sample data. This tool doesn't assume that the statistics or percentiles are normally distributed. The main input is the forecast to be analyzed. Outputs are a forecast chart of the distributions for each statistic or percentile.

Correlation Matrix

The Correlation Matrix tool defines a matrix of correlations between assumptions to more accurately model the interdependencies between variables. Inputs are the assumptions to correlate. The output is a correlation matrix, loaded into the model.

Data Analysis

The Data Analysis tool imports data directly into Crystal Ball forecasts for analysis in Crystal Ball.

Decision Table

Decision variables are values you can control, such as such as how much to charge for a product or how many wells to drill. The Decision Table tool runs multiple simulations to test different values for one or two decision variables. Inputs are the decision variables to test. The output is a table of results you can analyze further using forecast, trend, or overlay charts.

If you want to optimize decision variable values to reach a specific objective and you have OptQuest, you can use it to find solutions. For more information, see [“Optimizing Decision Variable Values with OptQuest” on page 31](#).

Scenario Analysis

The Scenario Analysis tool runs a simulation and then matches all of the resulting values of a target forecast with the corresponding assumption values. Then, you can see which combination of assumption values gives a particular result. The input is the forecast to be analyzed. The output is a table of all the forecast values matched with the corresponding value of each assumption.

Tornado Chart

The Tornado Chart tool measures the input of each model variable one at a time, independently, on a target forecast. The inputs are the target forecast and the assumptions, decision variables, and precedent cells to test against. The output is a tornado chart, which shows the sensitivity of the variables using range bars, or a spider chart, which shows the sensitivity of the variables using sloping lines.

2D Simulation

The 2D Simulation tool helps determine how much of the variation within a model is caused by uncertainty and how much by true variability. The inputs are the target forecast and the assumptions to analyze. The output is a table which includes the forecast means, the uncertainty assumption values, and the statistics, including percentiles, of the forecast distribution for each simulation. Results are also graphed on an overlay chart and a trend chart.

Integration Tools

The optional integration tools link Crystal Ball EPM with Oracle Hyperion Strategic Finance, Fusion Edition and other Enterprise Performance Management applications using the Strategic Finance Setup wizard and Oracle Hyperion Smart View for Office, Fusion Edition. The Strategic Finance tool creates a workbook of Strategic Finance information that can then be analyzed with Crystal Ball. The Enterprise Performance Management tool connects to Oracle Enterprise Performance Management applications such as Oracle Essbase using Smart View so you can run

Crystal Ball simulations on data in the underlying database. The integration tools are only available if you have Strategic Finance and Crystal Ball EPM. They are described in the *Strategic Finance Integration Guide* and a help file that is available after you start the Strategic Finance Setup wizard.

Compare Run Modes

If you have Crystal Ball Decision Optimizer including the Extreme Speed feature, you can use the Compare Run Modes tool to compare simulation run time in Normal and Extreme speed. For more information about this tool, see [Appendix C, “Using the Extreme Speed Feature”](#).

Process Capability Features

If you use Six Sigma or other quality methodologies, Crystal Ball’s process capability features can help you improve quality in your organization. For a brief description of these features and how to use them, see [Appendix E, “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*.

Optimizing Decision Variable Values 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 desired 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.

“What is a Model?” on page 18 discusses spreadsheet models. Also see the references in the Bibliography.

2. Start Crystal Ball.

If you have not set up Crystal Ball to load automatically with Microsoft Excel, start Crystal Ball as described in “Starting and Closing Crystal Ball” on page 32.

3. Load your spreadsheet model.

4. Using Crystal Ball, define assumption cells and forecast cells. If appropriate for your situation, you can also define decision variable cells.

For more information, see “Entering Assumptions” on page 38 and continue on with Chapter 4.

5. Set run preferences for your simulation, as described in “Setting Run Preferences” on page 76.

6. Run the simulation, following the instructions in “Starting Simulations” on page 81.

7. Analyze your results. See “Understanding and Using Forecast Charts” on page 95 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.

Resources for Learning Crystal Ball

If you are new to Crystal Ball, [Appendix D](#) offers tutorials to quickly introduce Crystal Ball’s features and workflow. Consider completing the tutorials before you continue on with the more detailed instructions that follow.

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

<http://www.oracle.com/crystalball>

Starting and Closing Crystal Ball

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

Starting Crystal Ball Manually

- To start Crystal Ball manually, in Windows, choose **Start**, then **All Programs**, then **Oracle Crystal Ball**, then **Crystal Ball**.

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

Starting Crystal Ball Automatically

► To set Crystal Ball to start automatically each time you start Excel:

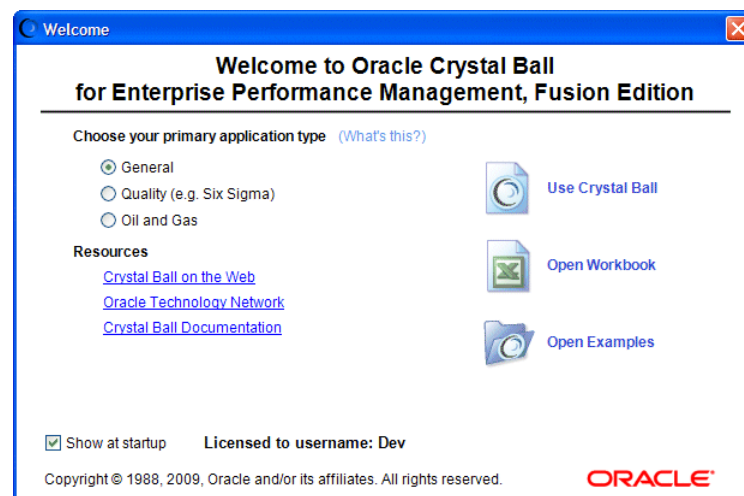
- 1 In Windows, choose **Start**, then **All Programs**, then **Oracle Crystal Ball**, then **Application Manager**.
- 2 Check **Automatically Launch Crystal Ball When Excel Starts**.
- 3 Click **OK**.

Note: You can also use the Excel Add-ins Manager to open Crystal Ball within Excel when Excel is already open and to close Crystal Ball without closing 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 10](#), following. Depending on the Crystal Ball version, your license features, and whether you are using a purchased or a trial version, the screen might differ somewhat from this illustration.

Figure 10 Crystal Ball Welcome Screen



You can use the Welcome screen to:

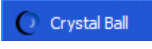
- Set certain preferences according to how you use Crystal Ball
- View the Crystal Ball Web site
- View an online list of new features
- Display the Oracle Technology Network, where you can download applications and documentation
- Display the Crystal Ball online documentation in HTML format
- Close the screen and start using Crystal Ball
- Display the Excel File, then Open dialog

- Display the *Oracle Crystal Ball Examples Guide*
- Purchase Crystal Ball, if you are using a time-limited trial version

For an explanation of the “primary application type” settings, click the [What Is This?](#) hyperlink.

Closing Crystal Ball

➤ To close Crystal Ball, use one of the following options::

- Right-click the Crystal Ball icon, , in the Windows taskbar and choose Close, or
- Close Excel.

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

Crystal Ball Menus and Toolbar

The following sections describe the main elements of the Crystal Ball user interface:

- [“The Crystal Ball Menus” on page 34](#)
- [“The Crystal Ball Toolbar” on page 35](#)

The Crystal Ball Menus

When you load Crystal Ball with Microsoft Excel, some new menus are displayed in the Excel menubar:

- Define — contains commands that define and select assumption, decision variable, and forecast cells; perform Crystal Ballcopy data, paste data, and clear data operations; and set cell preferences.
- Run — contains commands that start, stop, reset, and single-step through simulations; freeze variables; launch the Crystal Balltools and Predictor as well as OptQuest, if available; and set run preferences.
- Analyze — contains commands that create a variety of charts and reports, extract data, and save or restore results.

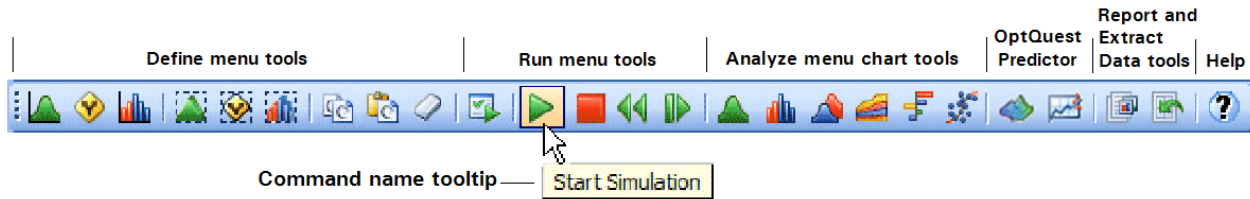
For specific information about commands, see [Appendix B, “Accessibility.”](#)

Note: If you are using Crystal Ball in Excel 2007, you will see a single Crystal Ball menu and then a ribbon instead of a toolbar. For more information about using Crystal Ball with Office 2007, see [Appendix B](#).

The Crystal Ball Toolbar

To help you set up spreadsheet models and run simulations, Crystal Ball has a customized toolbar that provides instant access to the most commonly used menu commands.

Figure 11 The Crystal Ball Toolbar



The tools in the first three groups are from the Define menu. The tools from the next two groups are from the Run menu. The remaining tool groups are for creating charts, running the OptQuest and Predictor tools (if available to you), creating reports and extracting data from results, and displaying Crystal Ball online help. When you point to a tool icon, the tooltip is displayed and identifies it.

- To hide or display the Crystal Ball toolbar for the current session, choose **View**, then **Toolbars**, then **Crystal Ball**.

Note: If you are using Crystal Ball in Excel 2007, you will see a single ribbon instead of a toolbar. For more information about using Crystal Ball with Office 2007, see [“Crystal Ball Ribbon in Excel 2007”](#) on page 301.

Crystal Ball Tutorials

The easiest way to learn Crystal Ball is to work through the tutorials in [Appendix D](#). Tutorial 1 is basic and will help you understand the material in the following chapters. Tutorial 2 shows more about how to create models and run Crystal Ball simulations as described in the following chapters.

3

Defining Model Assumptions

In This Chapter

Introduction.....	37
Types of Data Cells	37
About Assumptions and Probability Distributions.....	38
Defining Assumptions	38
Entering Assumptions	38
Additional Assumption Features.....	41
Using the Crystal Ball Distribution Gallery	51

Introduction

This chapter provides step-by-step instructions for setting up assumption cells in Crystal Ball models so simulations can be run against them. This chapter also describes all the ways you can use the Distribution Gallery to organize your favorite distributions and define categories of distributions to share with others. The next chapter describes how to define decision variable and forecast cells and to cut, copy, and paste data.

If you are a new user, you should start by working through the tutorials in [Appendix D](#), and then read this chapter. After you complete this chapter and [Chapter 4](#), read [Chapter 5](#) for information on setting preferences and running simulations.

Types of Data Cells

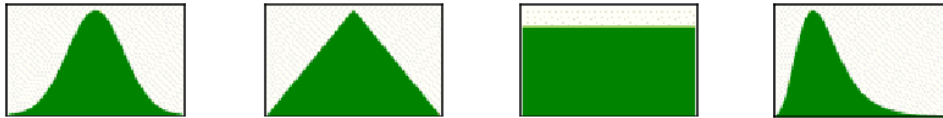
Crystal Ball uses three types of data cells as inputs and outputs:

- **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, might contain the formula `=C17*C20*C21`.

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 12](#).

Figure 12 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 225](#).

Defining Assumptions

- To define an assumption:
 - 1 **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 229](#).
 - Consider using Crystal Ball’s distribution fitting feature, described in [“Fitting Distributions to Data” on page 44](#).
 - Select the distribution that characterizes the variable.
 - 2 Enter the assumption as described in the next section, [“Entering Assumptions” on page 38](#).

Entering Assumptions

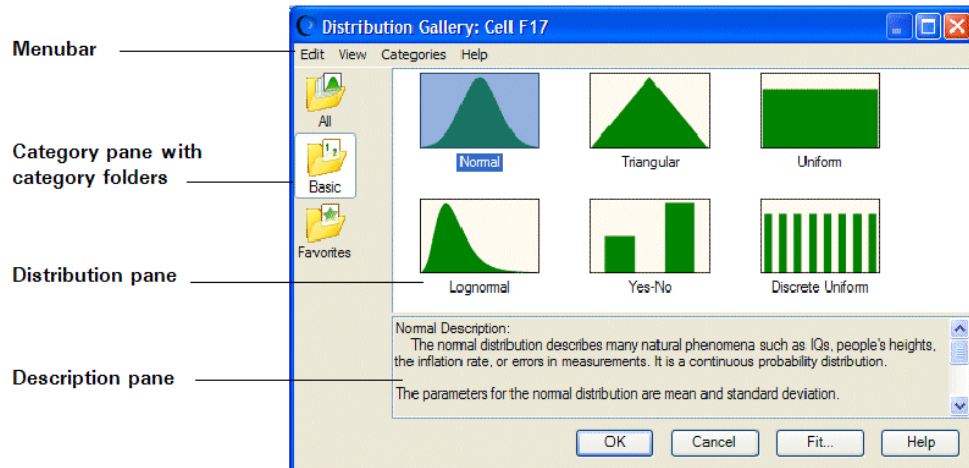
- To enter an assumption:
 - 1 **Select a cell or a range of cells.** The cells can be blank or have numeric values, but they cannot have formulas or text.

- 2 Choose **Define**, then Define Assumption, .

(In Excel 2007, 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 13).

Figure 13 The Distribution Gallery with Basic category Selected



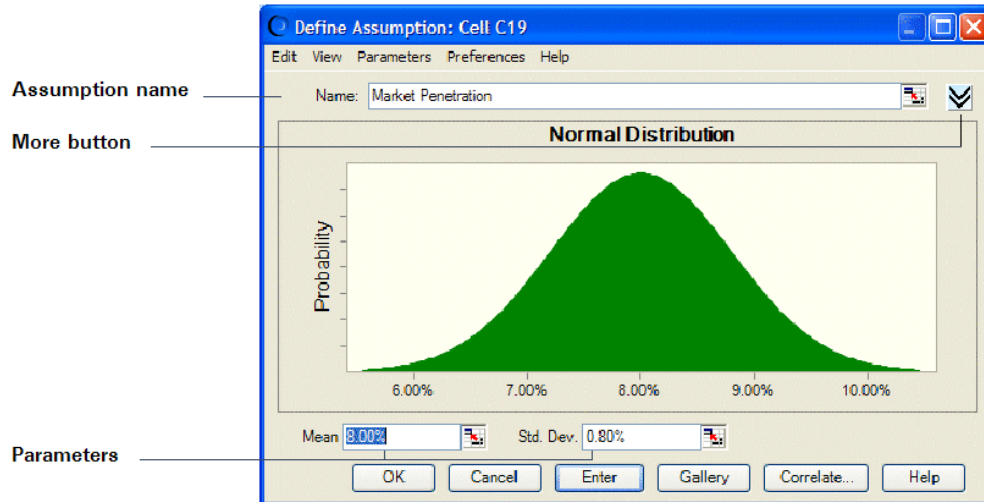
- 3 In the Distribution Gallery, select the distribution you want from the gallery. The Basic category contains several frequently used distributions. Click All to view all distributions shipped with Crystal Ball. For details, see [“Using the Crystal Ball Distribution Gallery” on page 51](#).

Alternately, click the Fit button to fit a distribution to historical data, as described in [“Fitting Distributions to Data” on page 44](#).


For more information on the Distribution Gallery, see [“Distribution Gallery Window” on page 51](#).

- 4 When the Define Assumption dialog opens (Figure 14), type in a title and the parameters for the distribution. The parameters can be either numeric values or cell references.

Figure 14 Normal Distribution

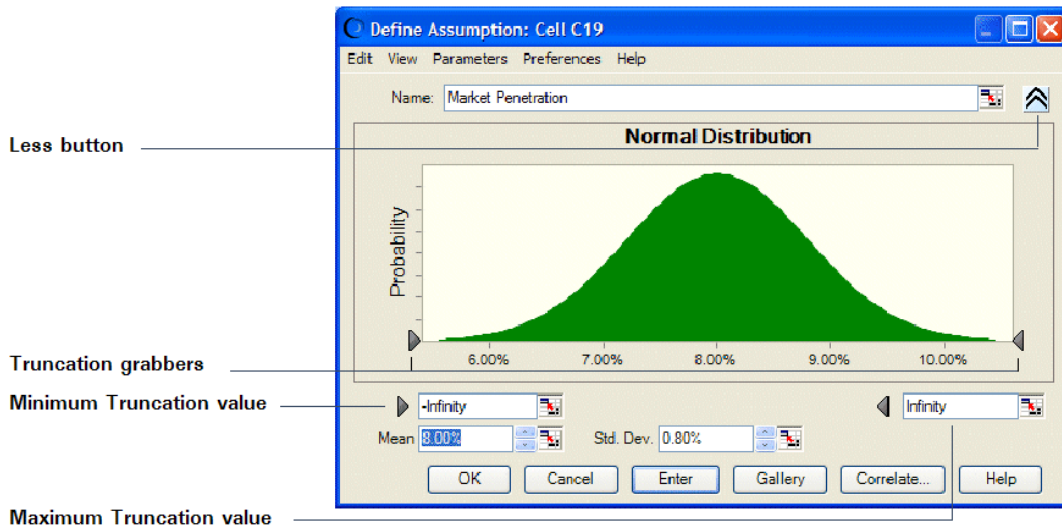


To change the distribution type, click Gallery to return to the Distribution Gallery and then select another distribution.

- 5 To see more information, click the More button, , near the Name field.


More information is displayed in the Define Assumption dialog as shown in Figure 15.

Figure 15 The Define Assumption Dialog, Expanded



In the expanded Define Assumption dialog, you can:

- Enter truncation minimum and maximum values in the fields just below the distribution.
- Use the truncation grabbers to truncate the value range.
- Use numeric spinners (arrows to the right of the field) to adjust parameter settings.

- Click the Less button, , to hide the minimum and maximum value fields and truncation grabbers. (For more information about truncating distributions, see [“Truncating Distributions” on page 280.](#))

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 choose another distribution.
 - Click the Correlate button to define correlations as described in [“Specifying Correlations Between Assumptions” on page 47.](#)
 - Choose **Edit**, then **Add** in the menubar 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 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 41.](#)
- 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.

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 sections discuss advanced features that help you refine assumption definitions and use assumptions more effectively:

- [“Entering Cell References and Formulas” on page 42](#) below
- [“Alternate Parameter Sets” on page 43](#)
- [“Fitting Distributions to Data” on page 44](#)
- [“Specifying Correlations Between Assumptions” on page 47](#)
- [“Setting Assumption Preferences” on page 50](#)
- [“Freezing Crystal Ball Data Cells” on page 80](#)

Entering Cell References and Formulas

In addition to numeric values, you can enter a reference to a specific cell in a parameter field. 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 fields 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 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 fields, choose **Parameters**, then **Show Cell References** in the Define Assumption dialog.

The following topics contain details about cell references, range names, and formulas:

- [“Dynamic vs. Static Cell References” on page 42](#)
- [“Relative References” on page 42](#)
- [“Absolute References” on page 43](#)
- [“Range Names” on page 43](#)
- [“Formulas” on page 43](#)

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 field 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 field, enter the cell reference =\$C\$5. This causes the value in cell C5 to be used in the assumption cell parameter field. Later, if you decide to copy and paste this assumption in the worksheet, the cell references in the parameter field 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 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.

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 variable in your 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 menubar of the Define Assumption dialog. The currently selected parameter set has a check mark next to it. If you choose 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, choose 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 Statistical Guide*.

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

Fitting Distributions to Data

If you have historical data available, Crystal Ball's distribution fitting feature can substantially simplify the process of selecting a probability distribution. Not only is the process simplified, but the resulting distribution more accurately reflects the nature of your 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 choose from among all distributions supported by Crystal Ball except the yes-no distribution.

Using Distribution Fitting

► To use distribution fitting:

- 1 **Select the cell where you want to create an assumption.**

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

- 2 **Choose **Define**, then **Define Assumption**,** .

(In Excel 2007, click the upper half of the Define Assumption icon.)

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

The Fit Distribution dialog opens.

- 4 **Choose a data location.**

- If the historical data is in a worksheet in the active workbook, choose 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 check Column and enter the number of columns in the text file.

When you use a file as your 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 quotes. 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 choose 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.
- **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.
- **Kolmogorov-Smirnov.** The result of this test is essentially the largest vertical distance between the two cumulative distributions.

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

7 If you know your data corresponds to certain shape, location, or other special parameter values for some distributions, you can choose to lock parameters to those values.

Check **Lock Parameters** and enter appropriate values in the Lock Parameters dialog. For details, see [“Locking Parameters When Fitting Distributions”](#) on page 47.

8 By default, only values for the selected ranking statistic are displayed in the Comparison Chart dialog. To show values for all three statistics, check **Show All Goodness-of-fit Statistics** at the bottom of the Fit Distribution dialog.

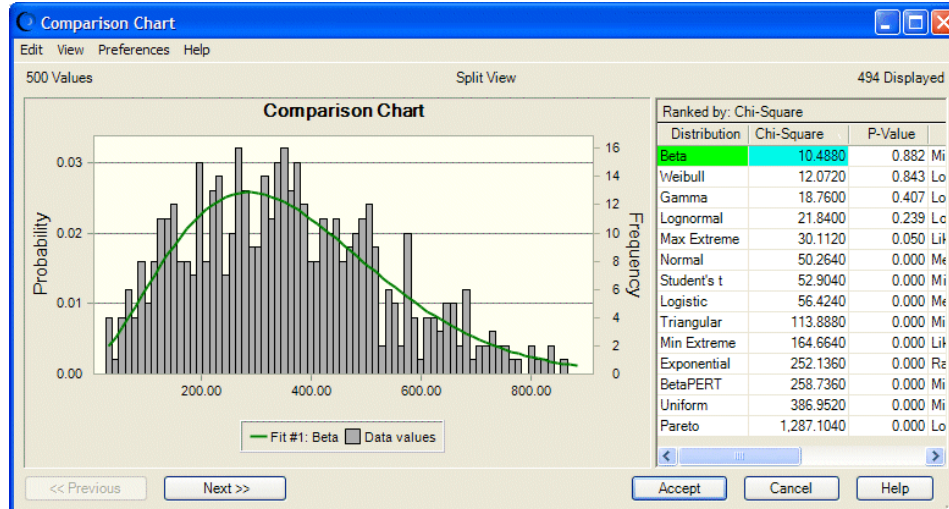
9 Click **OK**.

The Comparison Chart opens.

Confirming the Fitted Distribution

When the Comparison Chart opens ([Figure 16](#)), 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 16 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-of-fit statistics. You can:

- Use the Next and Previous buttons to scroll through the fitted probability distributions. Each probability distribution is shown superimposed over the data.
- Choose Preferences, then Chart to change chart features so that similarities or differences are more clearly accentuated.
- Click Cancel to return to the Fit Distribution dialog.

2 To use the currently displayed distribution, either the best fit or another of your choice, click 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 106 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 your 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 your 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 Check **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.

Specifying Correlations Between Assumptions

In Crystal Ball, assumption values are usually calculated independently of each other. Crystal Ball generates random numbers for each assumption without regard to how random numbers are generated for other assumptions. However, dependencies often do exist between variables in a system being modeled.

You can define correlations between pairs of assumptions. These 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 is likely to be high. A negative value means that the assumptions are inversely related; when one is high, the other is likely to be low.

Crystal Ball uses rank correlation (Spearman) for all correlation computations to relate assumptions with different distribution types. For more information, see the "Statistical Definitions" chapter of the *Oracle Crystal Ball Statistical Guide*.

► To correlate an assumption to one or more assumptions:

- 1 Select an assumption cell.

- 2 Choose **Define**, then **Define Assumption**, .

The Define Assumption dialog opens.


- 3 Click the **More** button to the right of the Assumption name in the Define Assumption dialog.

4 Click Correlate.

The Define Correlation dialog opens.

5 In the Define Correlation dialog, click Choose to select the assumption to correlate from the Choose Assumptions dialog. (You can only correlate assumptions in the same workbook.)

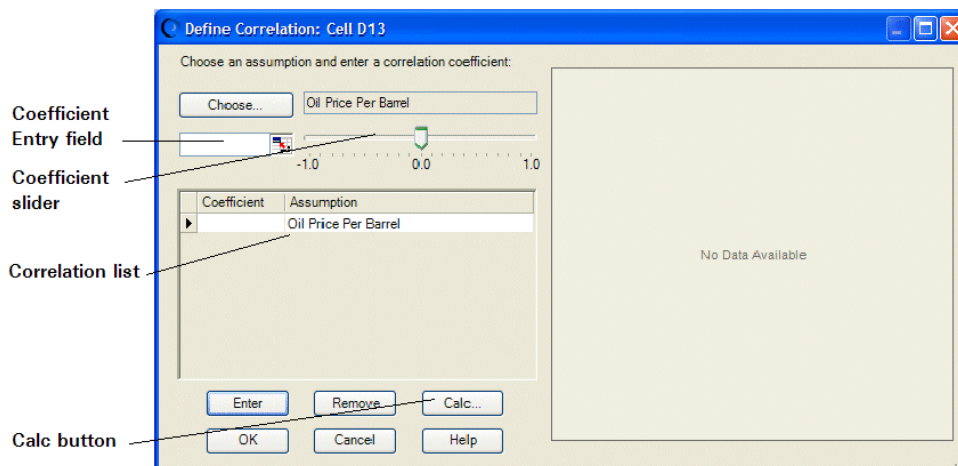
The Choose Assumptions dialog provides a list of the names of all the assumptions defined in your workbook.

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.

6 Choose one or more of the assumption names on the list and click OK.

The cell reference or name of the assumption is displayed in the list in the left pane of the Define Correlation dialog, as shown in [Figure 17](#).

Figure 17 Define Correlation Dialog with Second Assumption



After you select the second assumption, the cursor moves to the field below the Choose button, the Coefficient Entry field.

The chosen assumptions are displayed in the list of correlations. The currently selected assumption is also displayed immediately next to the Choose button.

7 Enter a correlation coefficient using one of the following methods and then click OK to accept the correlation and close the dialog box:

- Enter a value between -1 and 1 (inclusive) in the Coefficient Entry field.

Type the number that to use in the field to the left of the slider control. After you type the number, the slider control on the correlation coefficient scale moves to the selected value.

- Choose a cell that contains the correlation coefficient.

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

- Drag the slider control along the correlation coefficient scale.

The value you select is displayed in the field to the left of the scale.

- Type the desired correlation coefficient in the Coefficient field in the correlation list.
- Click Calc.

A small dialog opens at the bottom of the first dialog. Enter the range of cells on your spreadsheet that contains the empirical values that Crystal Ball should use to calculate a correlation coefficient.

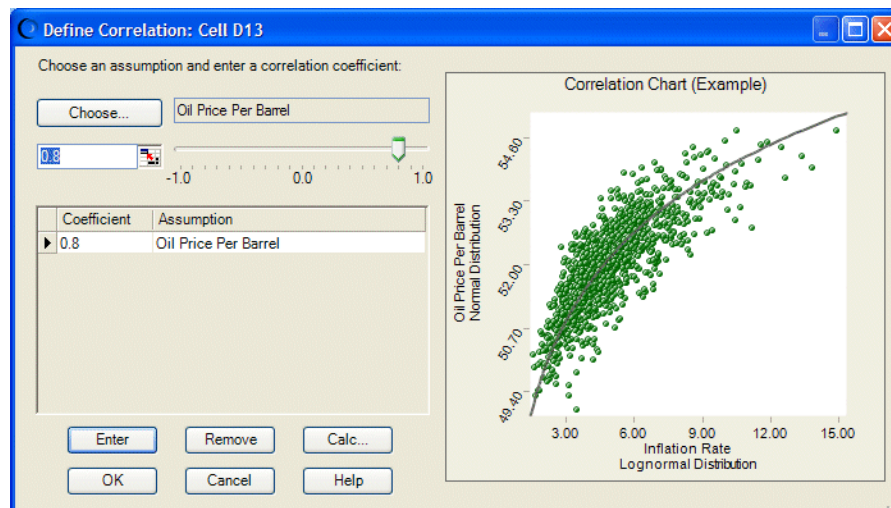
Enter the range of cells in the standard A1:A2 format, where A designates the column and 1 and 2 designate the first and last cell rows, respectively. For example, if one set of values is in column Q, rows 10 through 15 and the second set of values is in column R, rows 10 through 15, enter the range in the left field as Q10:Q15 and the range in the right field as R10:R15.

Crystal Ball calculates the correlation coefficient, enters it in the field to the left of the correlation coefficient scale, and moves the slider control to the correct position.

The two cell ranges do not necessarily have to 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.

Each time you select a new assumption or correlation coefficient, Crystal Ball displays a sample correlation of the correlated assumption values in the chart to the right.

Figure 18 Correlation Chart



The points on the chart represent the pairing of assumption values as they would actually 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) would fall. The closer the points are to the solid line, the stronger the correlation.

In the example above, an Inflation Rate assumption and an Oil Price/Barrel assumption have been correlated using a coefficient of 0.8, a strong positive correlation. As the points on the chart show, higher inflation values tend to be associated with higher oil prices and vice versa. This chart can help you begin to understand how the two assumptions are related.

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

You can generally ignore correlations between variables if one or both variables do not impact the output or are not highly correlated.

Setting Assumption Preferences

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

Table 1 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 112](#).

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

You can use this dialog to:

- Choose 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 102](#).

- 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, 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.

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 email 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, , or choose Define, then Define Assumption.

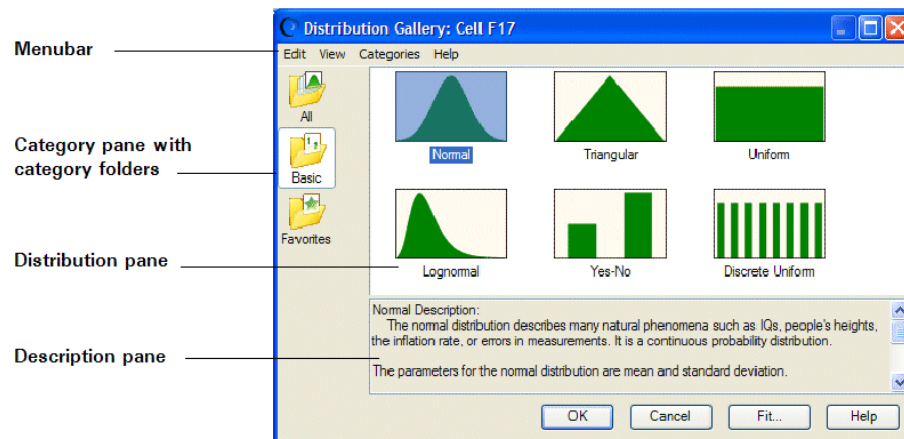
(In Excel 2007, click the upper half of the Define Assumption icon. Or, click the bottom half of the Define Assumption icon and choose Distribution Gallery at the bottom of the distribution list.)

The Distribution Gallery opens, as shown in [Figure 19](#).

Distribution Gallery Window

As shown in [Figure 19](#), the Distribution Gallery has a menubar, 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.

Figure 19 The Distribution Gallery Window



The following sections explain each part of the Distribution Gallery:

- “The Distribution Gallery Menubar and Buttons” on page 52
- “The Category Pane” on page 52

- “The Distribution Pane” on page 52
- “Description Pane” on page 53

The Distribution Gallery Menubar and Buttons

The Distribution Gallery menubar has the menus summarized in [Table 2](#).

Table 2 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 Data](#)” on page 44.

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

The 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.

The 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 3](#).

Table 3 Distribution View Examples

View Command	Example									
Thumbnails										
Large Icons										
Small Icons										
Details	<table border="1"> <thead> <tr> <th>Name</th> <th>Parameters</th> <th>Summary</th> </tr> </thead> <tbody> <tr> <td>Normal</td> <td>Mean, Standard Deviation</td> <td>Familiar bell curve used to describe natural phenom</td> </tr> <tr> <td>Triangular</td> <td>Minimum, Likeliest, Maximum</td> <td>Used for rough estimation when data is limited</td> </tr> </tbody> </table>	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
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								

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 turn off Show Description in the View menu to show more distributions in the Distribution pane.

Managing Distributions

Working with distributions is a key part of defining a model in Crystal Ball. Assumptions are the main source of simulation input and distributions are the core component of assumption definitions.

Several Crystal Ball features help you modify and save distributions for future use and share them with other Crystal Ball users:

- To create new distributions, see [“Creating New Distributions” on page 54.](#)
- To copy distributions, see [“Copying and Pasting Distributions” on page 54.](#)
- To paste distributions, see [“Copying and Pasting Distributions” on page 54.](#)
- To modify distributions, see [“Modifying Distributions” on page 55.](#)
- To modify distribution summaries and descriptions, see [“Modifying Distribution Summaries and Descriptions” on page 55.](#)
- To delete distributions, see [“Deleting Distributions” on page 56.](#)
- To set up pages for printing, see [“Setting Up Distributions for Printing” on page 56.](#)
- To print distribution information, see [“Printing Distribution Information” on page 56.](#)

Creating New Distributions

You can create new distributions by:

- Copying and renaming a distribution within the Distribution Gallery (“[Creating Distributions by Copying](#)” on page 54)
- Defining a distribution in the Define Assumption dialog and adding it to the Distribution Gallery (“[Creating Distributions by Saving Assumptions](#)” on page 54)

Creating Distributions by Copying

To create a distribution by copying another distribution, follow the steps in the next section, “[Copying and Pasting Distributions](#)” on page 54

Then, you can rename and modify the new distribution as needed.

Creating Distributions by Saving Assumptions

➤ To create a distribution by saving an assumption:

- 1 With Crystal Ball running, click a cell in the spreadsheet.

It can be a value cell where you want to define an assumption or a blank cell.

- 2 Click the Define Assumption tool or choose Define, then Define Assumption.
- 3 Follow the steps in “[Defining Assumptions](#)” on page 38 to select a distribution and enter parameters.
- 4 Choose Edit, then Add To Gallery in the Define Assumption dialog.
- 5 The Add To Gallery dialog opens, where you can name the new distribution and select a category for it.
- 6 Click OK to save the distribution in the selected category.

If you created correlation data, it is not saved although the distribution type and any parameter settings are saved.

Now, the new distribution is available for use just as another other distribution, either supplied with Crystal Ball or user-defined.

Copying and Pasting Distributions

➤ To copy and paste a distribution within Favorites or another user-defined category or from one category to another:

- 1 In the Distribution Gallery, click a category in the Category pane.
- 2 Click a distribution in the Distribution pane.
- 3 Choose Edit, then Copy or right-click and choose Copy from the right-click menu.
- 4 Click Favorites or another user-defined category in the Category pane.
- 5 Choose Edit, then Paste or right-click and choose Paste from the right-click menu.

The distribution is pasted into the selected category. If another distribution in that category had the same name, the new distribution is displayed with the next larger number at the end. For example, if the category already had Normal1, a new normal distribution would be named Normal2.

- 6 To rename the copied distribution, click its name and wait a moment. The name is highlighted for editing.
- 7 Type the new name and press Enter.
- 8 Modify the new distribution as needed.

Note: To easily copy a distribution from one category to another, select the category with the distribution to copy. Then, drag the distribution into the closed category folder where you want to copy it. When you select that category, the copied distribution is displayed and you can rename it or modify it as described in the next section. However, the distribution you copied remains in its original folder, unchanged.

Modifying Distributions

Distributions in the Basic or All categories are read-only and cannot be changed. However, after you have copied a distribution or used it to define an assumption, you can modify it in a number of ways.

► To modify a distribution:

- 1 Create a distribution as described in [“Creating New Distributions” on page 54](#) and [“Copying and Pasting Distributions” on page 54](#).
- 2 Right-click the user-defined distribution and choose **Modify** (or click the distribution and choose **Edit**, then **Modify** in the Distribution Gallery menubar).

A prompt opens as a reminder that you are modifying a distribution and not defining an assumption.

- 3 Click **OK** to display the distribution in a window that looks like the Define Assumption dialog.
- 4 Modify the distribution as if it were an assumption, following the instructions in [“Defining Assumptions” on page 38](#).
- 5 When you are finished, click **OK**.

The modifications are saved with the distribution in the category and no assumption is created in the spreadsheet.

Modifying Distribution Summaries and Descriptions

You can edit the distribution Summary and Description text for any distribution in Favorites or another user-defined category.

► To modify Summary text for a distribution:

- 1 In the Distribution Gallery, set the View menu to **Details**.

- 2 In the Distribution pane, right-click the Summary text to edit.
- 3 In the right-click menu, choose **Modify Summary For** *distribution name*.
- 4 When the Modify Summary dialog opens, enter the new text in the edit field and click **OK**.

The new text immediately replaces the original Summary text.

- To modify Description text for a distribution:

- 1 Select the distribution in the Distribution Gallery.
- 2 Be sure **View**, then **Show Description** is checked.
- 3 Right-click the text in the Description pane.
- 4 In the right-click menu, choose **Modify Description For** *distribution name*.
- 5 When the Modify Description dialog opens, edit the description in the edit field and click **OK**.

(Alternately, you can just select the description text to modify and edit it. Be careful to avoid modifying descriptions accidentally.)

The new text immediately replaces the original description.

Deleting Distributions

You can delete a distribution in the Favorites category or other user-defined category. However, the original distribution of that type remains in Basic or All.

To delete a distribution, choose Edit, then Delete in the Distribution Gallery menubar, or right-click the distribution and choose Delete.

Setting Up Distributions for Printing

- To select paper, print orientation, and margins before printing:
- 1 Double-click a distribution in the Distribution Gallery to display it in the Define Assumption dialog.
 - 2 Choose Edit, then Page Setup in the Define Assumption menubar.
 - 3 Set paper size and source, orientation, and margins.
 - 4 Click OK to accept the settings.

Printing Distribution Information

- To print a distribution:
- 1 Double-click a distribution in the Distribution Gallery to display it in the Define Assumption dialog.
 - 2 Choose **Edit**, then **Print** in the Define Assumption menubar.
 - 3 Confirm the printer and other settings.
 - 4 Click **OK** to print the distribution.

Printed information includes the chart with current parameter settings. The distribution name and parameters are displayed in a box beneath the graphic.

You can preview before printing. In step 2, choose Edit, then Print Preview before you choose Edit, then Print.

Managing Categories

You can use distribution categories to organize distributions and share them with other users in your organization:

- To create new categories, see [“Creating New Categories” on page 57](#).
- To view and edit category properties, see [“Viewing and Editing Category Properties” on page 58](#).
- To delete categories, see [“Deleting Categories” on page 58](#).
- To rearrange category order, see [“Rearranging Category Order” on page 58](#).
- To share categories over networks, see [“Sharing Categories over Networks” on page 59](#).
- To use categories shared by others, see [“Using Shared Categories” on page 59](#).
- To send and receive categories, see [“Sharing Categories Through Email” on page 60](#).
- To edit shared categories, see [“Editing Shared Categories” on page 60](#).
- To unpublish shared categories, see [“Unpublishing Shared Categories” on page 61](#).
- To change distribution display within categories, see [“The Distribution Pane” on page 52](#).

Creating New Categories

You can create a category of distributions to help with model development or to share with other users.

► To create a category:

1 Choose **Categories, then **New**.**

The New Category dialog box opens.

2 Enter the name of your category. Optionally, you can enter a description, your name, and a version number (helpful for shared categories).

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 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.

Viewing and Editing Category Properties

Category properties include the information entered in the New Category dialog when a category is created. You can view properties for any category, but you can only edit properties for user-defined categories.

➤ To view or edit properties:

- 1 Click a category in the Category pane.
- 2 Choose **Categories**, then **Properties**.

The Category Properties dialog opens.

- 3 **Optional:** Edit the information in any field that appears white. Read-only fields are gray.
- 4 When you have finished viewing or editing category properties, click **OK**.

The Category Properties dialog closes and any property changes are saved.

Deleting Categories

You can delete user-defined categories and all the distributions within them, but be careful not to delete a distribution you will need to use later.

➤ To delete a category:

- 1 Select the category in the Category pane.
- 2 Choose **Categories**, then **Delete**.

A confirmation message is displayed.

- 3 When you click **OK**, the category and all its distributions are immediately deleted.

Original built-in distributions shipped with Crystal Ball are never deleted; only copies can be deleted.

Rearranging Category Order

Changing the order of folders in the Category pane can be helpful if you want to arrange categories in alphabetical order or put frequently used categories near the top.

➤ To move a category folder:

- 1 Select the folder to move in the Category pane.
- 2 Choose **Categories**, then **Move Up** or **Categories**, then **Move Down**.

The folder moves up or down one position each time you choose the menu command.

- 3 Continue moving folders up and down until they are arranged as preferred.

Sharing Categories over Networks

The ability to publish and subscribe to categories is powerful. You can create large numbers of specific distributions, add them to a category, and then publish it on the network for other users in your organization. Likewise, you can easily subscribe to categories published by others. You can also email categories to others and use categories sent to you.

- To publish a category to a shared folder on your computer or to a location on a network:

- 1 **Select a category in the Distribution Gallery.**
- 2 **Choose **Categories**, then **Publish**.**

The Browse For Folder dialog opens.

- 3 **Browse to locate the folder where you want to place the category. You can click + to expand a folder and view its subfolders. If you need to create a new folder, select the folder that should include the new folder.**

The new folder is displayed and you can rename it. For example, if you want to create a folder under My Documents, select My Documents. Then, when you click New Folder, the new folder is displayed under My Documents at the same level as My Pictures.

- 4 **Click **OK**.**

The dialog closes and a copy of your category is saved there.

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, then:

- 1 **Open the Distribution Gallery and choose **Categories**, then **Subscribe**.**

The Subscribe To A Category dialog opens.

- 2 **Click **Add**.**

The Browse For Folder dialog opens.

- 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 and close the Subscribe To A Category dialog box.**

All loaded categories are available for use as if they were on your 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 your 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 might 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 above.**

- 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.

Sharing Categories Through Email

You can use email to share a user-defined category with a Crystal Ball user who is not on your network.

- To share categories using email:

- 1 Create and address an email message.
- 2 Use the file attachment command and browse to the category folder on your machine.

By default, this is C:\Documents and Settings*your username*\Application Data\Oracle\Crystal Ball\11.0\Store.

- 3 Select the user-defined category to send.

Crystal Ball category files have this format: CBCategory_*name*.cbc. For example, the Favorites category The Browse For Folder dialog opens. as CBCategory_Favorites.cbc.

- 4 Send the email.

- To use a category received in an email:

- 1 Open the email.
- 2 Save the attachment in the Crystal Ball category folder, by default C:\Documents and Settings*your username*\Application Data\Oracle\Crystal Ball\11.0\Store.

The next time you start Crystal Ball, the new category is displayed in the Category pane of the Distribution Gallery.

Alternately, you can save the attachment in another folder, then follow the steps in [“Using Shared Categories” on page 59](#) to subscribe to it.

Editing Shared Categories

- To edit a published user-defined category:

- 1 Make the changes in your Distribution Gallery.
- 2 Follow the steps in [“Sharing Categories over Networks” on page 59](#) to publish the category to the same place.
- 3 When you are prompted to overwrite the existing file, click **OK**.

This publishes the modified category. Now, the next time a subscriber loads Crystal Ball, the modified category is displayed in the Distribution Gallery.

Unpublishing Shared Categories

- ▶ If you have published a user-defined category and want to remove it from publication, or "unpublish" it:

- 1 Use My Computer or Windows Explorer to browse to the folder where the category was published.**

The category file is displayed as `CBCategory_name.cbc`. For example, the Favorites category is displayed as `CBCategory_Favorites.cbc`.

- 2 Select the category file and delete it.**

The next time a subscriber loads Crystal Ball, the deleted category will not be displayed in the Distribution Gallery. Existing assumptions based on distributions from that category will still work but those distributions won't be available for creating new assumptions.

A Note About Modifying Shared Categories

If a shared category is moved, deleted, or otherwise modified, subscribers to that category will not notice the changes until they close Crystal Ball and open it again. It is wise to notify subscribers when a change of that type occurs so they can start a new Crystal Ball session and refresh their view of the Distribution Gallery.

4

Defining Other Model Elements

In This Chapter

Introduction.....	63
Defining Decision Variable Cells.....	63
Defining Forecasts.....	64
Working with Crystal Ball Data.....	68
Setting Cell Preferences.....	72
Saving and Restoring Models.....	73

Introduction

[Chapter 3](#) describes how to start building a spreadsheet model by defining assumption cells. This chapter provides 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.

After you complete this chapter, read [Chapter 5, “Running Simulations”](#) for information on setting run preferences and running simulations.

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 non-numeric cell.

- 2 Select Define , 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-numerical 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 42).
- 5 Click OK.
- 6 Repeat these steps for each decision variable in your 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 your 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, then Define Forecast, .

The Define Forecast dialog opens .

If you have activated Crystal Ball's process capability features, additional fields are displayed. These are described in [“Setting Specification Limits and Targets” on page 387](#).

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 fields, listed in [“Setting Forecast Preferences” on page 65](#).

5 Click OK.

6 Repeat steps 1–4 for each forecast in your 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, , 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 66](#) — window display and distribution fitting for the forecast
- [“Precision Tab” on page 66](#) — precision control settings
- [“Filter Tab” on page 67](#) — value filtering, which discards values inside or outside a range for the current forecast
- [“Auto Extract Tab” on page 67](#) — automatic data extraction to Excel when a simulation stops.

Note: See "Confidence intervals" in the "Statistical Definitions" chapter of the online *Oracle Crystal Ball Statistical 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 102).
- **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 76).
 - **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 76). The statistics available for precision control are the mean, the standard deviation, and an indicated percentile. Check 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 your 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 fields. 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 fields. 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 checked 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 checked 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 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 161](#).

You can choose from the following settings:

- **Extract forecast statistics automatically to your spreadsheet when the simulation stops** — Activates the auto-extract feature.
- **[listbox at the left]** — The list of statistics you can extract. Check the statistics you want, then use the up and down arrows to rearrange their order, if you want.
- **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 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.

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 Excel commands and must be used to copy Crystal Ball cell definitions (data). Other Crystal Ball commands select data and highlight it for your review.

The following sections describe these special commands:

- [“Editing Crystal Ball Data” on page 68](#)
- [“Selecting and Reviewing Data” on page 70](#)

Editing Crystal Ball Data

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

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 or clear.

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

The following sections describe how to edit Crystal Ball data:

- [“Copying Crystal Ball Data” on page 69](#)
- [“Pasting Crystal Ball Data” on page 69](#)
- [“Clearing Crystal Ball Data” on page 69](#)
- [“Clearing All Crystal Ball Data of a Single Type” on page 70](#)

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**, 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 Check 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; see note below) 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.

- 2 Choose **Define**, then **Paste [Data]**, .

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. You are probably already familiar with this from using Excel; if you copy in Excel and then do anything else but select a range for pasting, the copied area is unselected and you must select it again before continuing.

Clearing Crystal Ball Data

- To clear Crystal Ball data:

- 1 Select a cell or a range of cells that contains the Crystal Ball data to clear.

- 2 Select **Define**, then **Clear [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 clear.

- 3 Check the type or types to clear and click **OK**.

Crystal Ball clears the selected Crystal Ball data type (assumptions, decision variables, and forecast definitions) from each cell.

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:

1 Select one of the following options:

- Define, then Select All Assumptions
- Define, then Select All Decisions
- Define, then Select All Forecasts

(In Excel 2007, choose Define, then Select and then choose one of the Select commands.)

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

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

Edit, then Clear, then All also clears all Crystal Ball data from selected cells.

Selecting and Reviewing Data

After you define assumptions, decision variables, and forecast cells and return to the spreadsheet, you might want to check the cell definitions to make sure you have defined them as you intended. You can select all the assumption, forecast, and decision variable cells and check their corresponding dialogs in sequence.

The following sections describe how to review and select Crystal Ball data:

- [“Reviewing Assumption Cells” on page 70](#)
- [“Reviewing Decision Variable Cells” on page 71](#)
- [“Reviewing Forecast Cells” on page 71](#)
- [“Reviewing Selected Cells” on page 72](#)

Note: Regarding the following sections concerning selection, in Excel 2007, choose Define, then Select and then choose one of the Select commands.

Reviewing Assumption Cells

➤ To review all assumption cells:

1 Select **Define**, then **Select All Assumptions**, .

Crystal Ball selects each cell defined as an assumption.

- 2 Select **Define**, then **Define Assumption**, .

The distribution dialog for the first assumption cell opens .

- 3 **Optional:** Change the assumption parameters.
- 4 Click **OK**.

If you have more than one assumption cell, each assumption is displayed in turn. Repeat steps 3 and 4 to check the assumptions for each cell.

Reviewing Decision Variable Cells

- To review all decision variable cells:

- 1 Select **Define**, then **Select All Decisions**, .

Crystal Ball selects each cell defined as a decision variable.

- 2 Select **Define**, then **Define Decision**, .

The Define Decision Variable dialog for the first decision variable cell opens.

- 3 **Optional:** Change the decision variable parameters.
- 4 Click **OK**.

If you have more than one decision variable cell, each decision variable opens in turn. Repeat steps 3 and 4 to check the decision variables for each cell.

Reviewing Forecast Cells

- To review all forecast cells:

- 1 Select **Define**, then **Select All Forecasts**, .

Crystal Ball selects each cell defined as a forecast.

- 2 Select **Define**, then **Define Forecast**, .

The forecast dialog for the first forecast cell opens.

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

If you have selected more than one forecast cell, each forecast is displayed in turn. Repeat steps 3 and 4 to check the forecast for each cell.

Reviewing Selected Cells


- To review Crystal Ball data cells on any open workbook:

- 1 **Select Define, then Select.**

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 **Check the cells to select.**

- 3 **Click OK to highlight all the selected cells so you can change their preferences or perform other actions on them.**

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 desired, 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 on your 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 **Choose Define, then Cell Preferences.**

(In Excel 2007, choose Define, 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 an 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.)
- **Set Cell Value To...** — Changes assumption cell values to the selected value (Mean or Median) when no simulation is running.

- **Set To Range Midpoint** — Changes decision variable cell values to the selected value (range Midpoint, Minimum, or Maximum) when no simulation is running.
- 4 **Click Apply To and choose whether to apply settings from only the current tab or all tabs in the Cell Preferences dialog.**
 - 5 **Choose whether to apply the settings to all cell preferences of the chosen type(s) on the current 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 your 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 Excel save process. When you open the spreadsheet again, Crystal Ball retains your 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 86).

5

Running Simulations

In This Chapter

Introduction.....	75
About Crystal Ball Simulations.....	75
Setting Run Preferences	76
Freezing Crystal Ball Data Cells.....	80
Running Simulations.....	81
Managing Chart Windows	84
Saving and Restoring Simulation Results.....	86
Functions for Use in Excel Models.....	88
Running User-Defined Macros	88

Introduction

[Chapter 3](#) and [Chapter 4](#) describe how to define a spreadsheet model in Crystal Ball. This chapter provides step-by-step instructions for setting run preferences and running a simulation in Crystal Ball.

After you complete this chapter, read [Chapter 6](#) for information about analyzing simulation results.

About Crystal Ball Simulations

After you define assumption, forecast, and decision variable cells in your spreadsheet model, you are ready to run the simulation. Crystal Ball uses a technique called Monte Carlo simulation to forecast the entire range of results most likely to occur in the model scenario. For more information on Monte Carlo simulation, see [“Monte Carlo Simulation and Crystal Ball” on page 20](#).

Crystal Ball provides statistics that describe the forecast results. For more information on forecast results and statistics, see [Chapter 6, “Analyzing Forecast Charts,”](#) and the "Statistical Definitions" chapter of the *Oracle Crystal Ball Statistical Guide*.

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

1. Define assumptions ([“Entering Assumptions” on page 38](#)), forecasts ([“Defining Forecasts” on page 64](#)), and decision variable cells if appropriate ([“Defining Decision Variable Cells” on page 63](#)).



2. If you want, customize the appearance of each cell as described in [“Setting Cell Preferences” on page 72](#).
3. Set run preferences as described in the next section, [“Setting Run Preferences” on page 76](#).
4. Optionally, exclude certain data cells from the simulation by “freezing” them, described in [“Freezing Crystal Ball Data Cells” on page 80](#).
5. Run the simulation as described in [“Running Simulations” on page 81](#).

The following sections explain each step.

Setting Run Preferences

Run preferences determine how Crystal Ball runs a simulation.

► To change run preferences:

- 1 Reset the previous simulation, if necessary, .
- 2 Choose **Run**, then **Run Preferences** to display the Run Preferences dialog, .
- 3 Click the tab with the preferences to change, described in the following sections:
 - [“Setting Trials Preferences” on page 76](#) — Specify when to stop a simulation, namely number of trials, calculation errors, and precision control.
 - [“Setting Sampling Preferences” on page 77](#) — Set the sampling seed value, method, and sample size.
 - [“Setting Speed Preferences” on page 78](#) — Determine whether a simulation runs in Normal, Demo, or Extreme (if available) and set additional speed control options.
 - [“Setting Options Preferences” on page 79](#) — 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 low memory triggers, a warning, and whether the Crystal Ball Control Panel opens.
 - [“Setting Statistics Preferences” on page 80](#) — 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 76](#).

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 check 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 checked, 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 checked stops the simulation when certain statistics reach a specified level of precision. You choose the statistics and define the precision that triggers this option in each Define Forecast dialog. For instructions, see [“Precision Tab” on page 66](#). 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 76](#).

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 field.
- **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, check 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 Excel 2007 with multi-threading, 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 choose Normal or Demo speed, the Options button is active and you can make additional settings.

Note: If your license includes Extreme speed, be sure to read Appendix C, “[Using the Extreme Speed Feature](#)” on page 311, for important information about model compatibility.

For general instructions, see “[Setting Run Preferences](#)” on page 76.

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

- **Run Mode settings** — Determine overall simulation speed.
 - **Extreme Speed** — Available as a Crystal Ball option. This setting runs simulations up to 100 times faster than Normal mode but is not suitable for some models. For details, see Appendix C, “[Using the Extreme Speed Feature](#)” on page 311.
 - **Normal Speed** — The standard simulation option for general model processing.
 - **Demo Speed** — Runs simulations in "slow-motion" to make it easier to watch values change in spreadsheet cells and charts.
- **Options settings** — Set update rules for the active worksheet (Normal and Demo speeds only). See “[Speed Tab Options Settings](#)” on page 78 for details.
- **Chart Windows settings** — Set the redraw rate for any charts open during a simulation.
 - **Redraw Every _ Seconds** — 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.

The following options are provided for Normal speed:

- **Update Every Trial** — Updates Crystal Ball data in 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 Excel window. This option produces the fastest simulations.
- **Bring Excel 2007 To The Foreground While Running Normal Speed Simulations (Faster)** — This option is available when Crystal Ball is running on Excel 2007 and Service Pack 1 (SP 1) is not installed. When checked, Excel runs in the foreground in Normal speed and performance improves.

Note: If you are using Crystal Ball on Excel 2007 without SP 1 and switch to Normal speed, a dialog opens asking if you want to move Excel to the foreground. If so, you can use this setting to move it to the background later. For best performance, SP 1 for Excel 2007 is required when running Crystal Ball on Excel 2007.

The following option is provided for 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 76](#).

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

- **Store Assumption Values For Sensitivity Analysis** — Stores the randomly generated values used during the simulation for display while running. To see those values during a simulation, select this option and the appropriate Window preference for each assumption to display. Values can also be exported to a spreadsheet after the simulation using the Extract Data command. This setting also generates sensitivity data during simulations. The sensitivity chart can display this information to show how much each assumption influences a particular forecast. For more information on the sensitivity chart, see [“Understanding and Using Sensitivity Charts” on page 138](#). The sensitivity chart is not available unless you select this option before you run a simulation.
- **Enable Correlations** — Activates any defined correlations between assumptions.
- **Run User-Defined Macros** — Runs any user-defined macros as part of the simulation process. For details, see [“Running User-Defined Macros” on page 88](#).
- **Warn If Insufficient Memory** — When checked, issues a warning dialog if you don’t have enough memory to complete a full simulation. This dialog lists several options to consider, such as reducing the number of simulation trials and turning off the saving of assumption values. Saving assumption values is required for calculating sensitivity charts, but it can consume a significant amount of memory for large models.

- **Show Control Panel** — When checked, activates the Crystal Ball Control Panel. For more information, see [“The Crystal Ball Control Panel” on page 83](#).
- **Leave Control Panel Open On Reset** — When checked, continues to display the Control Panel after a simulation is reset.

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 76](#).

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 checked Crystal Ball displays capability metrics indicating process quality, provided at least an upper or lower specification limit is entered in the Define Forecast dialog.
- **Options button** — When Calculate Capability Metrics is checked, 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. For more information, see [“Setting Capability Calculation Options” on page 386](#).


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 **Choose Define, 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

After you have defined assumption and forecast cells — and, optionally, decision variable cells — in your 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. By default, these charts are displayed as the simulation runs. As you run the simulation, observe the shape of the distribution to get a feel for the problem you are trying to solve. If you are new to Crystal Ball, try running simulations in Demo speed to watch the forecast values change from trial to trial.

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. For details, see [“The Crystal Ball Control Panel” on page 83](#).

During the simulation, Crystal Ball saves the forecast values in a list that grows as the simulation progresses. In [“Extracting Data” on page 161](#), you will learn how to export these forecast values to other programs, such as a statistical analysis program.

The following sections describe how to run and control simulations:

- [“Starting Simulations” on page 81](#)
- [“Stopping Simulations” on page 82](#)
- [“Continuing Simulations” on page 82](#)
- [“Resetting and Rerunning Simulations” on page 82](#)
- [“Single-Stepping” on page 82](#)
- [“The Crystal Ball Control Panel” on page 83](#)

Starting Simulations


- To start a simulation, choose **Run**, 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 choose **Stop [Simulation]**, the simulation halts and the command changes to **Continue Simulation** (in Excel 2003 or earlier). Choosing **Continue Simulation** restarts the simulation where it left off, and changes the menu command back to **Stop [Simulation]**.

(In Excel 2007, choose Run, then Start to continue the simulation.)

Stopping Simulations


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

Continuing Simulations

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

(In Excel 2007, choose Run, then Start or click the Start button.)

Resetting and Rerunning Simulations


- To reset the simulation and start over again:
 - 1 Select **Run**, then **Reset [Simulation]** or click the **Reset** button on the Crystal Ball toolbar or Control Panel, .

A dialog opens with a message asking you to confirm your request to reset the simulation.

- 2 Click **OK**.

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 Change any assumptions or forecasts as needed.

- 4 Select **Run**, then **Start [Simulation]** or click the **Start** button on the Crystal Ball toolbar, .

The simulation starts over again.


Single-Stepping

Before you run a simulation or after you have stopped 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 your assumption cells are valid.

- To observe an individual trial:
 - 1 Select **Run**, then **Reset [Simulation]** or click the **Reset** button on the Crystal Ball toolbar or Control Panel, .
 - 2 Select **Run**, 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. .

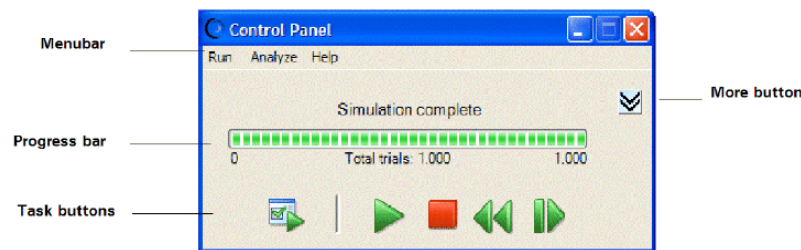
The Crystal Ball Control Panel


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, uncheck **Show Control Panel** on the Options tab of the Run Preferences dialog (click the Run Preferences tool or choose Run, then Run Preferences). .
- By default, the Control Panel stays open following a reset. To close it, uncheck **Leave Open On Reset** on the Options tab of the Run Preferences dialog.

For a description of the Control Panel menu commands, see [“The Crystal Ball Control Panel Menubar” on page 83](#).

Figure 20 The Crystal Ball Control Panel



When you click the More button, , 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 Crystal Ball Control Panel Menubar

The following table describes the Control Panel menus and their commands:

Table 4 Crystal Ball Control Panel Menus

Menu	Commands
Run	Start Simulation/Continue Simulation (“Resetting and Rerunning Simulations” on page 82) Reset Simulation (“Resetting and Rerunning Simulations” on page 82)

Menu	Commands
	Single Step (“Single-Stepping” on page 82) OptQuest Predictor More Tools (“Overview” on page 167) Save Results (“Saving Crystal Ball Simulation Results” on page 86) Restore Results (“Restoring Crystal Ball Simulation Results” on page 87) Run Preferences (“Setting Run Preferences” on page 76)
Analyze	Assumption Charts (“Understanding and Using Assumption Charts” on page 147) Forecast Charts (“Defining Forecasts” on page 64) Overlay Charts (“Understanding and Using Overlay Charts” on page 126) Trend Charts (“Understanding and Using Trend Charts” on page 131) Sensitivity Charts (“Understanding and Using Sensitivity Charts” on page 138) Cascade (“Multiple Windows” on page 84) Close All (“Multiple Windows” on page 84) Create Report (“Creating Reports” on page 157) Extract Data (“Extracting Data” on page 161)
Help	Control Panel Help

Managing Chart Windows

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.

The following sections describe how to work with single and multiple chart windows:

- [“Single Windows” on page 84](#)
- [“Multiple Windows” on page 84](#)

Single Windows

To close one window, click the Close icon in the upper right corner of the chart window.

Multiple Windows









You can use several commands on the Analyze menu and Crystal Ball toolbar to:

- Close and cascade all open forecast windows and other chart windows.
- Open charts that have been closed.
- Create new charts.

- Delete overlay, trend, and sensitivity charts.

If you are using Crystal Ball in Excel 2007, choose Analyze, then View Charts and then choose a command.

You can click a chart button (shown below) to open all windows for that chart type, or use one of the following commands:

- Analyze, then Open Selected Cells (In Excel 2007, choose Analyze, then View Charts, then Open From Selection) — Opens charts for all assumption and forecast cells in the selected range. [xxx confirm command names; may be the same now]
-  Analyze, then Assumption Charts (In Excel 2007, choose Analyze, then View Charts, then Assumption Charts) — Opens a dialog so you can choose which assumption charts to open or close.
-  Analyze, then Forecast Charts (In Excel 2007, choose Analyze, then View Charts, then Forecast Charts) — Opens a dialog so you can choose which forecast charts to open or close.
-  Analyze, then Overlay Charts (In Excel 2007, choose Analyze, then View Charts, then Overlay Charts) — Opens a dialog so you can choose which overlay charts to open or close, create, or delete.
-  Analyze, then Trend Charts (In Excel 2007, choose Analyze, then View Charts, then Trend Charts) — Opens a dialog so you can choose which trend charts to open or close, create, or delete.
-  Analyze, then Sensitivity Charts (In Excel 2007, choose Analyze, then View Charts, then Sensitivity Charts) — Opens a dialog so you can choose which sensitivity charts to open or close, create, or delete.
-  Analyze, then Scatter Charts (In Excel 2007, choose Analyze, then View Charts, then Scatter Charts) — Opens a dialog so you can choose which scatter charts to open or close, create, or delete.
-  Analyze, then OptQuest Charts (In Excel 2007, choose Analyze, then View Charts, then OptQuest Charts) — If OptQuest is available and you have just run an optimization, opens a dialog so you can choose which OptQuest charts to open or close, create, or delete.
-  Analyze, then Predictor Charts (In Excel 2007, choose Analyze, then View Charts, then Predictor Charts) — If you have just run a time series forecast, opens a dialog so you can choose which Predictor charts to open or close, create, or delete.
- Analyze, then Close All (In Excel 2007, choose Analyze, then View Charts, then Close All) — Closes all chart windows and clears the current simulation results and stored results from memory.
- Analyze, then Cascade (In Excel 2007, choose Analyze, then View Charts, then Cascade) — Neatly stacks all windows in front of Excel.

See [“Setting Speed Preferences” on page 78](#) for ways to control whether and how often chart windows display and redraw.

Saving and Restoring 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.

The following sections describe how to save, restore, and work with saved simulation results:

- [“Saving Crystal Ball Simulation Results” on page 86](#)
- [“Restoring Crystal Ball Simulation Results” on page 87](#)
- [“Using Restored Results” on page 87](#)
- [“Restored Results with Capability Metrics” on page 87](#)

Saving Crystal Ball Simulation Results

► To save Crystal Ball results:

- 1 **Choose Run, then Save Results.** The Save Results dialog opens.

(In Excel 2007, choose Run, then Save or Restore, and then choose 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**, then **Restore Results**. If you are using Crystal Ball in Excel 2007, choose **Run**, then **Save or Restore**, then **Restore Results**.
 - 2 When the **Restore Results** dialog opens, select the results file (.cbr file type) to restore and click **Open**.

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 — not just one as in Crystal Ball 2000 or earlier versions of Crystal Ball. However, you can only choose one at a time in the **Restore Results** dialog.

Note: If you try to load results from Crystal Ball 7.3 or later into an earlier version of Crystal Ball, an error message might be displayed, explaining that the Crystal Ball data contained in the selected result set cannot be loaded. One reason this message might be displayed is that a new chart type, scatter charts, was added in Crystal Ball 7.3. In this case, it could be helpful to load the entire model, not just saved results. If you load a model containing scatter charts into an earlier version of Crystal Ball, the model will run and the scatter charts will be ignored.

Using Restored Results

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.

- To remove restored results from memory, choose **Analyze**, then **Close All**. In Excel 2007, choose **Analyze**, then **View Charts**, then **Close All**.

Restored Results with Capability Metrics

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 machine where the results are restored. These might 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 might differ somewhat from the original results.

Functions for Use in Excel Models

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 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.

➤ To use these functions with Crystal Ball loaded:

- 1** Select an empty spreadsheet cell and choose **Insert**, then **Function**. In Excel 2007, choose **Formulas**, then **Insert Function**.
- 2** Select the **Crystal Ball** category in the category list box.
- 3** Find the function in the function list. Select it and click **OK**. Always choose the function ending in **FN**, since the other runs significantly slower in most cases.
- 4** In the **Function Arguments** dialog, enter any required arguments and click **OK**.

The requested value is displayed in the cell with the function.

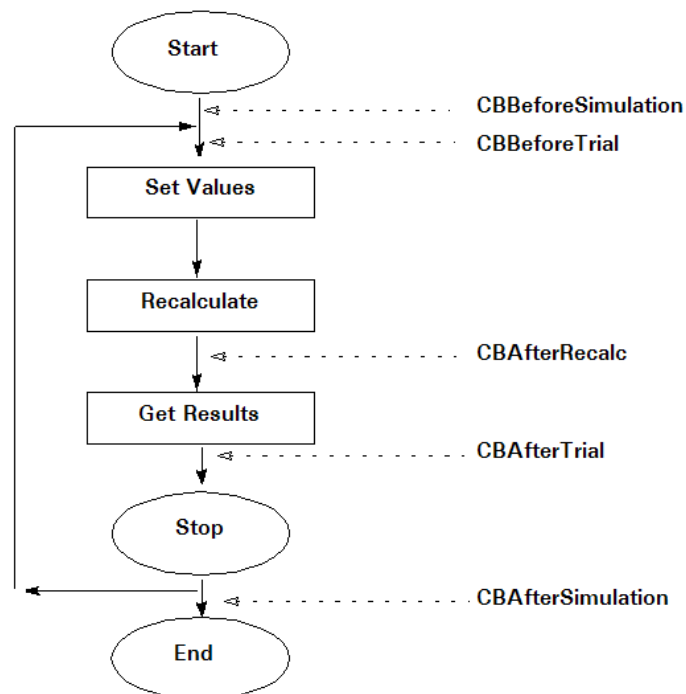
Running User-Defined Macros

You can run user-defined Excel VBA macros automatically during a simulation by naming them with predefined names:

- **CBBeforeSimulation** — Runs immediately after the **Start Simulation** command or **Single-Step** command
- **CBBeforeTrial** — Runs before random numbers have been placed in assumption cells
- **CBAfterRecalc** — Runs after Excel has recalculated the model but before a trial value has been retrieved from the forecast cells
- **CBAfterTrial** — Runs after the forecast trial values have been retrieved and entered into the forecast charts
- **CBAfterSimulation** — Runs when the simulation is complete or stopped with a **Stop** command, by single-stepping (after each step), or for any other reason

The following figure (Figure 21) shows where each macro fits into the Crystal Ball simulation cycle.

Figure 21 When User-Defined Macros Run



Crystal Ball searches for macros with these names in open workbooks and runs them at the appropriate points during the simulation. The macros must be contained within workbooks and worksheets (not VBA modules) and Run User-Defined Macros must be checked on the Options tab of the Run Preferences dialog.

Crystal Ball checks for the presence of any CBBeforeTrial, CBAfterTrial, and CBAfterRecalc macros before the simulation runs by attempting to execute them. If this poses a problem, you may skip the logic in your macro by first testing for aTrial = 0.

In Extreme speed, only two user-defined macros are allowed: CBBeforeSimulation and CBAfterSimulation. For more information on running user-defined macros in Extreme speed, see [“Running User-Defined Macros”](#) on page 316.

The following sections provide details on user-defined macros:

- [“User-Defined Macro Interfaces”](#) on page 89
- [“Priority Rules”](#) on page 91
- [“Global Macros”](#) on page 91
- [“Toolbar Macros”](#) on page 92

User-Defined Macro Interfaces

You must use special VBA interfaces for the macros, described in the following sections:

- “CBBeforeSimulation” on page 90
- “CBAfterSimulation” on page 90
- “CBBeforeTrial” on page 90
- “CBAfterTrial” on page 91
- “CBAfterRecalc” on page 91

Note: If a macro returns anything other than zero (0), the simulation stops.

CBBeforeSimulation

```
Public Function CBBeforeSimulation() As Integer
    Your code is here
End Function
```

CBAfterSimulation

```
Public Function CBAfterSimulation( _
    aIterations As Long, _
    aTrials As Long, _
    aMaxTrials As Long, _
    aProgress As Double, _
    aWasAborted As Boolean, _
    aWasStopOnError As Boolean, _
    aWasStoppedOnPrecision As Boolean, _
    aHasNewBestSolution As Boolean) _
As Integer
    'Your code is here
End Function
```

In this interface, parameters or arguments are defined as follows:

- aIterations = The number of the simulation in a multi-simulation run, usually 1
- aTrials = Number of trials run
- aMaxTrials = Number of trials scheduled to run
- aProgress = Percent of trials completed
- aWasAborted = True if manually stopped
- aWasStopOnError = True if stopped on error
- aWasStoppedOnPrecision = True if stopped on precision control
- aHasNewBestSolution = New value of objective

CBBeforeTrial

```
Public Function CBBeforeTrial(aTrial As Long) As Integer
    'Your code is here
End Function
```

CBAfterTrial

```
Public Function CBAfterTrial (aTrial As Long) As Integer
    'Your code is here
End Function
```

CBAfterRecalc

```
Public Function CBAfterRecalc (aTrial As Long) As Integer
    'Your code is here
End Function
```

Priority Rules

The following rules govern the running order of macros:

- If multiple workbooks are open, Crystal Ball searches the workbooks in the order of their priority. The priority number is set by the `CB.SetCBWorkbookPriority` macro. If this macro has not been called on the workbook, no workbook order is guaranteed.

`CB.SetCBWorkbookPriority` sets the running order for macros when multiple workbooks are open. For example, a workbook with `order=10` will run before a workbook with `order=20`. `CB.SetCBWorkbookPriority` runs only at the workbook level and not at the worksheet level.

The definition of this macro is:

```
Public Function CB.SetCBWorkbookPriority (aPriority As Long)
```

A syntax example, used in a subroutine at the module level, is:

```
Application.Workbooks("Book1.xls").Activate
    CB.SetCBWorkbookPriority(10)
```

This example assigns a priority of 10 to the workbook `Book1.xls`.

- Within each workbook, macros on worksheets run in left-to-right sheet order in the workbook provided there are no macros at the workbook level. If there are macros at the workbook level, macros in that workbook at the worksheet level do not run.
- If there are no Crystal Ball data cells in a workbook, no macros run against it.
- Macros in modules are not supported.

Global Macros

If you want to run certain macros with any or all of your Crystal Ball models, you need to make sure that the workbook containing those macros is open in Excel. Then, you can use calls within each model to run those macros as required.

Previous versions of Crystal Ball handled global macros differently. Now, you can run specific macros only for certain models and are no longer required to turn the macros on and off depending on the model that is being run.

Toolbar Macros

If you want to use custom Excel toolbar macros defined in a separate workbook while Crystal Ball is loaded, be sure to save that workbook to the folder C:\Documents and Settings*yourname*\Application Data\Microsoft\Excel\XLSTART.

6

Analyzing Forecast Charts

In This Chapter

Introduction.....	93
Guidelines for Analyzing Simulation Results.....	93
Understanding and Using Forecast Charts.....	95
Setting Chart Preferences	112
Managing Existing Charts.....	121

Introduction

This chapter describes how to use forecast charts to analyze simulation results. As you read through the chapter, you will learn to focus on a particular range of simulation results, analyze forecast charts, and interpret relevant descriptive statistics.

You will also learn how to customize forecast charts, work with chart windows, and share charts with other applications.

[Chapter 7](#) introduces additional charts. [Chapter 8](#) describes how to extract Crystal Ball simulation data for use in Excel and other applications and how to prepare reports.

Guidelines for Analyzing Simulation Results

While a simulation runs, Crystal Ball creates a forecast chart for each forecast cell. Forecast charts condense much information into a small space. You can display that information in several different ways, both graphically and numerically.

When you analyze a simulation, you can focus on forecast charts. You can also display other kinds of charts, generate reports, and extract data for further processing using Excel or other analysis tools.

The following steps can help guide your simulation analysis by focusing on details as well as 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 "outliers" that fall outside of the display range?

The statistical concepts in the "Statistical Definitions" chapter of the online *Oracle Crystal Ball Statistical Guide* can help with this part of your 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're 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 96](#) explains these and other ways of analyzing certainty.

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 100](#) discusses this analysis technique.

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 choose whether to show charts and statistics simultaneously or separately. For instructions, see ["Changing the Distribution View and Interpreting Statistics" on page 102](#).

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. ["Setting Chart Preferences" on page 112](#) describes the many ways you can format charts for analysis and presentation of results.

6. Create other kinds of charts.

You can display overlay charts (["Understanding and Using Overlay Charts" on page 126](#)), trend charts (["Understanding and Using Trend Charts" on page 131](#)), sensitivity charts (["Understanding and Using Sensitivity Charts" on page 138](#)), assumption charts (["Understanding and Using Assumption Charts" on page 147](#)), and scatter charts (["Understanding and Using Scatter Charts" on page 149](#)). As with forecast charts, you can customize these charts as well. Selecting different views of the data can help you analyze it and present it to others.

7. Create reports.

Create reports with charts and data (["Creating Reports" on page 157](#)). You can quickly produce pre-defined or custom reports for analysis and presentation.

8. Extract data for numeric analysis and presentation.

You can extract simulation results to Excel for further analysis or for further export into other analytical tools. See [“Extracting Data” on page 161](#) for details.

9. Use other Crystal Ball tools for different types of analyses.

Depending on the types of problems you are analyzing, the Crystal Ball Batch Fit, Bootstrap, Correlation Matrix, Decision Table, Scenario Analysis, Tornado Chart, and 2D Simulation tools offer additional analysis techniques. These tools are described in Chapter 9. You can use Predictor for time-series analysis and, if you have OptQuest, you can use it to optimize simulation results.

Understanding and Using Forecast Charts

Forecast charts use frequency distributions to show the number (frequency) of values occurring in a given interval. The highest value on the frequency scale to the right of the chart is the frequency for the interval that contains the greatest number of forecast values — the mode of the graphed distribution. You can estimate the frequency for other points on the forecast chart using this frequency scale.

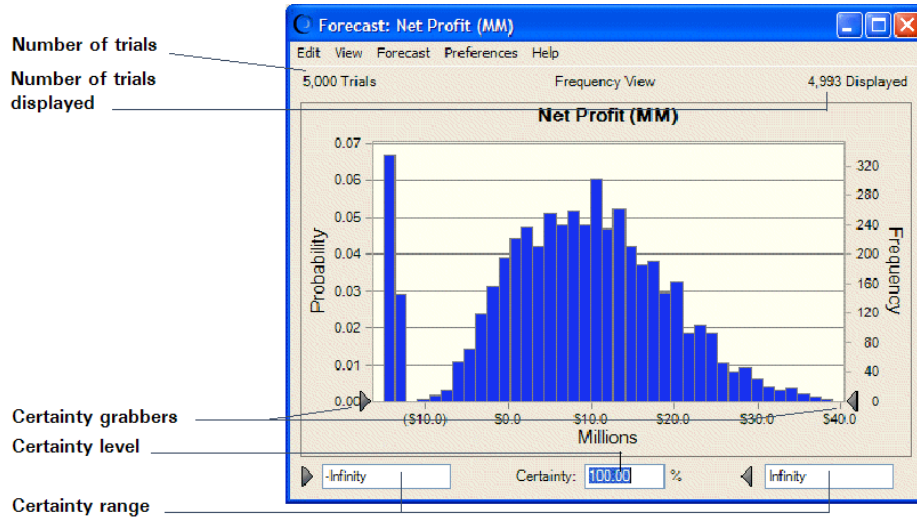
You can now display forecast charts in Split View ([“Using Split View” on page 107](#)), which shows charts and statistics side by side. This section focuses on each type of chart separately. For more information about Split View and its features, see .

The highest value on the probability scale to the left of the chart is the probability for the mode. You can estimate the probability for other points on the forecast chart using this probability scale.

In the example below, the mode (in the middle of the distribution) has a frequency of about 300, meaning that there are 300 values in the interval expressed by that column. 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.

[Figure 22](#) shows the elements of the forecast chart.

Figure 22 Forecast chart



Crystal Ball forecasts the entire range of results for a given situation. However, the forecast chart shows only the display range, which is a subset of the whole. By default, the display range includes all trials within 2.6 standard deviations of the mean (approximately 99% of the forecast values). Crystal Ball then rounds the display range to the next even number of units. For this reason, outlying trials might be excluded from the display range.

Note: To display all trials, change the chart axis preferences to display fixed endpoints between $-\infty$ and $+\infty$ (“[Focusing On the Display Range](#)” on page 100).

The number of trials run for a forecast are displayed in the upper left corner of the forecast chart. The number of trials actually shown (the number of trials run minus the number of outlying values) are displayed in the upper right corner. The display range is the linear distance between the minimum and maximum trials on the chart (from about $-\$15.00$ to $\$35.00$ in [Figure 22](#)).

The following sections provide details about viewing and analyzing forecast charts:

- “[Determining the Certainty Level](#)” on page 96
- “[Focusing On the Display Range](#)” on page 100
- “[Formatting Chart Numbers](#)” on page 101
- “[Changing the Distribution View and Interpreting Statistics](#)” on page 102
- “[Setting Forecast Preferences](#)” on page 110
- “[Setting Forecast Chart Preferences](#)” on page 111

Determining the Certainty Level

The forecast chart also shows the certainty range for the forecast, all trials between the certainty grabbers. In the next section, you will learn how to change the certainty range.

Note: When the certainty grabbers are at $-\infty$ and $+\infty$, the certainty range includes every forecast value regardless of the size of the display range.

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 for the forecast. The example in [Figure 22](#) shows a certainty level of 100% since the default certainty range includes all possible values. By default, Crystal Ball calculates the certainty level based on the entire range of forecast values.

On either side of the Certainty field, the certainty minimum and maximum are displayed.

The certainty level is one of Crystal Ball's key statistics because it shows the probability of achieving the values within a specific range. With Crystal Ball, you can determine the certainty level for specific value ranges either by moving the certainty grabbers on the forecast chart or typing the certainty minimum and maximum in the fields. You can also type a certainty level in the certainty field to get a certainty range centered around the median.

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 field, Crystal Ball moves the certainty grabbers to show you the value range for the certainty level you specified.

The following sections describe how to adjust and analyze certainty levels in Crystal Ball:

- [“Moving Certainty Grabbers” on page 97](#)
- [“Changing the Certainty Minimum and Maximum Fields” on page 99](#)
- [“Entering Certainty Directly” on page 99](#)
- [“Anchoring a Grabber and Entering Certainty Directly” on page 99](#)
- [“Resetting the Certainty Range” on page 100](#)

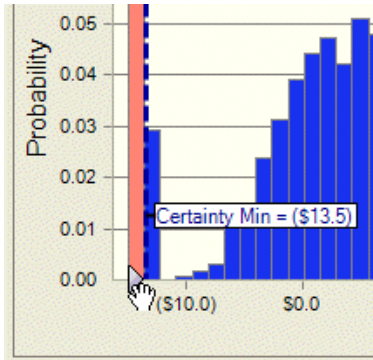
Moving Certainty Grabbers

➤ To determine the certainty level for a specific value range using certainty grabbers:

- 1 Make sure the forecast chart to use is the active (selected) window.
- 2 Move the certainty grabbers on the forecast chart, as shown in [Figure 23](#).

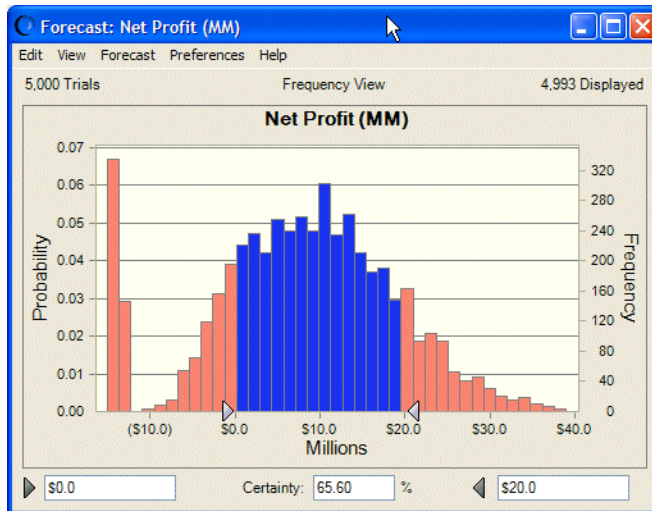
Click the grabber and then drag it when the cursor changes to a hand.

Figure 23 Moving the Left Certainty Grabber



The certainty minimum field shows the value that corresponds to the position of the left certainty grabber; the certainty maximum field shows the value that corresponds to the position of the right certainty grabber. The Certainty field shows the certainty level for the area between the certainty grabbers. Crystal Ball shades the columns outside the certainty grabbers a different color to show that those values have been excluded, as illustrated in [Figure 24](#).

Figure 24 Certainty level: values \$0 to \$20 (in Millions)



The Net Profit forecast chart in [Figure 24](#) is the same as the example preceding it, except that the certainty grabbers have been moved. The certainty minimum shows \$0.0 and the certainty maximum shows \$20.0. The key statistic is the certainty level of 65.6% in the Certainty field. By moving the certainty grabbers, you have changed the certainty range. Crystal Ball compares the number of values lying within the certainty range to the number of values in the entire range — from negative \$14.7 million to positive \$34.4 million — to recalculate the certainty level. With a certainty level of 65.6%, you can be 65.6% confident of making a net profit between \$0 and \$20 million.

Changing the Certainty Minimum and Maximum Fields

- ▶ To determine the certainty level for a specific value range using the certainty minimum and maximum fields:

- 1 In the forecast chart, type a value in the certainty minimum field.
- 2 Type a value in the certainty maximum field.
- 3 Press Enter.

The certainty grabbers move to correspond to the values you entered.

Entering Certainty Directly

Alternately, you can type the certainty level on the forecast chart and allow Crystal Ball to calculate the minimum and maximum for you. Make sure that the certainty grabbers are free (whenever you click an certainty grabber, it turns to a lighter color and is considered anchored). To free the lighter color certainty grabber, click it. Then when you type in a certainty level, you will center the certainty range on the median statistic.

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

- ▶ In the following procedure, you can enter a certainty level of 10% and watch Crystal Ball move the certainty grabbers:

- 1 Press Ctrl+click (or Shift+click) until both certainty grabbers are free (a lighter color).
- 2 Type 10 in the Certainty field.
- 3 Press Enter.

Crystal Ball moves the certainty grabbers to include 10% of the trials centered around the median statistic of the entire range.

Anchoring a Grabber and Entering Certainty Directly

You can also anchor a certainty grabber and type the certainty level. Then, Crystal Ball moves the free grabber to correspond to the value range for the level.

- ▶ To anchor a certainty grabber:

- 1 Move the left certainty grabber until the certainty minimum value is \$0.0.

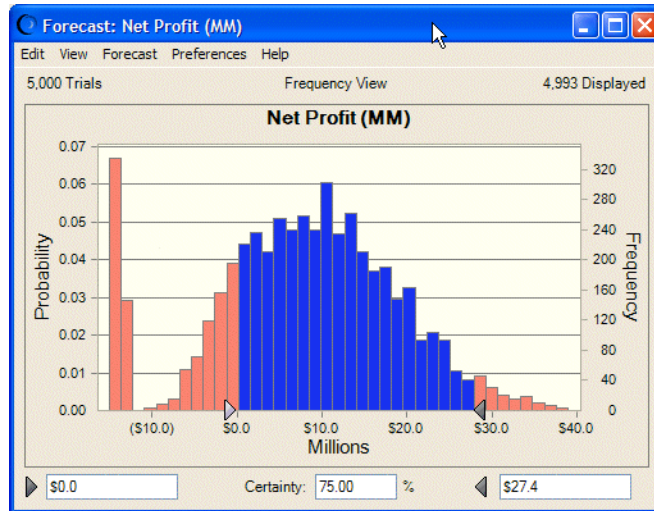
The certainty grabber turns to a lighter color and is considered anchored.

- 2 Type 75 in the Certainty field.
- 3 Press Enter.

Crystal Ball moves the free certainty grabber toward the anchored certainty grabber to include 75% of the values as in [Figure 25](#).

If both grabbers are free, the distribution is centered on the median.

Figure 25 Certainty level: 75% from left certainty grabber



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 the simulation.

Resetting the Certainty Range

➤ To reset the original certainty range before beginning the next section:

1 In the forecast chart, either:

- Move the right certainty grabber until the certainty maximum field shows positive infinity, or
- Type +Infinity in the right field

2 Either:

- Move the left certainty grabber until the certainty minimum field shows negative infinity, or
- Type -Infinity in the left field

The forecast chart displays a certainty level of 100%, as displayed in the original forecast.

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 120.

➤ To define the display range:

1 In a forecast chart, select **Chart Preferences**, then **Axis**, then **Scale**, then **Type**.

2 Choose 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 uncheck 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. For details, see [“Setting Chart Preferences” on page 112](#).

Also see [“Setting Preferences with Shortcut Keys” on page 112](#) 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 100](#).
 - 2 Note the values for the display range minimum and maximum.
 - 3 In the forecast chart menubar, choose Preferences, then Forecast, 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 Choose View, then Statistics in the forecast chart menubar to show statistics for the display range (or, in Split View, look at the statistics table on the right side).

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, choose Preferences, then Chart.**

The Chart Preferences dialog opens.
 - 2 **Click the Axis tab.**

Find the Format Number group.
 - 3 **Choose a format from the drop-down list.** Available formats are similar to Excel formats. For most formats, you can specify the number of decimal places and whether to use a thousands separator.
 - 4 **Click OK to apply the settings, or use Apply To as described in [“Applying Settings to the Current Chart and Other Charts” on page 120.](#)**

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 **Choose 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 388.](#))
 - **Split View** — Shows all selected views simultaneously ([“Using Split View” on page 107.](#))

See [“View Examples” on page 103](#) for descriptions and illustrations of each view.

View Examples

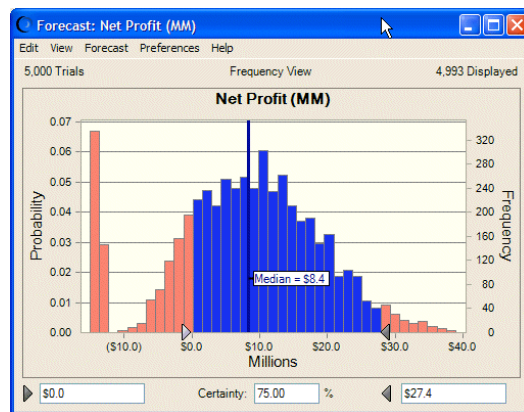
The following sections provide descriptions and illustrations of each view:

- “Frequency” on page 103
- “Cumulative Frequency” on page 103
- “Reverse Cumulative Frequency” on page 104
- “Statistics” on page 105
- “Percentiles” on page 105
- “Goodness Of Fit” on page 106
- “Capability Metrics” on page 106
- “Split View” on page 107

Frequency

Frequency, the default forecast view, shows a simple count of values (the frequency) for each interval on the x -axis. [Figure 26](#) 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.

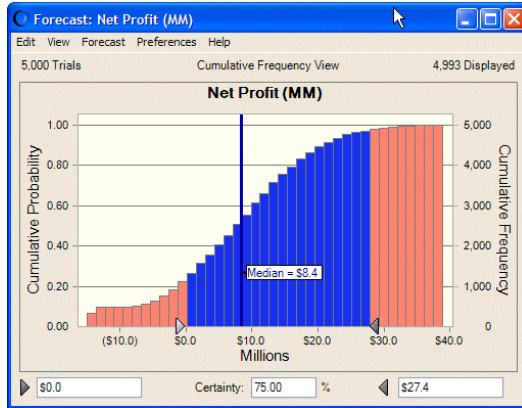
Figure 26 Forecast Chart –Frequency



Cumulative Frequency

[Figure 27](#) 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 27 Forecast Chart—Cumulative Frequency

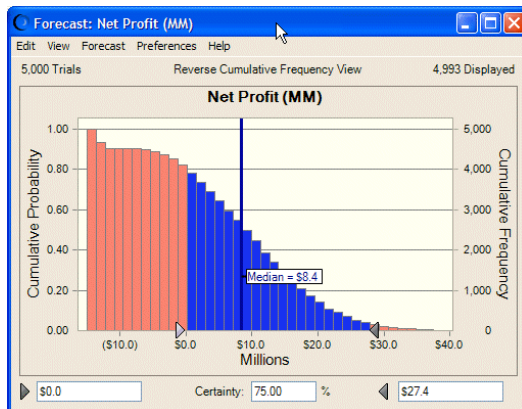


To create this chart, the frequencies are added cumulatively, starting from the lower end of the range, and then plotted as a cumulative frequency curve. To understand the cumulative distribution, look at a particular value, \$8.4 million (in the example above). The chart shows that the probability of \$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. Note 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 28 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 28 Forecast Chart—Reverse Cumulative Frequency



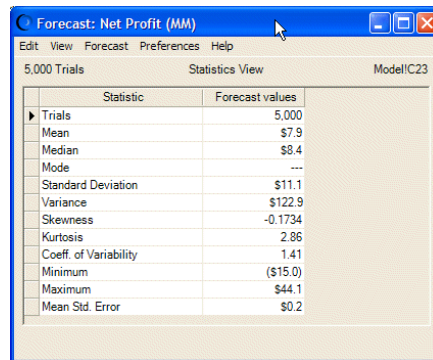
To create this chart, the frequencies are added cumulatively starting at the higher end of the range, and then plotted as a declining cumulative frequency curve. To understand the reverse cumulative distribution, look at a particular value, \$8.4 million (in the example above). The chart shows that the 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. Note also that the chart shows that the probability for \$27.4 million is about .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, then Statistics.

Figure 29 Forecast Window—Statistics



Statistic	Forecast values
► Trials	5,000
Mean	\$7.9
Median	\$8.4
Mode	---
Standard Deviation	\$11.1
Variance	\$122.9
Skewness	-0.1734
Kurtosis	2.86
Coeff. of Variability	1.41
Minimum	(\$15.0)
Maximum	\$44.1
Mean Std. Error	\$0.2

The example in [Figure 29](#) shows statistics for the entire range of values (100% of the forecast values, including the outliers — extreme values excluded from the default display range). Statistical terms listed in this table are discussed in the "Statistical Definitions" chapter of the *Oracle Crystal Ball Statistical Guide* and the Glossary in this User's Guide.

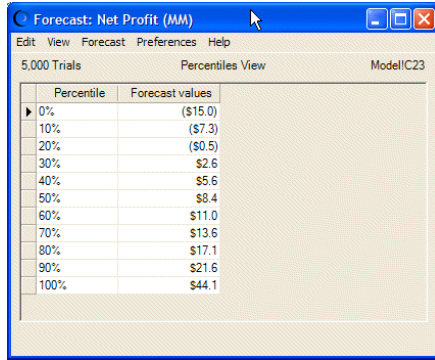
Note: If the Precision Control feature is checked in the Run Preferences dialog and the forecast has Precision Control options set, the Precision column opens in the Statistics view.

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 30](#) 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 30 Forecast–Percentiles View

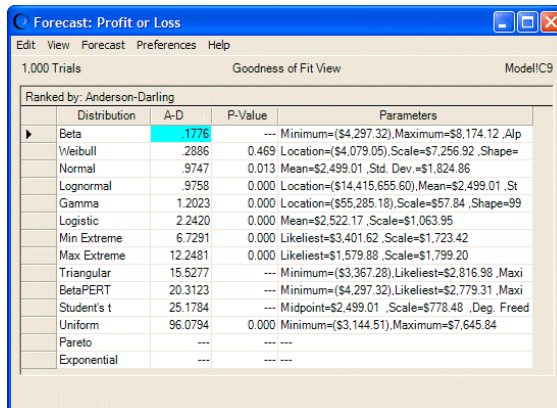


If the Precision Control feature is checked in the Run Preferences dialog and the forecast has Precision Control options set, the Precision column is displayed in the Percentiles view.

Goodness Of Fit

If you have selected distribution fitting, described in the next section, you can choose 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 31 shows statistics for the Anderson-Darling ranking method and each continuous distribution type. Notice that Beta is ranked highest for this forecast.

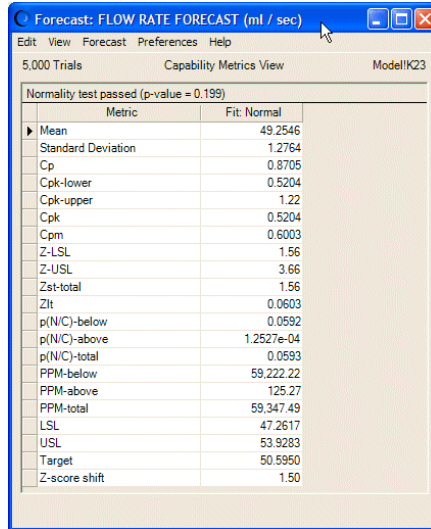
Figure 31 Forecast–Goodness Of Fit View



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 “[Capability Metrics List](#)” on page 393.

Figure 32 Capability Metrics View



Split View

Split View shows forecast charts and related statistics onscreen at the same time. For more information, see [“Using Split View” on page 107](#).

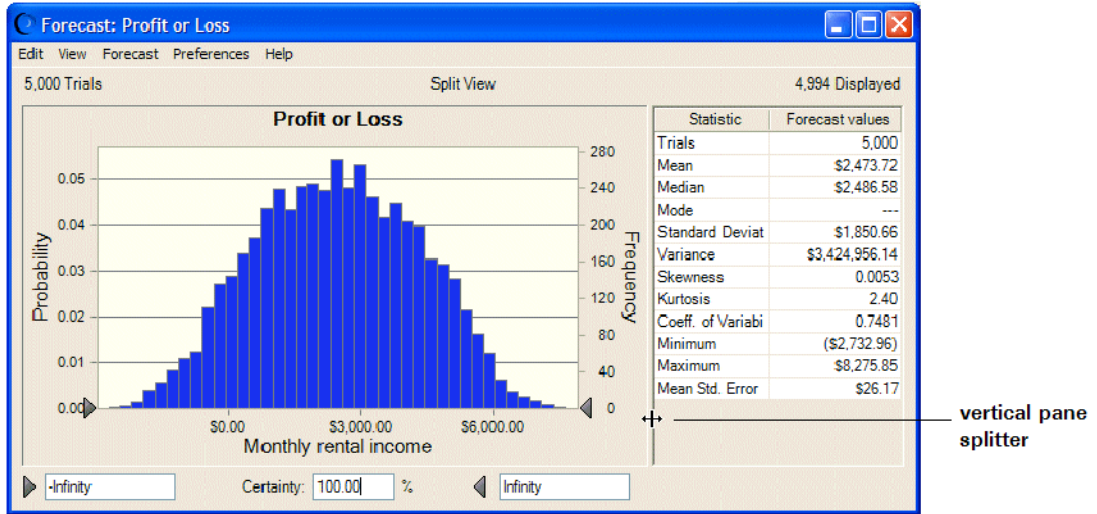
Using Split View

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, choose View to open the View menu.
 - 2 Choose Split View at the bottom of the menu.

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

Figure 33 Frequency Chart and Statistics in Split View

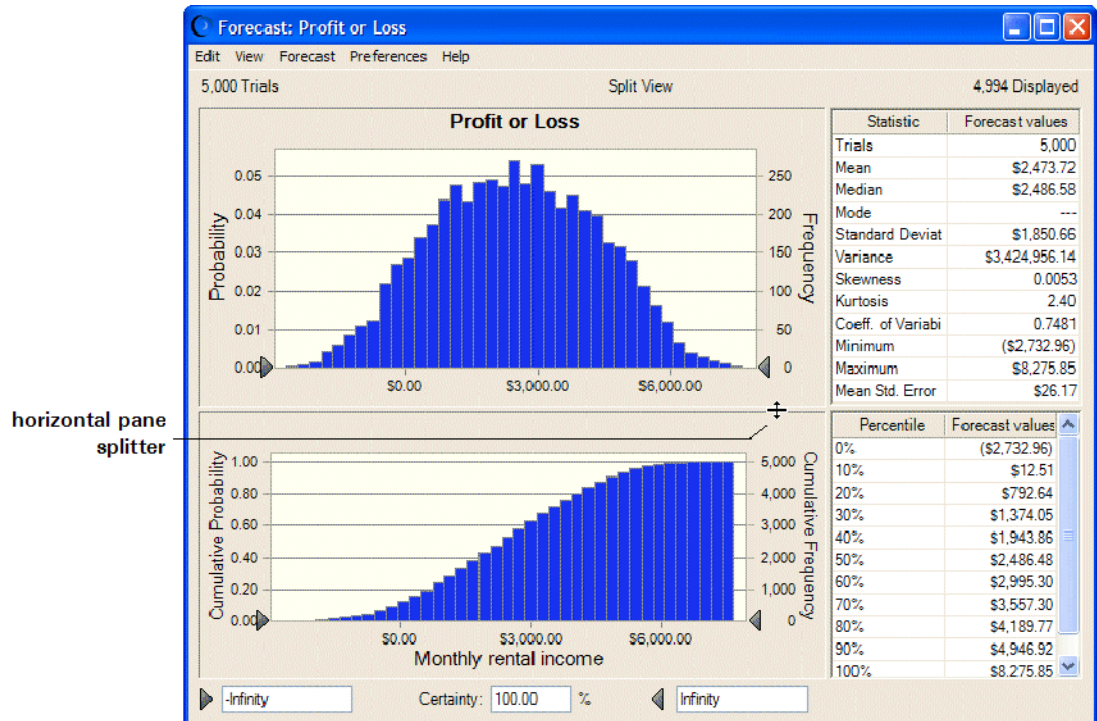


You can resize the window and use the vertical pane splitter to adjust the size of the chart and the statistics pane.

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 34 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 5.

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 uncheck each view you want to close.

Fitting a Distribution to a Forecast

You can fit distributions to forecast charts, a feature that is similar to distribution fitting for assumptions (described in “[Fitting Distributions to Data](#)” on page 44).

You can fit distributions to forecasts two ways:

- You can choose Forecast, then Fit Probability Distribution in the forecast chart menubar 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 choose Preferences, then Forecast, then Forecast Window in the forecast chart menubar to specify particular distributions and to choose 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 Preferences, then Forecast command:

- 1 **Create a model and run a simulation.**
- 2 **Select a forecast chart.**
- 3 **In the forecast chart menubar, choose Preferences, then Forecast.**
- 4 **In the Forecast Window tab of the Forecast Preferences dialog, check Fit A Probability Distribution To The Forecast and click Fit Options.**

The Fit Options panel opens.

- 5 **Specify which distributions to fit:**
 - **AutoSelect** performs a basic analysis of the data to choose 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.

- **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.
- **Kolmogorov-Smirnov** — The result of this test is essentially the largest vertical distance between the two cumulative distributions.

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

- 7 If you know location, shape, or other parameter values that might help create a more accurate fit with certain distributions, check **Lock Parameters** and enter appropriate values in the **Lock Parameters** dialog ([“Locking Parameters When Fitting Distributions” on page 47](#)).
- 8 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, check **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.

Setting Forecast Preferences

You can set a number of specific forecast preferences to customize how Crystal Ball calculates and displays your forecast charts. These are in addition to the general chart preferences discussed in [“Setting Chart Preferences” on page 112](#).

You can control several forecast features with preference settings, described in the section in parentheses. You can:

- Change the forecast chart view ([“Forecast Window Tab” on page 66](#))
- Determine when the forecast window opens ([“Forecast Window Tab” on page 66](#))
- Fit a distribution to the forecast ([“Fitting a Distribution to a Forecast” on page 109](#))
- Set precision controls for forecast statistics ([“Precision Tab” on page 66](#))
- Filter ranges of forecast values ([“Filter Tab” on page 67](#))
- Automatically extract forecast data to a spreadsheet ([“Auto Extract Tab” on page 67](#))

For an overview, see [“Basic Instructions for Setting Forecast Preferences” on page 110](#).

Basic Instructions for Setting Forecast Preferences

Like the chart preferences, forecast preferences can be set differently for each forecast chart.

➤ To set forecast preferences:

- 1 **Choose Preferences, then Forecast** in a forecast chart’s menubar.

The Forecast Preferences dialog opens.

2 Click a tab and set preferences as required.

These tabs are also displayed in the expanded Define Forecast dialog. For details see the following sections:

- [“Forecast Window Tab” on page 66](#) — Manages window display and distribution fitting for the forecast.
- [“Precision Tab” on page 66](#) — Manages precision control settings.
- [“Filter Tab” on page 67](#) — Discards values inside or outside a range for the current forecast.
- [“Auto Extract Tab” on page 67](#) — Specifies which statistics to extract automatically to Excel when a simulation stops.

Also see the previous section, [“Setting Forecast Preferences” on page 110](#).

See "Confidence intervals" in the "Statistical Definitions" chapter of the online *Oracle Crystal Ball Statistical Guide* for more information about how absolute and relative precision relate to the confidence interval.

3 To reset forecast preference defaults to the original settings shipped with Crystal Ball, click **Defaults.**

4 To copy preferences to other forecasts, click **Apply To.**

You can specify whether to apply all forecast preferences or just the current tab and whether to apply them to the current Excel sheet, all sheets in the workbook, or all open and new workbooks.

5 When all settings are complete, click **OK to apply them.**

Setting Forecast Chart Preferences

The chart preferences can help you customize the appearance of forecast charts. To make these settings, choose Preferences, then Chart Preferences in the forecast chart menubar. For details, see [“Setting Chart Preferences” on page 112](#).

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 big picture" 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 122](#).

Setting Chart Preferences

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

- Add or edit and format a title (“[Adding and Formatting Chart Titles](#)” on page 114)
- Change the chart type (“[Setting the Chart Type](#)” on page 115)
- Show more or fewer columns or data points (“[Changing the Chart Density](#)” on page 116)
- Show or hide grid lines (“[Showing Grid Lines](#)” on page 117)
- Show or hide the chart legend (“[Showing the Chart Legend](#)” on page 117)
- Set special chart effects such as transparency or 3D lines, areas, and columns (“[Setting Special Chart Effects](#)” on page 118)
- Set chart colors (“[Setting Chart Colors](#)” on page 118)
- Show mean, median, mode, standard deviation, percentile, or capability limit/target marker lines (“[Showing the Mean and Other Marker Lines](#)” on page 119)
- 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 120)
- Format chart numbers (“[Formatting Chart Numbers](#)” on page 101)
- Specify whether to use these preferences for more than the current chart (“[Applying Settings to the Current Chart and Other Charts](#)” on page 120)

Also see “[Setting Preferences with Shortcut Keys](#)” on page 112, for ways to change the appearance of charts without using menu commands. See “[Basic Customization Instructions](#)” on page 113 and “[Specific Customization Instructions](#)” on page 114 for other general customization tips.

Setting Preferences with Shortcut Keys

Table 5 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.

Table 5 Shortcut keys for Chart Preferences

Shortcut Key	Command Equivalent	Description
Ctrl+d	View menu; Preference , then <i>chartname</i> Preferences , 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

Shortcut Key	Command Equivalent	Description
Ctrl+i	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+3	Preferences, then Chart Preferences, then General, then 3D Chart	Cycles between two-dimensional and three-dimensional chart display
Ctrl+m	Preferences, then Chart Preferences, then Chart Type, then Marker Lines, then <i>central tendencies</i>	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%
Spacebar	View menu; Preferences, then <i>chartname</i> 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 choose Preferences, then Chart Preferences from the chart's menubar.**

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 step: 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 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 [“Specific Customization Instructions”](#) on page 114.

Specific Customization Instructions

This section explains how you can customize each part of your Crystal Ball charts to present the information most effectively. Topics for each Chart Preferences dialog tab are as follows.

General tab:

- [“Adding and Formatting Chart Titles”](#) on page 114
- [“Changing the Chart Density”](#) on page 116
- [“Showing Grid Lines”](#) on page 117
- [“Showing the Chart Legend”](#) on page 117
- [“Setting Special Chart Effects”](#) on page 118

Chart Type tab:

- [“Setting the Chart Type”](#) on page 115
- [“Setting Chart Colors”](#) on page 118
- [“Showing the Mean and Other Marker Lines”](#) on page 119

Axis tab:

- [“Customizing Chart Axes and Axis Labels”](#) on page 120

All tabs:

- [“Applying Settings to the Current Chart and Other Charts”](#) on page 120

For basic chart customization instructions, see [“Basic Customization Instructions”](#) on page 113.

Adding and Formatting Chart Titles

► To add or change a chart title:

- 1 Display the General tab of the Chart Preferences dialog.

The Chart Title group is displayed at the top of the General page.

By default, Auto is checked and a default title is displayed.

- 2 To edit the title, uncheck Auto and type the new title in the text box.
- 3 When all your settings are complete, click OK.

The chart is displayed with your new settings.

Setting the Chart Type

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

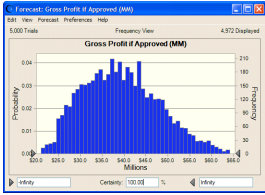
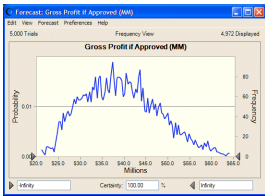
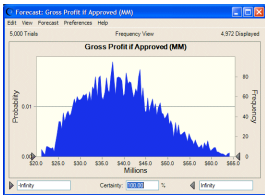
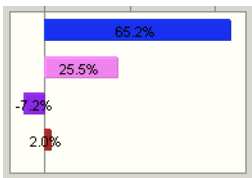
► To change the chart display type:

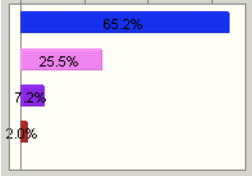
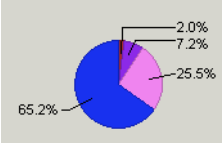
- 1 Display the Chart Type tab of the Chart Preferences dialog. The Chart Type group is displayed in the middle of the Chart Type page.

If more than one series is displayed in the list box at the top of the tab, select one to work with. 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 choose from among these display types (not including scatter charts):

Table 6 Chart Types

Example	Type	Description
	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.
	Line	Shows data as an outline of the peaks and valleys.
	Area	Shows data as darkened peaks and valleys.
	Bar (directional)	Shows sensitivity data as horizontal bars to the right and left of the 0 line

Example	Type	Description
	Bar (magnitude)	<p>showing magnitude and direction of sensitivity</p> <p>Shows sensitivity data as horizontal bars to the right of the 0 line showing magnitude of sensitivity but not direction</p>
	Pie	Shows sensitivity data as a circle divided into proportional "slices" showing the magnitude of sensitivity

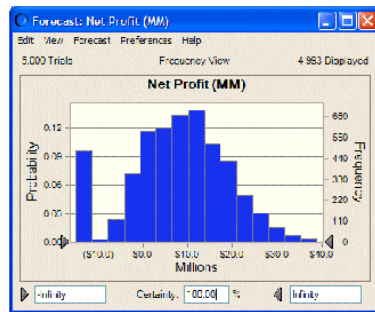
- 3 While you have a series selected, consider adjusting the chart color ("[Setting Chart Colors](#)" on page 118) and marker line settings ("[Showing the Mean and Other Marker Lines](#)" on page 119) too.
- 4 When settings for the current series are complete, follow steps 2 through 3 to customize settings for any other series in the chart.
- 5 When all your settings are complete, click OK.

The chart is displayed with your new settings.

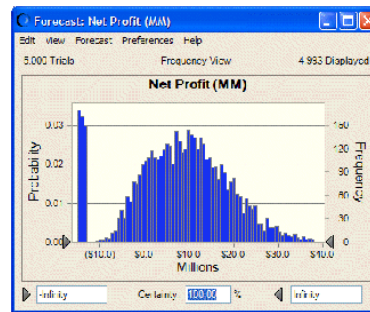
Changing the Chart Density

You can show more or less detail (such as data points and columns) in your chart by changing the number of bins used to group similar values. The level of detail or resolution is called the density of the chart. Higher densities more accurately reflect the actual distribution of data and lower densities highlight the overall shape and trend of data.

- To change the chart density:
 - 1 Display the General tab of the Chart Preferences dialog.
 - 2 Locate the Chart Bins group in the middle of the page.
 - 3 Choose a density level from the Density drop-down list. For example, the following figure shows the lowest and highest density settings for a column chart:



Lowest density



Highest density

- 4 To show a space between each column, or "bin," check **Show Column Gaps**.

Even if you uncheck **Show Column Gaps**, gaps will always be displayed in a discrete distribution.

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

The chart is displayed with your new settings.

Showing Grid Lines

Grid lines are vertical or horizontal lines that can be displayed on charts to help you compare the charted data with the values along the horizontal and vertical axes of the chart.

For basic chart customization instructions, see [“Basic Customization Instructions”](#) on page 113.

- To hide or show grid lines:

- 1 Display the **General** tab of the **Chart Preferences** dialog.
- 2 Locate the **Options** group in the middle of the page.
- 3 Choose 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 choose **None** to hide both horizontal and vertical grid lines.
- 4 When all your settings are complete, click **OK**.

The chart is displayed with the new settings.

You can press **Ctrl+I** to toggle the horizontal grid lines on and off.

Showing the Chart Legend

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

For basic chart customization instructions, see [“Basic Customization Instructions”](#) on page 113.

- To hide or show a chart legend:

- 1 Display the **General** tab of the **Chart Preferences** dialog.
- 2 Locate the **Options** group in the middle of the page.

- 3 Choose 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, choose None.
- 4 When all your settings are complete, click **OK**.

The chart is displayed with the new settings.

You can press Ctrl+n to toggle the legend on and off.

Setting Special Chart Effects

You can use special effects to help present your data most effectively. Transparency ensures that all chart series and values are visible and 3D 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 116](#)).

For basic chart customization instructions, see [“Basic Customization Instructions” on page 113](#).

➤ 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 check any or all of the available effects to see how they enhance your chart. If you check Transparency, you can also choose a percent. 0% is completely opaque and 100% is completely transparent.
- 4 When all your settings are complete, click **OK**.

The chart is displayed with the new settings.

You can press Ctrl+3 to toggle 3D display on and off.

Setting Chart Colors

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

For basic chart customization instructions, see [“Basic Customization Instructions” on page 113](#).

➤ 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 Chart Type page.

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

- 2 Open the **Color** drop-down list and choose a color.
- 3 While you have a series selected, consider adjusting the chart type ([“Setting the Chart Type” on page 115](#)) and marker line settings ([“Showing the Mean and Other Marker Lines” on page 119](#)) 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 your settings are complete, click OK.

The chart is displayed with your new settings.

Showing the Mean and Other Marker Lines

You can display mean, mode, median, standard deviation, 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 your forecast chart (“[Viewing LSL, USL, and Target Marker Lines](#)” on page 391).

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 **Marker Lines** group is displayed in the lower right corner of **Chart Type**.

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

- 2 To display a marker line, check the box for that item. If you choose **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, choose 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 choose **Custom** and create your own group of percentile points separated by commas.
 - For **Value**, enter the x-axis value where the line should be displayed in the **Value** field and click **Add**. If you want, enter an optional label and check **Show Value On Marker Line** to display the value on the chart. You can click **New** to add another value.
- 3 While you have a series selected, consider adjusting the chart type (“[Setting the Chart Type](#)” on page 115) and color (“[Setting Chart Colors](#)” on page 118) too.
- 4 When settings for the current series are complete, follow steps 2 and 3 to customize settings for any other series in the chart.

5 When all your settings are complete, click OK.

The chart is displayed with your new settings.

If the marker lines fall outside the maximum or minimum value displayed on a chart, they will not be displayed on the chart. For example, 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 Consider the label to use for the axis.

By default, Auto is checked in the Axis Label group. A label is automatically assigned depending on the chart type. For example, the value (x) axis of a forecast chart uses the Units entry in the Define Forecast dialog as the label. To enter a custom axis label, uncheck Auto and type a more descriptive label in the edit field.

3 Next, adjust the Scale settings. By default, Auto is displayed in the Type list and the chart is displayed with the most appropriate end points for that chart type. To use another scale, choose it from the Type drop-down list and enter the minimum (Min) and maximum (Max) values to use for the scale.

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. Choose appropriate settings for your chart.

- For Format settings, Cell Format uses the format of the underlying cell. Most choices are similar to those used in Excel: General, Number, Currency, Scientific, Percentage, or Date.
- The Decimal settings control the number of decimal points.
- When checked, 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.

The Format Number settings also control the format of assumption parameters in the Define Assumption dialog and assumption charts.

5 When all your settings are complete, click OK.

The chart is displayed with your new settings.

Applying Settings to the Current Chart and Other Charts

If you would like to apply the current settings to other charts in your model, you can choose what to apply and where to apply them. (These instructions apply anywhere the Apply To button is displayed.)

► To specify how chart settings should be applied:

1 Click the Apply To button.

The Apply To dialog opens.

2 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 on 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 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.

Apply To settings are both flexible and powerful. They can be used as focused or broad defaults.

Managing Existing 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 121](#)
- [“Copying and Pasting Charts to Other Applications” on page 122](#)
- [“Printing Charts” on page 123](#)
- [“Closing Charts” on page 123](#)
- [“Deleting Charts” on page 124](#)

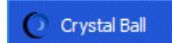
Opening Charts

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 87](#)).**
- 2 Open the Analyze menu and select the type of chart to display: Assumption Charts, Forecast Charts, Overlay Charts, Trend Charts, or Sensitivity Charts.**
- 3 When the dialog for that chart opens, check the box in front of each chart to display.**

4 Click Open.



You might 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 Excel 2007, choose Analyze, then View Charts, then Forecast Charts.

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

For instructions, see the following sections:

- [“Copying Charts” on page 122](#)
- [“Pasting Charts from the Clipboard” on page 122](#)

Copying Charts

➤ To copy charts for use in other applications:

- 1 **Select the chart to copy.**
- 2 **Open its View menu and choose the view to be copied.**

If you choose 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 menubar, choose **Edit**, 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 its own 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, choose **Edit**, then **Paste** or **Edit**, then **Paste Special**.**

(To paste in Excel 2007, press Ctrl+v or click the Home tab and choose Clipboard, then Paste at the left end of the ribbon.)

As described above, 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.

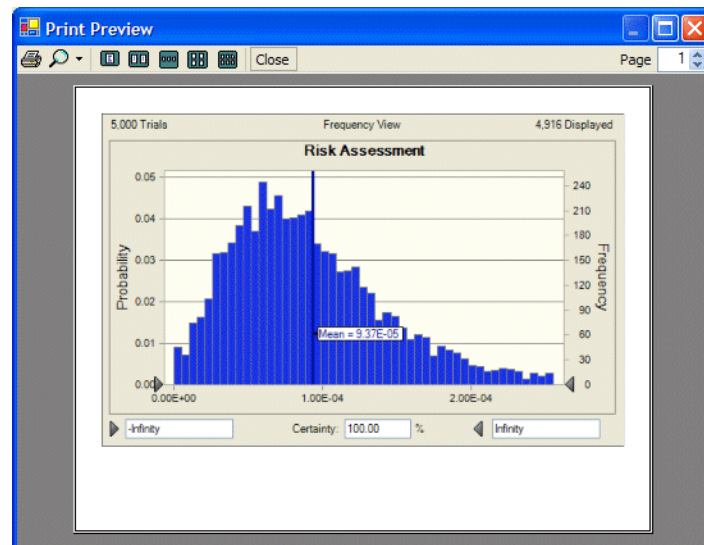
Printing Charts

- ▶ To print a chart, display it and choose Edit, then Print in the chart's menubar.

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

For example, [Figure 35](#) shows the Print Preview dialog for a forecast chart from Toxic Waste Site.xls in Landscape orientation on Letter paper.

Figure 35 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 Excel 2007, choose Analyze, then View Charts and then choose a command.

- 2 When the dialog for that chart opens, check 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, then Close All to close all chart windows from the current simulation and restored results. In Excel 2007, choose Analyze, then View Charts, 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 Excel 2007, choose Analyze, then View Charts and then choose a chart type.

- 3 When the dialog for that chart opens, check 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.

7

Analyzing Other Charts

In This Chapter

Overview	125
Understanding and Using Overlay Charts	126
Understanding and Using Trend Charts	131
Understanding and Using Sensitivity Charts	138
Understanding and Using Assumption Charts	147
Understanding and Using Scatter Charts	149

Overview

The previous chapter gave guidelines for analyzing and customizing simulation results with a focus on forecast charts.

This chapter extends the information on analyzing simulation results provided in [Chapter 6](#). You will learn how to use the following additional charts to interpret and present data:

- Overlay charts to view forecasts superimposed over each other (“[Understanding and Using Overlay Charts](#)” on page 126)
- Trend charts to view the certainty ranges of all your forecasts on a single chart (“[Understanding and Using Trend Charts](#)” on page 131)
- Sensitivity charts to view the impact your assumptions have on forecast results (“[Understanding and Using Sensitivity Charts](#)” on page 138)
- Assumption charts to confirm random number sampling (“[Understanding and Using Assumption Charts](#)” on page 147)
- Scatter charts to compare paired data (“[Understanding and Using Scatter Charts](#)” on page 149)

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](#).

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 Check the boxes in front of the assumptions, forecasts, decision variables, or other objects to include.

3 When the selection is complete, click OK.

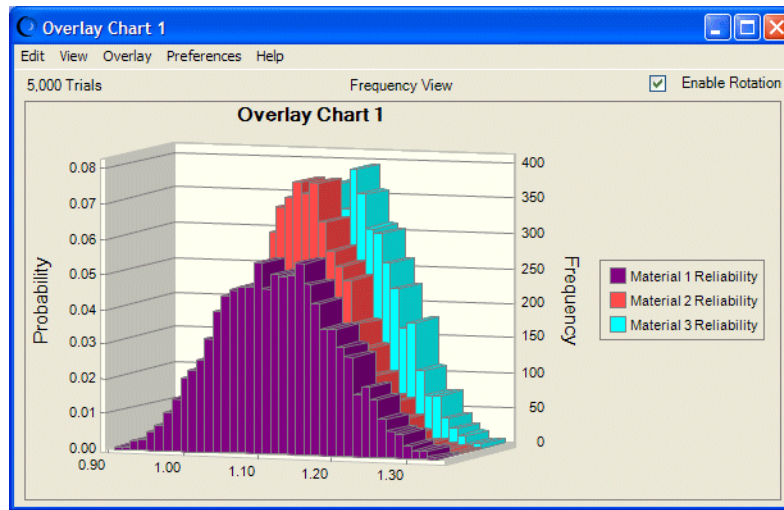
Understanding and Using Overlay Charts

After completing a simulation with multiple related forecasts, you can create an overlay chart to view the relative characteristics of those forecasts on one chart. You can compare differences or similarities that otherwise might not be apparent. There is no limit to the number of forecasts you can view at one time on an overlay chart.

For example, if a model has several forecasts based on slightly different interest rate assumptions, an overlay chart can be used to show how these slight differences manifest themselves in the variability of the forecasts. You can customize the overlay chart to accentuate these differences or similarities.

The following overlay chart ([Figure 36](#)) shows the relative reliabilities of three manufacturing materials.

Figure 36 An Overlay Chart with 3D Formatting



Note: The default overlay chart is two-dimensional, not rotated, and displays the legend below the chart. This and other illustrations may differ from the default view.

After the simulation stops, you can also use the overlay chart to fit probability distributions to the forecasts. This process is similar to the distribution fitting feature described in “[Fitting a Distribution to a Forecast](#)” on page 109, except that the fit is applied to forecast data, not historical data.

The following sections describe how to create and use overlay charts:

- “[Creating Overlay Charts](#)” on page 127
- “[Customizing Overlay Charts](#)” on page 130
- “[Using Distribution Fitting with Overlay Charts](#)” on page 130

Creating Overlay Charts


The example model used in this section, Reliability.xls, shows the reliability of a design component when it is manufactured from different materials and is subjected to varying stresses.

Each forecast chart displays the design component’s reliability as a ratio of two distributions, strength and stress. A reliable component has values greater than 1, because the component’s strength exceeds the stress subjected to it. An unreliable component has values less than 1, because its strength is less than the stress. For this model, the overlay chart can be used to compare component reliabilities.

► To create an overlay chart:

1 Run a simulation in Crystal Ball.

To produce a meaningful overlay chart, the simulation should have more than one forecast. Reliability.xls is used in these instructions.

2 Choose **Analyze, then **Overlay Charts**.** 

(If you are using Crystal Ball in Excel 2007, choose **Analyze**, then **View Charts**, then **Overlay Charts**.)

The **Overlay Charts** dialog opens. If you have not yet created any overlay charts for open workbooks or restored results files, the dialog is blank.

3 To create a new overlay chart, click **New.**

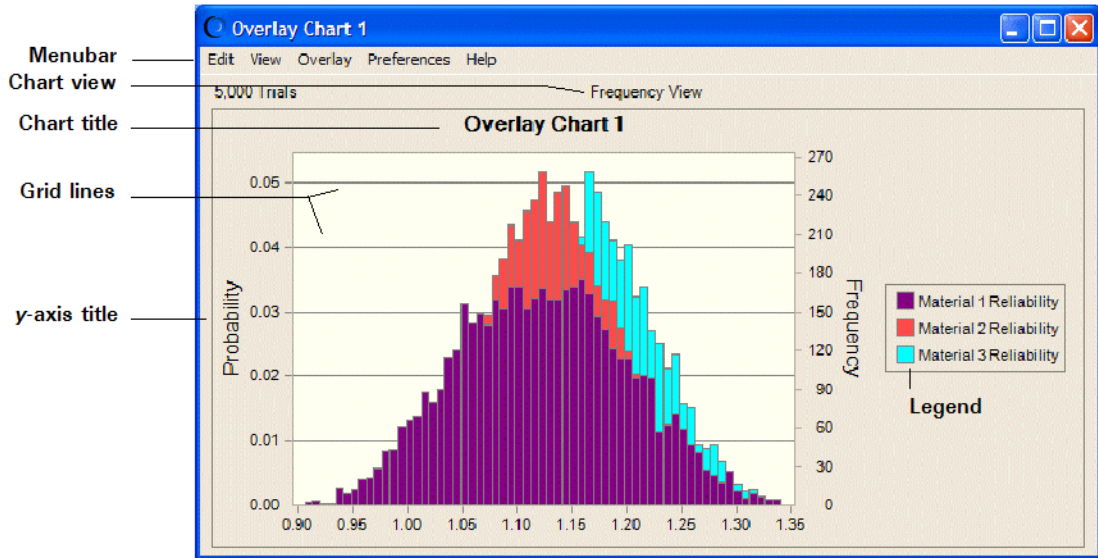
The **Choose Forecasts** dialog opens.

By default, this dialog opens in a hierarchical **Tree** view. If you prefer, click the **List** button to change the view from a tree to a list. 

4 Check the boxes in front of the forecasts to include in the overlay chart.

5 Click **OK to create a new overlay chart with the selected forecasts as shown in [Figure 37](#).**

Figure 37 Overlay Chart for Selected Forecasts



The overlay chart is displayed with the frequency distributions for the selected forecasts superimposed over each other. By default, they are displayed as columns. You can change them to lines or areas in two or three dimensions and can change the number of data points or intervals (bins) with the Chart Preferences settings (“[Setting Chart Preferences](#)” on page 112). A default name is assigned; you can also change it with the Chart Preferences settings.

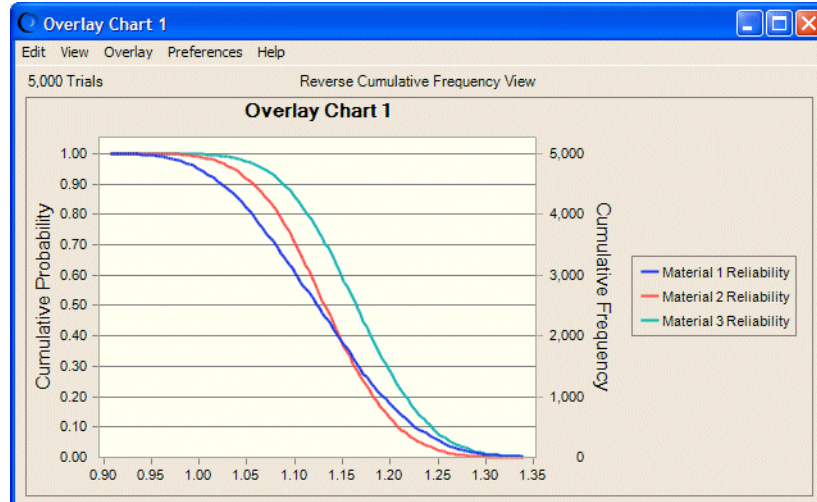
- 6 Follow the steps in “[Customizing Overlay Charts](#)” on page 130 and “[Setting Chart Preferences](#)” on page 112 to change a variety of chart features and highlight those of greatest interest.

You can also use "shortcut keys," or keyboard equivalents for commands to quickly change the chart preferences. For a list of these, see [Table 5](#) on page 112.

- 7 In this example, press Ctrl+d until the reverse cumulative chart view is displayed. Then, press Ctrl+t until the outline chart type is displayed.

As shown in [Figure 38](#), the chart view changes to show all three distributions completely. 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.

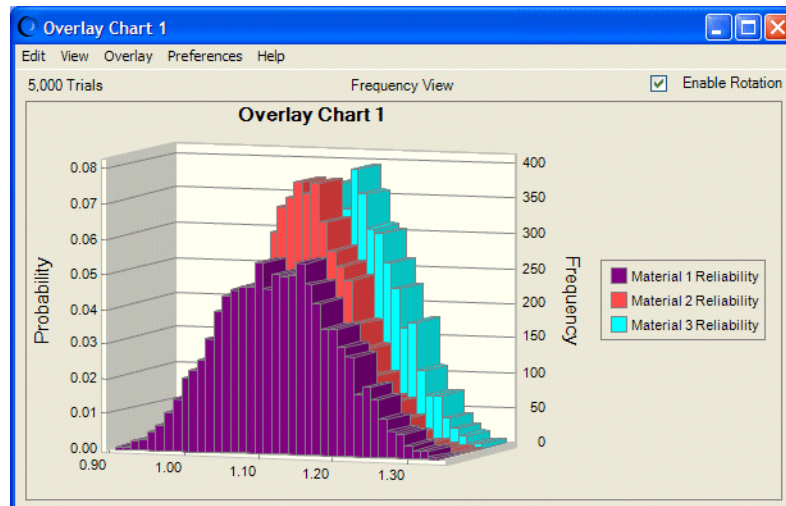
Figure 38 Overlay Chart with Three Distributions



8 Now, experiment with chart shortcut keys.

Press Ctrl+d again 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+3 to make the chart three-dimensional.

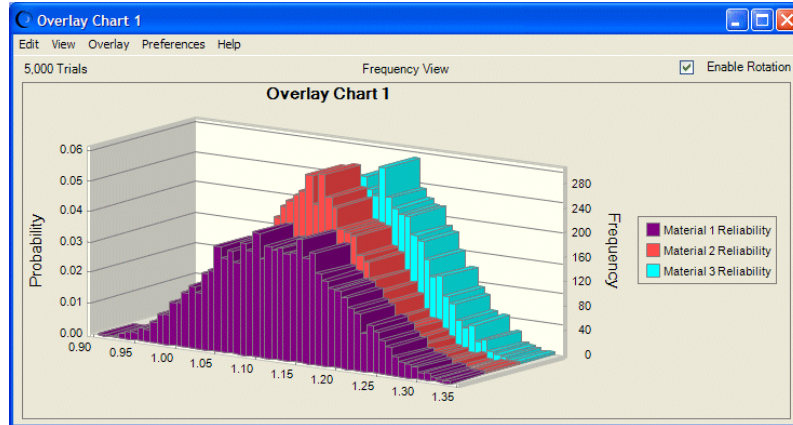
Figure 39 Overlay Chart, 3D View



If you want, you can drag the right or left edge of the chart to give it a taller, narrower look, as shown in [Figure 39](#), or a stretched look as in [Figure 40](#).

In 3D view, the Enable Rotation checkbox is displayed in the upper-right corner of the chart. When it is checked, you can click inside the chart and drag to rotate it. This can enhance the data display for both analysis and presentation. [Figure 40](#) shows a rotated overlay chart, stretched to emphasize x-axis differences.

Figure 40 A Rotated and Stretched Overlay Chart



Note: Rotation settings are for the current session only and are not saved with the chart. For more customization suggestions, see the next section.

Customizing Overlay Charts

You can customize overlay charts in a variety of ways:

- Use the View menu in the overlay chart window to switch among several graphic and numeric views.
- Use 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.
- Use Preferences, then Overlay to choose 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 130).
- Use Preferences, then Chart Preferences to further customize the chart’s appearance as described in [“Setting Chart Preferences”](#) on page 112.

Customizing overlay charts helps you compare forecasts by viewing their differences in several ways. For example, the area and column chart types might obscure parts of some distributions behind other distributions, but the outline and line chart types show virtually all of each distribution. For best display of many types of data, you can choose 3D view and then rotate the chart as shown in [Figure 40](#).

Using Distribution Fitting with Overlay Charts

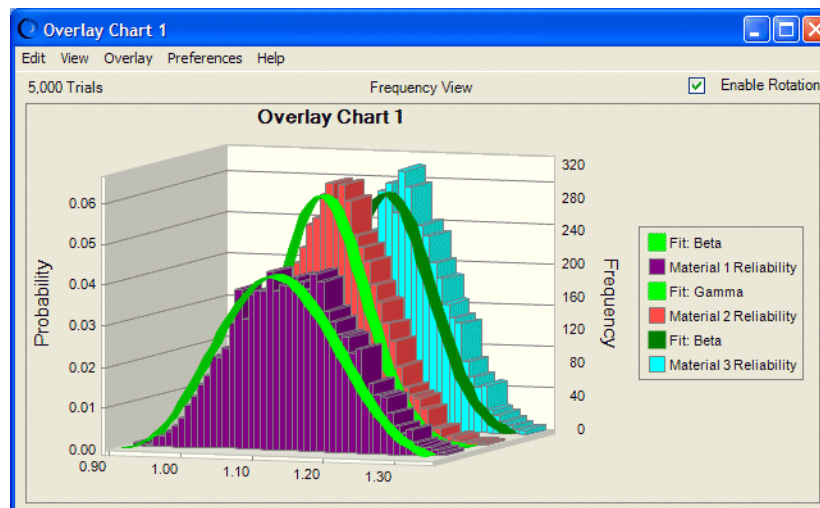
Similar to the distribution fitting with historical data described in [“Fitting Distributions to Data”](#) on page 44, you can fit standard probability distributions to forecasts in an overlay chart, in addition to comparing forecasts to each other.

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

- Choose Overlay, then Fit Probability Distributions in the overlay chart menubar 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.
 - Choose Preferences, then Overlay, then Overlay Window in the overlay chart menubar to specify particular distributions and to choose 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, then Overlay command:
- 1 Follow the steps for forecast charts given in [“Fitting a Distribution to a Forecast” on page 109](#). Wherever the instructions say Forecast, as in Preferences, then Forecast, substitute Overlay.
 - 2 Click **OK** to perform the fit.

Crystal Ball fits the distributions, and then displays a probability distribution for each forecast as shown in [Figure 41](#). As the legend shows, the forecast in the middle fits best to a gamma distribution, while the other two are beta fits. The Series tab of the Chart Preferences dialog was used to change the colors of the lines of best fit for greater contrast in the figure.

Figure 41 Overlay Chart with Forecasts and Lines of Best Fit



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

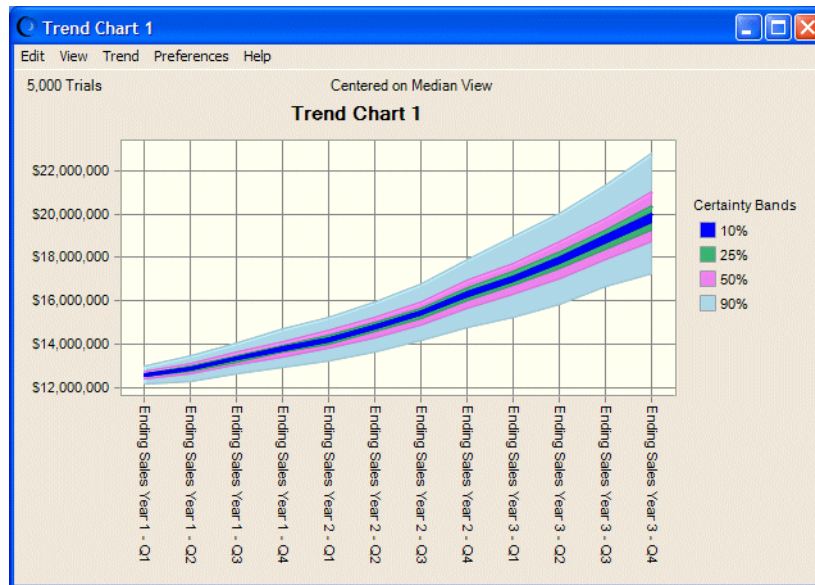
You can copy overlay charts and paste them into other applications. For more information, see [“Copying and Pasting Charts to Other Applications” on page 122](#).

Understanding and Using Trend Charts

After completing a simulation with multiple related forecasts, you can create a trend chart to view the certainty ranges of all the forecasts on a single chart. A trend chart summarizes and

displays information from multiple forecasts, making it easy to discover and analyze trends that might exist between related forecasts.

Figure 42 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 which 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 trend chart in [Figure 42](#) displays certainty ranges on a quarterly basis over a three year period. Because the model contains quarterly forecast formulas dependent on the previous quarter's results, the bands widen in the future. This occurs because the standard deviation of the forecasts increases or widens for each quarter. Trend charts like this one demonstrate the compounding of uncertainty that occurs as predictions are made farther and farther into the future.

You can customize trend charts to display the probability that given forecasts will fall in a particular part of a value range. For example, if a model contains forecasts related through time, you can use trend charts to view the certainty ranges for each forecast side by side. You can also compare at a glance the certainty ranges for an early time period and a later time period.

Trend charts are only meaningful when you have multiple forecasts that are related to each other.

The following sections describe how to create and work with trend charts:

- [“Creating Trend Charts” on page 133](#)
- [“Customizing Trend Charts” on page 133](#)
-

Creating Trend Charts

The following are basic steps for creating trend charts. The steps are illustrating using an example spreadsheet, Sales Projection.xls, shipped with Crystal Ball.

► To create a trend chart:

1 Run a simulation in Crystal Ball.

To produce a meaningful trend chart, the simulation should have more than one forecast.

2 When the simulation stops, choose Analyze, then Trend Charts. 

(If you are using Crystal Ball in Excel 2007, choose Analyze, then View Charts, then Trend Charts.)

The Trend Charts dialog opens. If no trend charts have been created for the open workbooks or restored results files, the dialog is blank.


3 To create a new trend chart, click New.

The Choose Forecasts dialog opens.

By default, this dialog opens in a hierarchical Tree view. If you prefer, click the List button to change to List view. 

4 Select two or more forecasts to include in the trend chart.

To select a forecast, check the box in front of its name. For this example, select all forecasts in the Sales Projection worksheet.

To select all forecasts in this example, you can click the Select All button or check the box in front of Sales Projection.xls or the Model tab name. 

5 Click OK.

The trend chart is displayed as shown in [Figure 42](#).

As with overlay charts, you can change the scale and proportions of the chart by dragging its edges. For other customization possibilities, see the next section.

Customizing Trend Charts

You can customize trend charts in several ways. Most of the following customizations are available through trend chart menus or the Trend Preferences dialog:

- [“Changing Trend Chart Views” on page 134](#)
- [“Specifying When Trend Charts Are Displayed” on page 135](#)
- [“Adding, Removing, and Ordering Forecasts” on page 135](#)

The following sections describe how to make settings using the Trend Chart Preferences dialog:

- [“Changing the Overall Appearance of Trend Charts” on page 136](#)

- “Setting Certainty Band Type and Colors” on page 136
- “Setting Certainty Bands” on page 137
- “Changing Value Axis Preferences” on page 137

For some of the options, you can use shortcut keys to bypass the Trend Preferences dialog. These shortcut keys are listed in [Table 5 on page 112](#) and [Appendix B, “Accessibility.”](#)

Changing Trend Chart Views

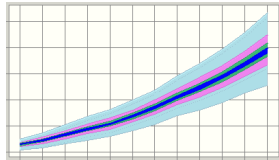
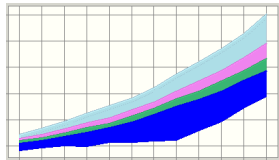
Use the trend chart View menu to change the placement of the certainty bands within the trend chart. The default setting centers the bands around the median of each forecast. You can change the location of the bands so that they are anchored at either the high end or the low end of the projected forecast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

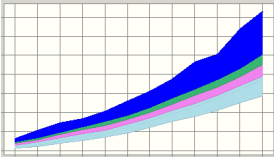
Smaller bands are always displayed on top of larger bands. This obscures the larger bands. Don’t confuse the actual width of a band with the portion that is visible. You can display the true size of a band using the certainty band preferences, described in [“Setting Certainty Bands” on page 137](#). Optionally, you can use these preferences to display the bands one at a time on the trend chart.

► To change the placement of the certainty bands:

- 1 In the trend chart, open the View menu.
- 2 Choose one of the views listed in [Table 7](#), following.

Table 7 Trend Chart Views

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

View	Effect	
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).

Alternately, you can choose Preferences, then Trend and choose a view in the View list of the Trend Preferences dialog.

You can use a Crystal Ball shortcut key to bypass the View menu. Each time you press Ctrl+d, the next trend chart view opens.

Specifying When Trend Charts Are Displayed

You can set preferences that determine whether the trend chart opens automatically, and if so, whether it is displayed while the simulation is running or after it stops.

► To set these display preferences:

1 Choose Preferences, then Trend.

The Trend Preferences dialog opens.

2 To change the trend chart view, use the drop-down View list.

The views are discussed in the previous section, [“Changing Trend Chart Views” on page 134](#).

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

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

4 You can click Defaults at any time to restore original default settings for the Trend Preferences dialog.

5 When all settings are complete, click OK to activate them and close the dialog.

Adding, Removing, and Ordering Forecasts

► To add and remove forecasts from a trend chart:

1 In the trend chart menubar, choose Trend, then Choose Forecasts.

The Choose Forecasts dialog opens.

2 Check and uncheck forecasts to add and remove them from the chart.

To clear all forecast selections, choose Trend, then Remove All in step 1, above.

3 Click OK to accept the settings and modify the chart.

After you select forecasts and create a trend chart, you can change the order of forecast display.

➤ To change the order of forecasts:

1 In the trend chart menubar, choose Preferences, then Chart, then Chart Type.

The Chart Type dialog opens.

All charted forecasts are displayed in the Series list at the top of the dialog. The forecast at the top of the list is displayed as the first forecast at the left of the forecast axis.

2 Select a forecast in the list and use the up and down arrow keys to the right of the list to move the forecast up or down the list.

3 Optional step: You can choose Defaults at any time to restore all settings to their original default values.

4 Optional step: To apply the settings to more than one chart, click Apply To. Then, specify how they should be applied (see [“Applying Settings to the Current Chart and Other Charts”](#) on page 120 for details) and click OK. Otherwise, go to step 5.

5 When all forecasts are positioned in order, click OK to accept the current Chart Preferences settings and modify the chart.

Changing the Overall Appearance of Trend Charts

When you first choose Preferences, then Chart in the trend chart menubar, 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.

You can set the following features, described in the sections in parentheses:

- Chart title ([“Adding and Formatting Chart Titles”](#) on page 114)
- Gridlines ([“Showing Grid Lines”](#) on page 117)
- Legend ([“Showing the Chart Legend”](#) on page 117)
- Chart effects ([“Setting Special Chart Effects”](#) on page 118)

For descriptions of each setting while you are viewing the dialog, click Help.

Setting Certainty Band Type and Colors

By default, the trend chart certainty bands are displayed as solid-colored areas. You can change the bands from solid areas to uncolored areas bordered by lines. You can also change the color of each certainty band.

➤ To change the chart type or color settings:

1 Choose Preferences, then Chart, then Chart Type.

The Chart Type tab of the Chart Preferences dialog opens.

2 To change all certainty bands from areas to lines, choose Line in the Chart Type drop-down list.

- 3 To change the color of a certainty band:
 - a. Select the certainty band to change from the list below the Certainty Bands button.
 - b. Select a color from the Band Color list.
- 4 To select a different set of certainty levels or define your own, click the Certainty Bands button and follow the steps in the next section, [“Setting Certainty Bands” on page 137](#)
- 5 Optional: You can choose 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 the Current Chart and Other Charts” on page 120](#) for details) and click OK. Otherwise, go to step 7.
- 7 When settings are complete, click OK to accept current settings on all tabs of the Chart Preferences dialog.

You can use the Chart Series list at the top of the Chart Type tab to change the order of forecasts in the forecast axis. For instructions, see [“Adding, Removing, and Ordering Forecasts” on page 135](#).

Setting Certainty Bands

You can easily choose a set of certainty bands (levels) to display in the trend chart or create your own custom set.

- To change or define a set of certainty bands:
 - 1 In the trend chart menubar, choose Preferences, then Chart.
 - 2 Click the Chart Type tab.
 - 3 On the Chart Type tab, click the Certainty Bands button.
 - 4 The Percentiles dialog opens.
 - 5 Choose a set of certainty bands to display on the trend chart.
 - 6 To create your own set, choose Custom and enter a series of certainty bands, separated by commas.
 - 7 Click OK.

The trend chart opens with the selected certainty bands. A legend is displayed on the right side of the trend chart indicating which levels are represented by which bands.

If the 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

You can change several trend chart axis preferences, as described below. You can add a name for the value axis, set number formats, and set value rounding. You can also change Scale settings from Auto to Fixed and specify a range minimum and maximum value. You can use these scale settings to display 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 menubar, choose Preferences, then Chart, then Axis.

The Axis tab of the Chart Preferences dialog opens.

- 2 By default, no name displays for the value axis. To add one, type it in the Axis Label field.
- 3 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 and other charts. For more information, see [“Customizing Chart Axes and Axis Labels” on page 120](#).

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

- 5 Optional: You can choose 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 the Current Chart and Other Charts” on page 120](#) for details) and click OK. Otherwise, go to step 7.
- 7 When settings are complete, click OK.

The trend chart opens with the value axis changed.

You can copy trend charts and paste them into other applications. For more information, see [“Copying and Pasting Charts to Other Applications” on page 122](#).

Understanding and Using Sensitivity Charts

As you become more proficient at building spreadsheet models, you will want to know how much a given assumption affects your result. In other words, you want to determine the sensitivity of the forecast to each assumption. 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

To determine the model sensitivity yourself, you would need to algebraically analyze the various relationships between your forecast cell and your assumption cells. Calculating these complex relationships could be a difficult and time-consuming task without a program like Crystal Ball.

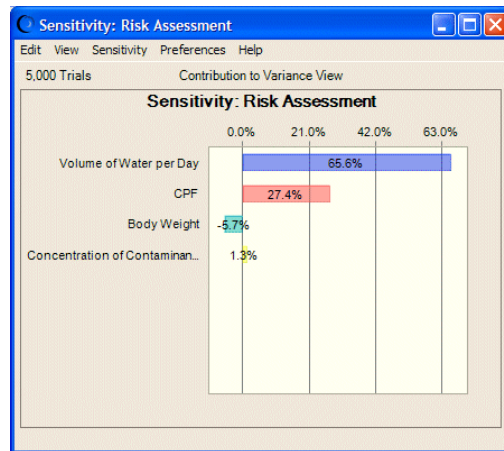
The following sections describe how to create and use sensitivity charts:

- [“About Sensitivity Charts” on page 139](#)
- [“Creating Sensitivity Charts” on page 139](#)
- [“How Crystal Ball Calculates Sensitivity” on page 141](#)
- [“Limitations of Sensitivity Charts” on page 142](#)
- [“Customizing Sensitivity Charts” on page 143](#)

About Sensitivity Charts

Sensitivity charts show the influence of each assumption cell on a particular forecast cell. During a simulation, Crystal Ball ranks the assumptions according to their importance to each forecast cell. The sensitivity chart displays these rankings as a bar chart, indicating which assumptions are the most important or least important in the model (Figure 43). You can output print the sensitivity chart on the report or copy it to the clipboard.

Figure 43 Assumptions and Their Effects on Toxicity Risk



Sensitivity charts provide these key benefits:

- You can find out which assumptions are influencing your forecasts the most, reducing the amount of time needed to refine estimates.
- You can find out which assumptions are influencing your forecasts the least, so that they can be ignored or discarded altogether.
- As a result, you can construct more realistic spreadsheet models and greatly increase the accuracy of your results because you know how your assumptions affect your model.

Creating Sensitivity Charts

The example model used in this section, Toxic Waste Site.xls, illustrates the risk assessment of a toxic waste site. The sensitivity chart created in the steps below displays, in descending order, the assumptions in this model. The assumption with the highest level of sensitivity can be considered as the most influential assumption in the model.

- To create a sensitivity chart:
- 1 Close any spreadsheets that are currently open.
 - 2 Open the spreadsheet to analyze.

Toxic Waste Site.xls is used in these instructions. You can choose Help, then Crystal Ballll, then Examples Guide to choose the model from a list.

(In Excel 2007, choose Resources, then Examples Guide in the Help group.)

3 Choose **Run**, then **Run Preferences**, then **Options**. 

4 Make sure **Store Assumption Values For Sensitivity Analysis** is checked and click **OK**.

Sensitivity analysis requires that all of the random numbers from the simulation be kept for comparison with forecast values.

5 Run a simulation until it stops.


6 Choose **Analyze**, then **Sensitivity Charts**. 

(If you are using Crystal Ball in Excel 2007, choose Analyze, then View Charts, then Sensitivity Charts.)

The Sensitivity Charts dialog opens. If you have not yet created any sensitivity charts for the active spreadsheet or restored results file, the dialog is blank.

7 Click the **New** button.

The Choose Forecast dialog opens.

By default, this dialog opens in a hierarchical Tree view. If you prefer, click the List box to change the view from a tree to a list. For more information on the Choose Forecast dialog, click the Help button. 

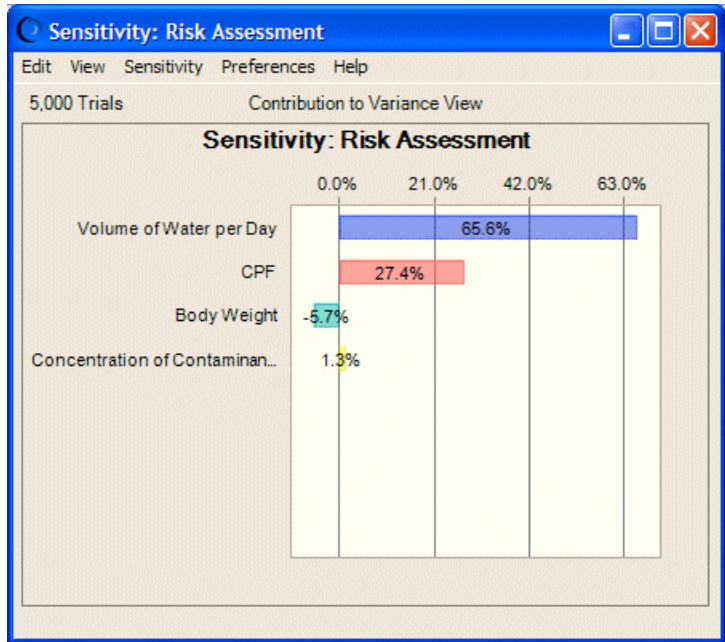
8 Check the box in front of the forecast name to include it in the sensitivity chart.

Toxic Waste.xls has only one forecast, Risk Assessment.

9 Click **OK** to create a new sensitivity chart as shown in [Figure 44](#).

The illustrated chart has a transparency effect applied using the chart preferences to make sensitivity values easier to read. For instructions, see [“Setting Special Chart Effects” on page 118](#).

Figure 44 Sensitivity Chart for the Selected Forecast



The assumptions are listed on the left side, starting with the assumption with the highest sensitivity. If necessary, use the scroll bar to view the entire bar chart (it is at the left of the 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 For Sensitivity Analysis was not checked in the Run Preferences dialog, check it, and then reset the simulation and run the simulation again.

In this example, Figure 44, there are four assumptions listed in the sensitivity chart. The first assumption, Volume Of Water Per Day, 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, Concentration Of Contaminant In Water, contributes the least to forecast variance (about 2%). In fact, this assumption has such a small effect, it could be ignored or altogether eliminated by clearing it from the spreadsheet.

Sensitivity charts like this one illustrate that one or two assumptions typically have a dominant effect on the uncertainty of a forecast.

How Crystal Ball Calculates Sensitivity

Crystal Ball calculates sensitivity by computing rank correlation coefficients between every assumption and every forecast while the simulation is running. Correlation coefficients provide a meaningful measure of the degree to which assumptions and forecasts *change together*. If an assumption and a forecast have a high correlation coefficient, it means that the assumption has a significant impact on the forecast (both through its uncertainty and its model sensitivity).

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.

To help interpret the rank correlations, Crystal Ball provides a default chart view called the Contribution To Variance view. This view makes it easier to answer questions such as "What percentage of the variance or uncertainty in the target forecast is due to assumption X?"

It is important to note that the Contribution To Variance method is only an approximation and is *not precisely* a variance decomposition. Crystal Ball calculates Contribution To Variance by squaring the rank correlation coefficients and normalizing them to 100%.

Both the alternate Rank Correlation View and the 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 8](#) to Bar (Magnitude).

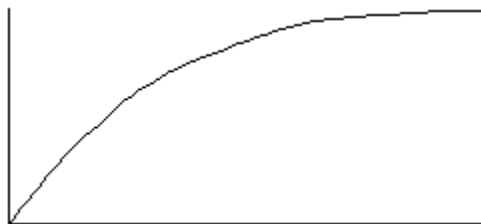
Note: To ensure appropriate accuracy in Contribution To Variance view, consider running at least 10,000 trials.

Limitations of Sensitivity Charts

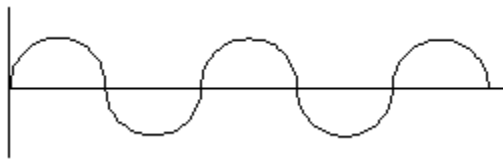
Sensitivity charts have several limitations:

- **Correlated assumptions.** Sensitivity calculations might be inaccurate for correlated assumptions. For example, if an important assumption were highly correlated with an unimportant one, the unimportant assumption would likely have a high sensitivity with respect to the target forecast. Assumptions that are correlated are flagged as such on the sensitivity chart. In some circumstances, turning off correlations in the Run Preferences dialog might help you to gain more accurate sensitivity information.
- **Non-monotonic relationships.** Sensitivity calculations might be inaccurate for assumptions whose relationships with the target forecast are not monotonic. A monotonic relationship means that an increase in the assumption tends to be accompanied by a strict increase in the forecast; or an increase in the assumption tends to be accompanied by a strict decrease in the forecast.

For example, the relationship $y = \text{Log}(x)$ is monotonic:



While $y = \text{Sin}(x)$ is not:



The Tornado Chart tool can help you discover if any of your assumptions have non-monotonic relationships with the target forecast. For more information, see [“Tornado Chart Tool” on page 183](#).

- **Discrete distributions.** Sensitivity calculations might be inaccurate for assumptions or forecasts that have a small set of discrete values. Because the sensitivity calculation relies on rank correlation, a slight loss of information occurs when the assumption or forecast values are replaced by ranks. This loss of information is generally offset by the advantage of being able to measure sensitivity between dissimilar types of distributions. However, 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 your spreadsheet result in identical values (for example, if-then logic, INT functions, and so on).

Customizing Sensitivity Charts

You can customize sensitivity charts by changing the assumptions, forecasts, and sensitivity preferences. As you become more familiar with the sensitivity chart, practice choosing the options that help you get the answers you seek and that are appropriate for your data.

The following sections describe how you can customize sensitivity charts:

- [“Adding and Removing Assumptions” on page 143](#)
- [“Changing the Target Forecast” on page 144](#)
- [“Setting Sensitivity Preferences” on page 144](#)
- [“Setting Sensitivity Chart Preferences” on page 145](#)

Adding and Removing Assumptions

By default, the sensitivity chart includes all of the assumptions from the simulation. To remove or change the assumptions included, follow the instructions in this section.

The total number of assumptions included in the chart affects the calculation of the Contribution to Variance percentages.

➤ To remove or change assumptions included in the sensitivity chart:

- 1 In the Sensitivity Chart window, choose **Sensitivity**, then **Choose Assumptions**.

The Choose Assumptions dialog opens.

- 2 Check the assumptions to add to the sensitivity chart and uncheck those to remove from the chart.
- 3 Click OK to activate the selected assumptions.

Changing the Target Forecast

► To change the target forecast in the sensitivity analysis:

- 1 In the Sensitivity Chart window, choose Sensitivity, then Choose Target Forecast.

The Choose Forecasts dialog opens.

- 2 Check a new target forecast.
- 3 Click OK to activate the selected forecast.

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 Choose Preferences, then Sensitivity.

The Sensitivity Preferences dialog opens.

- 2 To change how the sensitivities are presented, use the View drop-down 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.

- 3 Use settings in the Windows group to determine whether the chart opens automatically.

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

- 4 To limit sensitivities by rank or value, click the Criteria tab to display it.

If you have a model with a lot of assumptions, you can check 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 check both, the more restrictive of the two criteria is used.

- 5 You can click **Defaults** at any time to restore original default settings for the **Sensitivity Preferences** dialog.
- 6 When all settings are complete, click **OK** to activate them and close the dialog.

You can copy sensitivity charts and paste them into other applications. For more information, see [“Copying and Pasting Charts to Other Applications”](#) on page 122.

Setting Sensitivity Chart Preferences

Settings in the Sensitivity Preferences dialog determine how sensitivity is viewed and set the criteria for showing assumptions. Additional settings in the Chart Preferences dialog determine the appearance of the chart.

► To set sensitivity chart preferences:

- 1 In the sensitivity chart window, choose **Preferences**, 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 114)
- Gridlines ([“Showing Grid Lines”](#) on page 117)
- Legend ([“Showing the Chart Legend”](#) on page 117)
- Chart effects ([“Setting Special Chart Effects”](#) on page 118)

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

For descriptions of each setting while you are viewing the dialog, click **Help**.

- 3 Click the **Chart Type** tab for more settings.
- 4 You can use the **Chart Type** drop-down list to choose one of these chart types:

Table 8 Sensitivity Chart Types

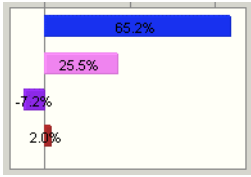
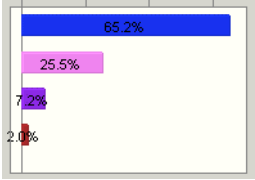
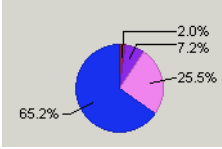
Chart Type	Description	Example
Bar (directional)	The default; horizontal bars to the right and left of the 0 line showing magnitude and direction of sensitivity	

Chart Type	Description	Example
Bar (magnitude)	Horizontal bars to the right of the 0 line showing magnitude of sensitivity but not direction	
Pie	A circle divided into proportional wedges showing the magnitude of sensitivity (only available for Contribution To Variance view)	

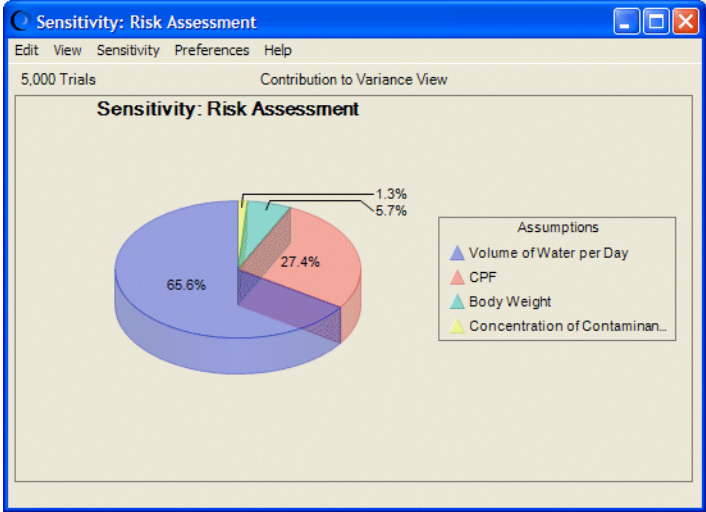
- For bar charts, choose whether to use a different color for each assumption (the default), or whether to use the same color for all assumptions.

If you uncheck Show Multiple Colors, you can choose a specific color to use for all assumptions.

- Choose whether to show value labels on the chart (the default), or uncheck Show Values On Chart to show only graphics but no values.
- Optional step: You can choose Defaults at any time to restore all settings to their original default values.
- Optional step: To apply the settings to more than one chart, click Apply To. Then, specify how they should be applied (see [“Applying Settings to the Current Chart and Other Charts”](#) on page 120 for details) and click OK. Otherwise, go to step 9.
- Click OK to apply the settings on all tabs to the active chart.

You can apply different combinations of settings for special effects. For example, [Figure 45](#) 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 44](#).

Figure 45 Transparent, Three-Dimensional Sensitivity Pie Chart

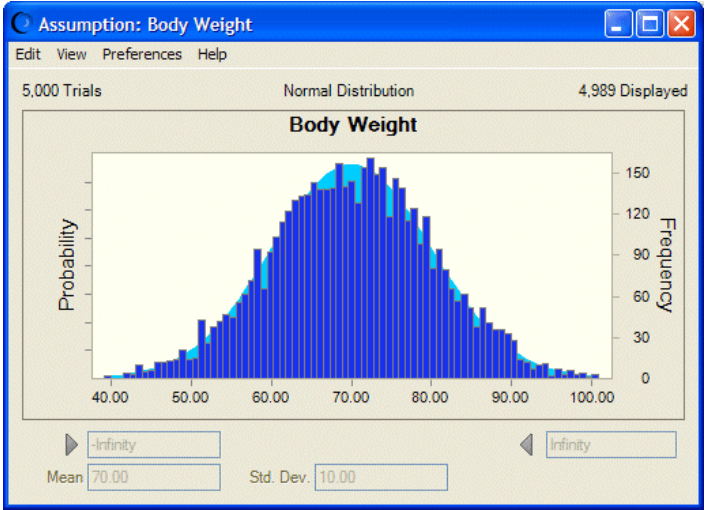


Understanding and Using Assumption Charts

Assumption charts are created automatically when you run a simulation. They cannot be deleted, only opened or closed.

During or after a simulation runs, you can view assumption charts to show trial values (that is, random numbers) for the current simulation layered over the assumption's ideal probability distribution (Figure 46).

Figure 46 Assumption Chart



Assumption charts are useful for checking and 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. If certain settings yield a noticeably better match between the random numbers and the ideal distribution, you might want to use those settings even if the simulation runs longer.

► To open an assumption chart:

- 1 **Run a simulation.**
- 2 **Choose *Analyze*, then *Assumption Charts*.**

(If you are using Crystal Ball in Excel 2007, choose *Analyze*, then *View Charts*, then *Assumption Charts*.)

- 3 **When the dialog opens, choose the assumptions to view and click **OK**.**

For customization instructions, see [“Customizing Assumption Charts” on page 148](#).

Customizing Assumption Charts

Because assumption charts look so similar to forecast charts, many of their menu commands and settings are the same.

The following sections describe how you can customize assumption charts:

- [“Setting Assumption Chart Views” on page 148](#)
- [“Setting Assumption Preferences” on page 148](#)
- [“Setting Assumption Chart Preferences” on page 148](#)

Setting Assumption Chart Views

You can use the View menu to choose 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 102](#).

Setting Assumption Preferences

Assumption preferences, set with Preferences, then Assumptions, are similar to those for forecasts, described in [“Setting Forecast Preferences” on page 110](#). 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 isn’t available in the Assumption Preferences dialog. Instead, there is a Run Preferences button so you can easily change the Store Assumption Values... setting on the Options tab of the Run Preferences dialog. For more information on the Assumption Preferences dialog, click the Help button in the dialog.

Setting Assumption Chart Preferences

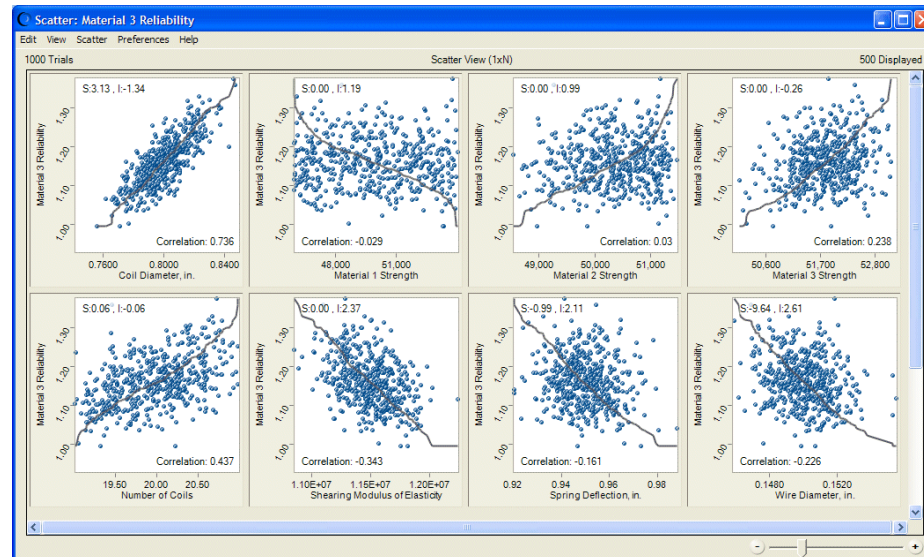
Assumption chart preferences are virtually identical to forecast chart preferences. To review or change them, choose Preferences, then Chart and follow the instructions in [“Setting Chart Preferences” on page 112](#).

Understanding and Using 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 47](#) shows a set of all model assumptions plotted against a target forecast. In this case, the Material 3 Reliability forecast is the target.

Figure 47 Scatter chart, Scatter view, with Optional Lines and Correlations

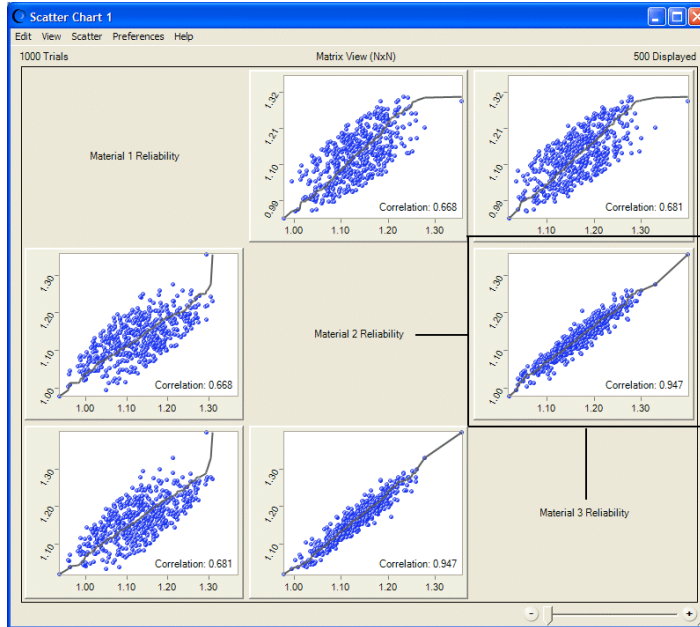


In [Figure 47](#), the line shows where the pairwise points would be displayed if they were sorted in ascending order. The closer the points conform to the line, the closer the relationship among the plotted variables. Lines sloped from the lower left to the upper right show positive relationships. If the relationship is negative, the line slopes from the upper left to the lower right.

[Figure 47](#) 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 48](#) 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 48 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 48, 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 choose Sensitivity, 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 47.

The following sections describe how to create and work with scatter charts:

- “Creating Scatter Charts” on page 150
- “Customizing Scatter Charts” on page 152

Creating Scatter Charts

► To create a scatter chart:


- 1 Run a simulation in Crystal Ball.
- 2 When the simulation stops, choose **Analyze**, then **Scatter Charts**. 

(If you are using Crystal Ball in Excel 2007, choose Analyze, then View Charts, then Scatter Charts.)

The Scatter Charts dialog opens. If you have not yet created any scatter charts for the open workbooks or restored results files, the dialog is blank.

- 3 Click the **New** button.

The Choose Data dialog opens.

By default, this dialog opens in a hierarchical Tree view. If you prefer, click the List box to change the view from a tree to a list. For more information on the Choose Data dialog, click the Help button. 

4 Check the box in front of an assumption or forecast name to include it 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 was not checked in the Run Preferences dialog, check it, and then reset the simulation and run the simulation again.

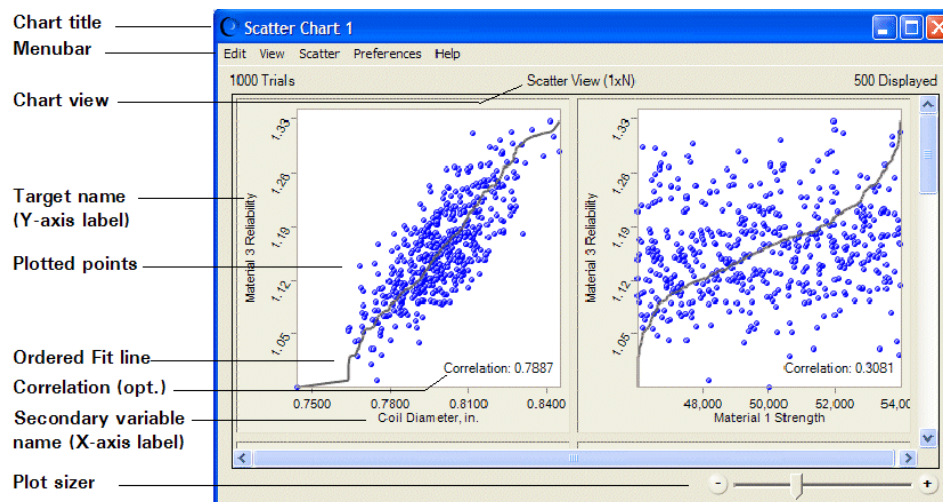
5 To create a scatter chart in Scatter view, set a single assumption or forecast as the target. You do not need to set a target to display the chart in Matrix view.

To set a target, check the box in front of the target assumption or forecast, click its name, and then click Set As Target. In this case, Material 3 Reliability is set as the target and all assumptions are selected as secondary variables.

6 Click OK to create the new scatter chart shown in [Figure 49](#).

Only a portion of the chart is shown here. For a view of the complete chart, see [Figure 47](#).

Figure 49 Scatter Chart for the Selected Target, Scatter View



Here is some information about features shown in [Figure 49](#):

- You can choose Preferences, then Chart Preferences to change the chart title.
- To change the number of trials displayed in the plots, choose Preferences, then Scatter, 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. You can choose Preferences, then Chart Preferences, 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

You can customize scatter charts by changing the plotted variables, scatter preferences, and chart preferences. As you become more familiar with the scatter chart, practice choosing the options that help you get the answers you seek and that are appropriate for your 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.

The following sections describe ways to customize scatter charts:

- [“Adding and Removing Assumptions and Forecasts” on page 152](#)
- [“Setting Scatter Preferences” on page 153](#)
- [“Setting Scatter Chart Preferences” on page 154](#)
- [“Scatter Charts and Filtered Data” on page 155](#)

Adding and Removing Assumptions and Forecasts

When you create a new scatter chart, all assumptions and forecasts in the model are available to use as targets, secondary variables, or matrix variables. Some variables may be closely related to the target or other elements in the matrix and some variables may be completely unrelated.

You can include up to 25 variables, but scatter charts are easier to interpret with smaller numbers of variables. It can be helpful to edit the chart, removing some secondary variables or matrix elements that show little relationship to each other or a target and adding others that might relate more closely.

In complex models with lots of assumptions and forecasts, you might find it helpful to begin by creating a sensitivity chart and then creating a scatter chart from the data included within it. For example, you could open a forecast chart and choose Forecast, then Open Sensitivity Chart to view a sensitivity chart. Then, within the sensitivity chart, you could choose Sensitivity, then Open Scatter Chart to create a scatter chart using that forecast as the target.

- However you create a scatter chart, you can follow these steps to remove or change the variables (forecasts and assumptions) included in it:

- 1 In the Scatter Chart window, choose Scatter, then Choose Data.**

The Choose Data dialog opens.

- 2 Check the assumptions or forecasts to add to the scatter chart and uncheck those to remove from the chart.**

- 3 If you want, set a different target.**

Click the variable name and then click Set As Target.

- 4 Click OK to display the edited chart.**

If you set a new target or remove a target, the view changes when the chart opens again. If you set a new target, the scatter chart is displayed in Scatter view with selected variables plotted against the new target. If you remove an existing target and do not set a new one, the chart is displayed in Matrix view.

Setting Scatter Preferences

You can set a number of preferences that determine:

- The scatter view that is displayed
- Whether the scatter chart opens automatically and whether it is displayed while the simulation is running or after it stops
- The plot size
- The number of trials that are plotted relative to the total number of trials in each simulation

- To set scatter preferences:

- 1 Choose Preferences, then Scatter.**

The Scatter Preferences dialog opens.

- 2 To change how the scatter chart is presented, use the View drop-down list:**

- Scatter View (1xN) shows secondary variables plotted against a target.
- Matrix View (NxN) shows all selected variables plotted against each other.

- 3 Use settings in the Window group to determine whether the chart opens automatically.**

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

- 4 To change the size and amount of detail shown in each plot, use the Plot Sizer.**

Slide it left to decrease or right to increase plot size. To set the new size as a global default or apply it to other scatter charts, click **Apply To** and choose appropriate settings. Click **Help** for additional information.

- 5 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.**

By default, only a portion of trials are plotted for each simulation, based on the total number of trials. To display all trials or a specific number, choose **Show The First ____ Trials** and enter the number of trials to display. Or, you can choose **Show The First ____% Of The Trials** to show a certain percent of the trials, from 1% to 100%.

- 6 You can click **Defaults** at any time to restore original default settings for the **Scatter Preferences** dialog or click **Apply To** to set new defaults.**

- 7 When all settings are complete, click **OK** to activate them and close the dialog.**

You can copy scatter charts and paste them into other applications. For more information, see [“Copying and Pasting Charts to Other Applications” on page 122](#).

Setting Scatter Chart Preferences

Settings in the **Scatter Preferences** dialog determine which scatter chart view is displayed and set the criteria for plotting all or a portion of trials actually run. Additional settings in the **Chart Preferences** dialog determine the appearance of the chart.

► To set scatter chart preferences:

- 1 In the scatter chart window, choose **Preferences**, 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 114](#))
- Gridlines ([“Showing Grid Lines” on page 117](#))
- Legend ([“Showing the Chart Legend” on page 117](#))
- Chart effects ([“Setting Special Chart Effects” on page 118](#))

Except for the disabled **Chart Bins** and **3D Chart** preferences, the **General** tab settings are the same as those for forecast charts.

For descriptions of each setting while you are viewing the dialog, click **Help**.

- 3 Click the **Chart Type** tab for more settings.**

- 4 You can use the **Chart Type** drop-down list to choose whether to:**

- Draw points, and if selected, to choose a symbol, color, and size for them.
- Draw a line, and if selected, to choose 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.

- Display correlation coefficients for each plot. These are computed using the Spearman rank correlation method.
 - Display points that have been filtered out (see the next section, “[Scatter Charts and Filtered Data](#)” on page 155).
- 5 You can use the Axis tab to choose a number format for the chart axes and to indicate whether to round axis values, as described in “[Customizing Chart Axes and Axis Labels](#)” on page 120.
 - 6 Optional step: You can choose Defaults at any time to restore all settings to their original default values.
 - 7 Optional step: To apply the settings to more than one chart, click Apply To. Then, specify how they should be applied (see “[Applying Settings to the Current Chart and Other Charts](#)” on page 120 for details) and click OK. Otherwise, go to step 7.
 - 8 Click OK to apply the settings on all tabs to the active chart.

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 67). If you include a filtered forecast in a scatter chart, you can choose whether or not to show filtered points in the chart.

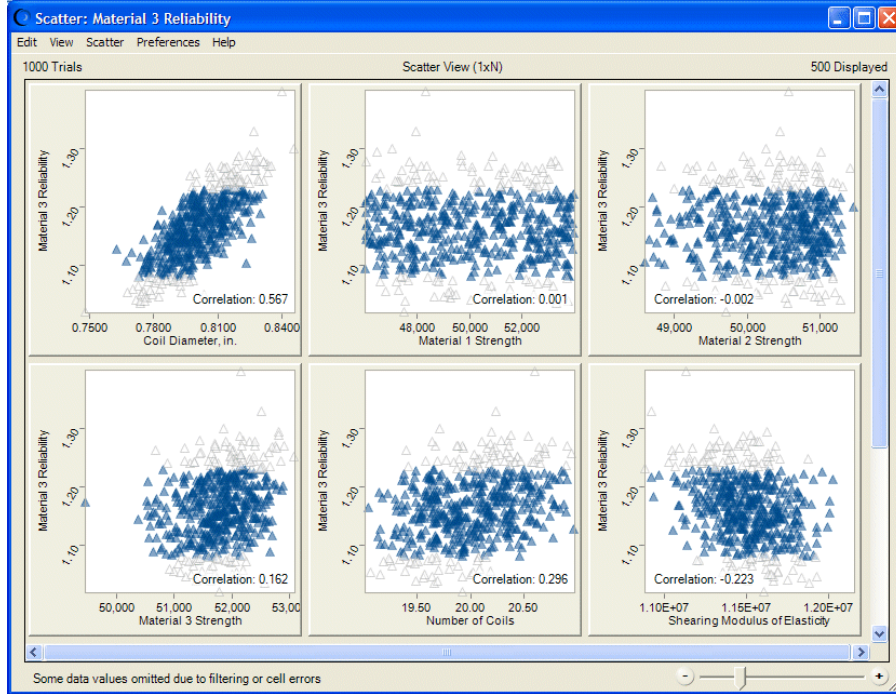
➤ To change this setting:

- 1 Open the scatter chart and choose Preferences, then Chart.
- 2 Click the Chart Type tab.
- 3 Check or uncheck 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 50](#) shows the same data as [Figure 47](#) 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 50 Scatter Chart Showing Filtered Points





Creating Reports and Extracting Data

In This Chapter

Introduction.....	157
Creating Reports	157
Extracting Data	161

Introduction

This chapter describes how to create reports with charts and data and how to extract data for use in other applications.

See the following sections for instructions:

- “Creating Reports” on page 157
- “Extracting Data” on page 161

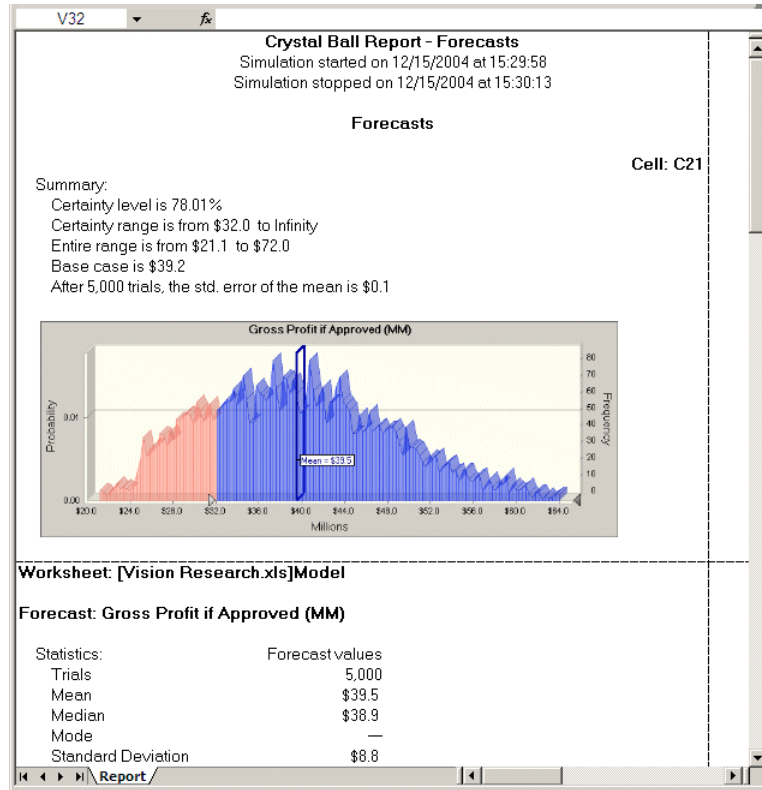
Creating Reports

You can generate pre-defined reports for your simulation or you can create a custom report with any or all of the following items:

- Report summary
- Forecasts
- Assumptions
- Decision variables
- Overlay charts
- Trend charts
- Sensitivity charts
- Scatter charts

Figure 51 shows part of a forecast report for the Vision Research model.

Figure 51 Sample Forecast Report




The following sections describe how to create and work with reports:

- “Basic Steps for Creating Reports” on page 158
- “Setting Report Options” on page 159
- “Defining Custom Reports” on page 160
- “Report Processing Notes” on page 161

Basic Steps for Creating Reports

➤ To create a report:

- 1 Choose Analyze, then Create Report. 

(In Excel 2007, 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, choose Report Preferences before you choose a report.)

The Create Report Preferences dialog opens.

- 2 Click an icon to choose 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 If you choose Custom, click the Custom button and complete the Custom Report dialog (“[Defining Custom Reports](#)” on page 160). Otherwise, continue with step 4.
 - 4 Click the Options tab to set a location and format for the report (“[Setting Report Options](#)” on page 159).
(In Excel 2007, if you clicked the lower half of the Create Report icon, choose Report Preferences to set a location and format for the report before you choose a report.)
 - 5 When all settings are complete, click **OK**.

Crystal Ball creates the report as an Excel worksheet. You can modify, print, or save the report in the same way as any other worksheet. For example, you can choose the File, then Print option for your spreadsheet model as you would for a normal spreadsheet.

Note: If ### is displayed in your 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.

(In Excel 2007, if you clicked the lower half of the Create Report icon, choose Report Preferences to set a location and format for the report before you choose a report.)

- 2 In the Location group, choose whether to create the report in a new Excel workbook or the current workbook.

If you choose Current Workbook, a new sheet is created right after the current sheet. You can enter a descriptive name for the new sheet in the Sheet Name field.

- 3 In the Formatting group, indicate whether to include the cell location (workbook, worksheet, and cell address) in the rightmost column of report headers and whether to include cell comments.

By default, these settings are checked.

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, choose **Image** to create a Crystal Ball chart or choose **Excel** to create an Excel chart.

If you choose **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 Follow the steps in [“Basic Steps for Creating Reports” on page 158](#) to display the Create Report dialog.
- 2 Click the **Custom** button.
- 3 In the Custom Report dialog, check 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, OptQuest)** — Includes the selected type of chart(s) in the report. You can scale the size of the charts by entering a percentage in the field.

Note: Excel charts cannot be created for assumptions defined as custom distributions.

If you have activated the process capability features and have generated capability metrics, you can include them in your custom report ([“Including Capability Metrics in Reports” on page 392](#)).

- 4 As each item is highlighted in the **Report Sections** group, check 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
 - **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 Charts: Chart And Size
- Predictor Charts: Chart And Size

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 checked in Report Sections, choose whether to display all of that type of item, only selected items, or all open items. If you select Choose, a dialog opens so you can check the box in front of each item to display.
- 6 When these settings are complete, click OK to close the dialog and return to the Create Report dialog.
- 7 In the Create Report dialog, click the Options tab to display it (“Setting Report Options” on page 159).
- 8 When all the report options are set, click OK to close the dialog and create the report.

Report Processing Notes


The following are special notes concerning Crystal Ball reports:

- No section is created if there are no Crystal Ball items for that section.
- 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 an assumption has been truncated, you might 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 Choose Analyze, then Extract Data. 

The Extract Data dialog opens.

- 2 To select the type of data to extract, choose the appropriate setting in the Select Data To Extract list:
 - Statistics — Descriptive statistics summarizing the assumption and forecast values.

- Percentiles — The probability of achieving values below a particular threshold in the selected increments. **Note:** You can reverse the meaning of the percentiles by changing the setting in the Run Preferences, then Options panel (“[Setting Statistics Preferences](#)” on page 80).
- 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.
- Sensitivity Data — Sensitivity data (such as the rank correlation coefficient) for all pairs of assumptions and forecasts indicating the strength of the relationship. If you plan to extract sensitivity data, be sure to check Store Assumption Values For Sensitivity Analysis on the Options tab of the Run Preferences dialog (“[Setting Options Preferences](#)” on page 79). **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 391).

If you choose Percentiles or Chart Bins, a dialog opens so you can choose which percentiles or how many bins to use. Choose Custom and enter a set of custom percentiles if the set you need is not already available in the dialog.


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, Choose, or None):

- To include the selected data and restored results for all forecasts in the current simulation, choose All.
- To include the selected data for only selected forecasts or to include forecasts in selected restored results files, choose Choose.
- Choose None if you don’t want to extract any forecast data.

If you choose Choose, the Choose Forecasts dialog opens.

Only forecasts for which data was generated or restored are included in the list. Any restored results are displayed after current data and have file names with the .cbr extension.

By default, the Choose Forecasts dialog is in a hierarchical Tree view. You can click the List button at the top to change it to List view. 

4 In the Assumptions group, select assumptions for data extraction (All, Choose, or None):

- To include the selected data for all assumptions and restored results in the current simulation, choose All.
- To include the selected data for only selected assumptions or to include assumptions in selected restored results files, choose Choose.

The Choose Assumptions dialog opens so you can choose from list of available assumptions. It works similarly to the Choose Forecasts dialog, described previously. For more information on the Choose Assumptions dialog, click the Help button.

- Choose None if you don't want to extract any assumption data.

You can only extract data for calculated assumption values using the Extract Data command. To view statistics for theoretical data, display an assumption chart and then choose View, then Statistics.

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, choose New Workbook.
- To extract data to a new worksheet in the active workbook, choose Current Workbook, then New Sheet.
- To extract data to the current sheet, choose Current Workbook, 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 Check settings in the Formatting group to indicate how to format the extracted data:

- When checked, Include Labels adds row and column headers to the data table. Otherwise, just the numeric values are extracted.
- When checked, Include Cell Locations adds the workbook, worksheet, and cell address above the object name in the column header. Otherwise, only the object name is displayed.

	Book1	
	Sheet1!A2	Cell Location labels
Statistics	A2	
Trials	1000	
Mean	0.02	

- When checked, 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 to values
 - AutoFit width to columns

10 You can click the Defaults button at any time to restore the original settings to both tabs of the Extract Data dialog.

11 When both 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 164](#).

Data Extraction Examples

The previous section, “Extracting Data” on page 161, 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 checked (forecasts only).

Figure 52 A sample of extracted data, Statistics format

	A	B	C
1	Statistics	Ending Sales Year 3 - Q1	Ending Sales Year 3 - Q2
2	Trials	1000	1000
3	Mean	\$17,081,883	\$17,950,914
4	Median	\$17,042,665	\$17,930,927
5	Mode	---	---
6	Standard Deviation	\$1,117,986	\$1,297,577
7	Variance	\$1,249,891,924,272	\$1,683,706,187,431
8	Skewness	0.19	0.15
9	Kurtosis	3.22	3.19
10	Coeff. of Variability	0.07	0.07
11	Minimum	\$13,695,983	\$14,060,365
12	Maximum	\$21,289,239	\$22,981,379
13	Range Width	\$7,593,255	\$8,921,013
14	Mean Std. Error	\$35,354	\$41,033

Figure 53 A sample of extracted data, Percentiles format

	A	B	C
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 54 A sample of extracted data, Chart Bins format

	A	B	C
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 55 A sample of extracted data, Sensitivity Data format

	A	B	C
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 56 A sample of extracted data, Trial Values format

	A	B	C
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	4	\$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

In This Chapter

Introduction.....	167
Overview	167
Batch Fit Tool.....	169
Correlation Matrix Tool.....	177
Tornado Chart Tool.....	183
Bootstrap Tool.....	191
Decision Table Tool	199
Scenario Analysis Tool.....	205
2D Simulation Tool	210
Data Analysis Tool	219

Introduction

This chapter describes the Crystal Ball tools. For each tool, there is a general description, a tutorial, and references to descriptions of all panels, fields, and options.

In addition, see [“Numerical Differences and the Compare Run Modes Tool”](#) on page 318 for information about the Compare Run Modes tool, used to determine how much faster your model could run with Extreme Speed, if you have Crystal Ball Decision Optimizer.

Overview

Crystal Ball tools are features in the Run, then More Tools menu that extend the functionality of Crystal Ball. They cover two aspects of Crystal Ball modeling plus integration with other Oracle products:

- [“Setup Tools”](#) on page 168
- [“Analysis Tools”](#) on page 168
- [“Integration Tools”](#) on page 168

This chapter describes each tool and provides a step-by-step example for using it.

Note: Some of the tools can take a long time to run. Should you need to cancel a tool before it stops by itself, click in the Excel window and hit Esc. A panel opens and you can choose to End or Continue.

Setup Tools

The following are Crystal Ball setup tools, described in the referenced sections:

- [“Batch Fit Tool” on page 169](#) — Automatically fits selected probability distributions to multiple data series.
- [“Correlation Matrix Tool” on page 177](#) — Rapidly defines and automates correlations of assumptions.
- [“Tornado Chart Tool” on page 183](#) — Individually analyzes the impact of each model variable on a target outcome.

Analysis Tools

The following are Crystal Ball analysis tools, described in the referenced sections:

- [“Bootstrap Tool” on page 191](#) — Addresses the reliability and accuracy of forecast statistics.
- [“Decision Table Tool” on page 199](#) — Evaluates the effects of alternate decisions in a simulation model.
- [“Scenario Analysis Tool” on page 205](#) — Displays what inputs created particular outputs.
- [“2D Simulation Tool” on page 210](#) — Independently addresses uncertainty and variability using a two-dimensional simulation.
- [“Data Analysis Tool” on page 219](#) — Imports one or more series of raw data and performs a variety of analyses on them.

Integration Tools

The integration tools, available with Crystal Ball EPM, enable you to run Crystal Ball simulations against Oracle Hyperion Strategic Finance, Fusion Edition and other Oracle Enterprise Performance Management products such as Oracle Essbase working through Oracle Hyperion Smart View for Office, Fusion Edition. For information about the Crystal Ball Decision Optimizer Strategic Finance and Enterprise Performance Management integration tools, see the *Oracle Crystal Ball Enterprise Performance Management, Fusion Edition Integration Guide*.

Tools and Run Preferences

For consistency from one run to the other, it can be helpful to choose Latin Hypercube sampling on the Sampling tab of the Run Preferences dialog. You can also choose to use the same sequence of random numbers with a specific random seed value. The default is 999.

Note: If you do not set a random seed value before running one of the Crystal Ball tools, Crystal Ball will set a value for you and will notify you of this when you run a tool.

Batch Fit Tool

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 your 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 your 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, your 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 your data series.

Using the Batch Fit Tool

To use the Batch Fit tool, you start it and then use the wizard panels to define inputs and outputs, set options, and run the tool.

Topics in this section include:

- [“Starting the Batch Fit Tool” on page 169](#)
- [“Using the Batch Fit Welcome Panel” on page 170](#)
- [“Setting Batch Fit Input Data Options” on page 170](#)
- [“Setting Batch Fit Fitting Options” on page 170](#)
- [“Setting Batch Fit Output Options” on page 171](#)

Also see [“Batch Fit Example” on page 172](#).

Starting the Batch Fit Tool

➤ To start the Batch Fit tool:

- 1 In 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, 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 chooses possible data for fitting. This information is displayed in the Location Of Data Series field and the illustration at the right side of the panel. You can choose different data if necessary. The fields and options in this panel are:

- Location Of Data Series — Used to enter or interactively select the cells that contain data to fit. If your data has headers or labels at the beginning of the rows or columns of data, include them in your selection and select the appropriate Headers setting(s). The data must be in adjacent rows or columns.
- Orientation — Indicates whether your 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 your data has headers and/or labels and whether they are located in the top row or the left header (varies with orientation). Checked items are used in the output. Top Row Has Headers/Labels, when checked, includes text in the top row in your selection. Left Column Has Labels/Headers, when checked, includes text in the left column in your selection.
- Back — Returns to the Welcome panel.
- Next — Advances to the Fitting Options panel.
- Run — Runs the tool, automatically fitting distributions to your 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 chooses 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 chooses 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.
 - 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.
 - Kolmogorov-Smirnov — Finds the largest vertical distance between the two cumulative distributions.
 - Lock Parameters — When you check this box or click the Ellipsis (...) button, opens the Lock Parameters dialog, where you can choose parameters to lock during fitting and specify their values.

Note: If you know location, shape, or other parameter values that might help create a more accurate fit with certain distributions, check Lock Parameters and enter appropriate values in the Lock Parameters dialog. For details, see [“Locking Parameters When Fitting Distributions”](#) on page 47.
 - Back — Returns to the Input Data panel.
 - Next — Opens the Output Options panel.
 - Run — Runs the tool, automatically fitting distributions to your 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 (Assumptions), Locations — Specifies locations of results:
 - New Workbook — Places results in a new workbook.

- Current Workbook — Places results in the current workbook. You can choose New Sheet, which places results in a new sheet of the current workbook, or Current Sheet, which places results in an existing sheet of the current workbook; you can specify the left corner of the output range (results are displayed to the right and downward from that cell).
- Fit Results (Assumptions), Format Output — When checked, uses special cell formatting for your data in your output.
- Correlations — Specifies whether correlations are generated and defined:
 - Show Correlation Matrix Between Data Series — When checked, 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 checked, 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 checked, changes correlations between assumptions if a new matrix is generated.
- Reports — Indicates which reports to generate and their sheet names:
 - Create Goodness-Of-Fit Report — When checked, creates a goodness-of-fit report on a separate worksheet with the specified name.
 - Show All Goodness-of-Fit Statistics — When checked, shows all goodness-of-fit statistics, not just the chosen type.
 - Create Assumptions Report — When checked creates an assumptions report for all assumptions created by Batch Fit on a separate worksheet with the specified name.
 - Full Statistics — When checked, the assumptions report includes values for all statistics and percentiles (deciles) for each assumption.
- Back — Returns to the Fitting Options panel.
- Run — Runs the tool, automatically fitting distributions to your data and creating output of the assumptions and statistics.

➤ When all Output Options settings are complete, click Run to run the Batch Fit tool.

Batch Fit Example

In the Crystal Ball Examples folder, there is a Magazine Sales.xls spreadsheet you can use to experiment with the Batch Fit tool. This spreadsheet model (Figure 57) shows the estimated gross profit resulting from newsstand sales of four of the company's most popular magazines.

Figure 57 Magazine Sales Workbook

	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 of 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 you replaced these formulas with assumptions based on historical data. To do this, you can use the Batch Fit tool to generate an assumption for each data column of the Sales Data worksheet. Then, you can use Crystal Ball commands to copy and paste those assumptions from the Batch Fit data to the first data row of the Magazine Sales model. Because Crystal Ball cannot define assumptions in formula cells, you need to convert the formulas in C5 to F5 to values before pasting the assumption cells.

Example topics include:

- [“Generating Batch Fit Results” on page 173](#)
- [“Using Batch Fit Results in a Model” on page 175](#)
- [“Interpreting Batch Fit Results” on page 176](#)

Generating Batch Fit Results

► To work through the Batch Fit example:

- 1 In Excel with Crystal Ball loaded, open the example workbook Magazine Sales.xls.
- 2 Start the tool; select **Run**, then **More Tools**, then **Batch Fit**. (In Microsoft Excel 2007, select **More Tools** in the **Tools** group.)

If this is the first time you have opened the Batch Fit tool, the Welcome panel opens.

- 3 If the Welcome panel opens, click **Next** to display the Input Data panel.

On the Input Data panel, the Batch Fit data selector attempts to select relevant data and indicate its orientation. In this case, you need to select data on another worksheet.

- 4 On the Input Data panel, click the **Select Cells** icon to the right of the Location Of Data Series field.
- 5 Select the **Sales Data** worksheet.
- 6 Select cells **A1** through **D361**.
- 7 Click **OK** to return to the Batch Fit panel.
- 8 Select **Data In Columns**, the default.

9 Check the **Top Row Has Headers** setting.

10 Click **Next**.

The Fitting Options panel opens.

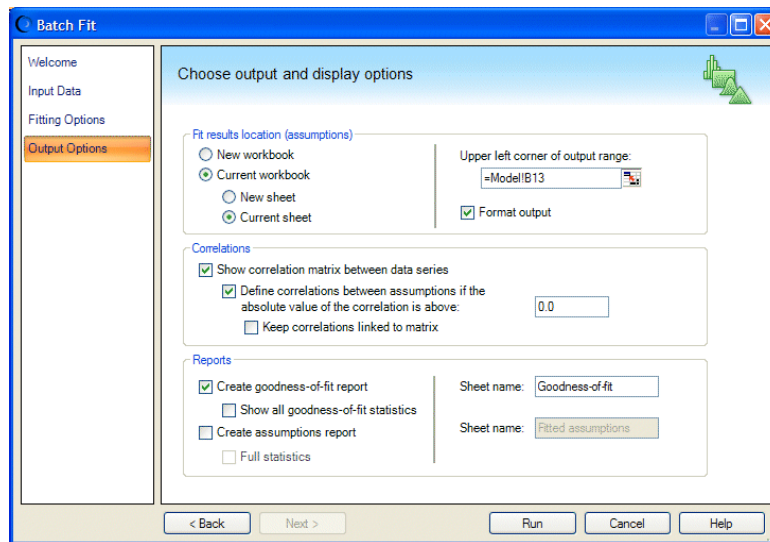
11 In the Fitting Options panel, choose **All Continuous** in the **Distributions To Fit** group.

12 Choose **Anderson-Darling** in the **Rank By Goodness-of-Fit Statistic** group.

13 Click **Next**.

The Output Options panel opens, similar to [Figure 58](#) but with different settings.

Figure 58 Output Options panel, Batch Fit tool



14 For **Fit Results**, choose **Current Workbook** and then choose **Current Worksheet**.

15 Click the **Select Cells** icon to the right of the **Upper Left Corner Of Output Range** box.

16 Select cell **B13** on the **Model** worksheet.

17 Click **OK** to return to the **Batch Fit** panel.

18 Make sure the **Format Output** box is checked.

19 Include a correlation analysis of the data:

a. Check "Show correlation matrix between data series."

b. Check "Define correlations between assumptions..." For now, leave 0.0 in the box to display all correlations.

The threshold must be between 0 and 1 (inclusive). The tool displays the correlation matrix at the end of the results section.

c. For now, do not check "Keep correlations linked to matrix."

20 Check the **Create Goodness-Of-Fit Report** but for now, do not check **Create Assumptions Report**.

Use the default **Sheet Name** setting.

Your settings should look like those in [Figure 58](#).

21 Click Run.

The tool fits each selected distribution to each data series. The Batch Fit results are displayed on the Model worksheet below the existing table, similar to [Figure 59](#).

Figure 59 Batch Fit Results Below the Model

	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 of Goods	\$2.20	\$3.80	\$1.95	\$2.40
Gross Profit	\$1,546	\$1,502	\$1,292	\$1,805
Total Gross Profit:	\$6,144			
Data Series:	Sales Volume A	Sales Volume B	Sales Volume C	Sales Volume D
Distribution:	498.96	354.37	639.2	480.71
Best Fit:	Max Extreme	Triangular	Beta	Gamma
Anderson-Darling:	0.0824	0.2129	0.4141	0.0893
P-Value:	0.989	---	---	0.997
Correlations:	Sales Volume A	Sales Volume B	Sales Volume C	Sales Volume D
	1.0000	0.0166	-0.0128	-0.0124
	0.0166	1.0000	-0.0059	0.0607
	-0.0128	-0.0059	1.0000	-0.0392
	-0.0124	0.0607	-0.0392	1.0000

Using Batch Fit Results in a Model

Now that assumptions have been generated from historic sales data, the next steps are to convert Sales Volume formulas to values and replace them with the new assumptions. Then, you can run a simulation with more accurate results.

- ▶ To use Batch Fit results in a model:
 - 1 Select the formulas in cells C5 through F5.
 - 2 Use Excel's Copy and Paste Special commands to copy the formula cells and paste them back into the same locations. When the Paste Special dialog opens, choose Values as the Paste setting. Leave the other default settings and click OK.
 - 3 Copy assumption data into the worksheet.
 - a. Select cells C14 through F14.
 - b. Select Define, then Copy Data.

Notice this is Crystal Ball's Copy Data command, not Excel's Copy command.
This function copies Crystal Ball data only, not the cell value.
 - c. Select cells C5 through F5.
 - d. Select Define, then Paste Data.

The assumptions copy to the first row of the table, leaving the current values.

- e. Select cells C14 through F14.
- f. Select Define, then Clear Data.

This deletes the original assumptions generated by Batch Fit to eliminate redundant assumptions and speed up the simulation, as shown in [Figure 60](#).

Figure 60 Crystal Ball Assumptions in Cells C5 through F5

	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 of Goods	\$2.20	\$3.80	\$1.95	\$2.40
Gross Profit	\$1,546	\$1,502	\$1,292	\$1,805
Total Gross Profit:	\$6,144			

	Sales Volume A	Sales Volume B	Sales Volume C	Sales Volume D
Data Series:	498.96	354.37	639.2	480.71
Distribution:	Max Extreme	Triangular	Beta	Gamma
Best Fit:	0.0824	0.2129	0.4141	0.0893
Anderson-Darling:	0.989	---	---	0.997
P-Value:				

	Sales Volume A	Sales Volume B	Sales Volume C	Sales Volume D
Correlations:				
Sales Volume A	1.0000	0.0166	-0.0128	-0.0124
Sales Volume B	0.0166	1.0000	-0.0059	0.0607
Sales Volume C	-0.0128	-0.0059	1.0000	-0.0392
Sales Volume D	-0.0124	0.0607	-0.0392	1.0000

4 In the Run, then Run Preferences, then Sampling dialog:

- Set Random Number Generation to use the Same Sequence Of Random Numbers and a seed value of 999.
- Select Monte Carlo simulation.

When using this tool, use these options to make the resulting simulations comparable.

5 In the Run, then Run Preferences, then Trials dialog, set the Number Of Trials To Run to 500.

6 Click OK.

7 Select Run, then Start Simulation.

The simulation runs until it stops.

Interpreting Batch Fit Results

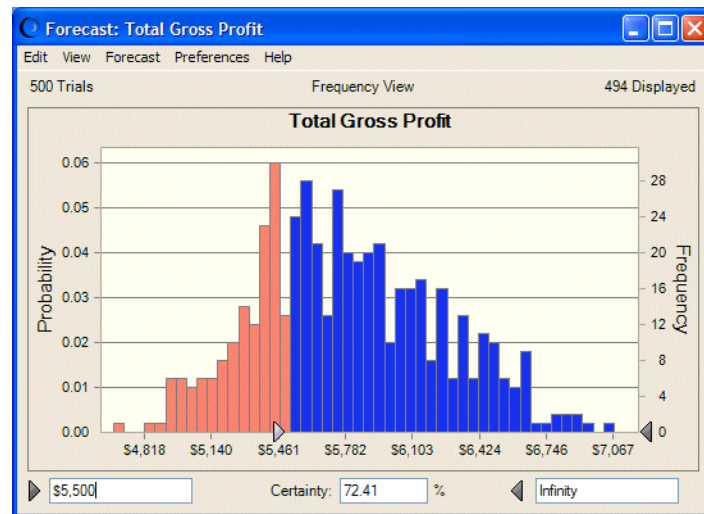
In this example, you had historical data with no trend or seasonality for all your variables.

If your historical data have a time-series element, trend, or seasonality, you should use Predictor instead of the distribution fitting functionality.

When the Batch Fit 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 your model.

In this example, the four columns of data resulted in four assumptions that you copied and pasted to the appropriate locations. The forecast is already defined for you, and running a 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 almost 75% (Figure 61).

Figure 61 Magazine Sales profit from newsstand sales



Correlation Matrix Tool

The following sections describe the Correlation Matrix tool and its use:

- “About Correlations” on page 177
- “About the Correlation Matrix Tool” on page 178
- “Using the Correlation Matrix Tool” on page 178
- “Correlation Matrix Example” on page 180

About Correlations

When the values of two variables depend on each other in any way, you should correlate them to increase the accuracy of your simulation's forecast results.

There are two types of correlations:

- Positive correlation — Indicates that two assumptions increase or decrease together. For example, the price of gasoline and shipping costs increase and decrease together.

- Negative correlation — Indicates that an increase in one assumption results in a decrease in the other assumption. For example, the more items you buy from a particular vendor, the lower the unit cost.

The correlation coefficient range is -1 to 1, where 0 indicates no correlation. The closer the coefficient is to ± 1 , the stronger the relationship between the assumptions. You should never use a coefficient of ± 1 ; represent relationships this closely correlated with formulas in the spreadsheet model.

About the Correlation Matrix Tool

In Crystal Ball, you usually enter correlations one at a time using the Correlation dialog. Instead of manually entering the correlations this way, you can use the Correlation Matrix tool to define a matrix of correlations between assumptions in one simple step. This saves time and effort when building your spreadsheet model, especially for models with many correlated assumptions.

The correlation matrix is either an upper or lower triangular matrix with 1s along the diagonal. When entering coefficients, think of the matrix as a multiplication table. 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 correlation coefficient. The matrix contains only the correlation coefficients you enter.

Figure 62 Correlation Matrix

	Assumption 1	Assumption 2	Assumption 3
Assumption 1	1.000		
Assumption 2		1.000	
Assumption 3			1.000

If you enter inconsistent correlations, Crystal Ball tries to adjust the correlations so they don't conflict. For more information on inconsistent correlations, see [“Specifying Correlations Between Assumptions”](#) on page 47.

Using the Correlation Matrix Tool

To use the Correlation Matrix tool, start it and then use the wizard panels to choose assumption, set options, and run the tool.

This section has the following topics:

- [“Starting the Correlation Matrix Tool”](#) on page 179
- [“Selecting Assumptions to Correlate”](#) on page 179
- [“Setting Correlation Matrix Location and Orientation Options”](#) on page 179
- [“Running the Correlation Matrix Tool”](#) on page 180

Also see [“Correlation Matrix Example”](#) on page 180.

Starting the Correlation Matrix Tool

- ▶ To start the Correlation Matrix tool, select **Run**, then **More Tools**, then **Correlation Matrix**. (In Microsoft Excel 2007, select **More Tools** in the **Tools** group.)

The Select Assumptions panel opens.

Selecting Assumptions to Correlate

The Select Assumptions panel of the Correlation Matrix tool indicates which assumptions are to be correlated. The settings in this panel include:

- **Available Assumptions** — Lists all the assumptions defined in the active workbook. To move an assumption into the Selected Assumptions list, either double-click an assumption or select an assumption and click, then >. You can also make an extended selection using the Shift or Ctrl keys.

By default, no assumptions are in this list.

- **Top** — Moves one or more selected assumptions in the Selected Assumptions list to the top of the list.
- **Bottom** — Moves one or more selected assumptions in the Selected Assumptions list to the bottom of the list.
- **Up** — Moves one or more selected assumptions in the Selected Assumptions list up one position.
- **Down** — Moves one or more selected assumptions in the Selected Assumptions list down one position.
- **Next** — Opens the Specify Options panel for defining correlation matrix options.

Setting Correlation Matrix Location and Orientation Options

The Specify Options panel of the Correlation Matrix tool sets two kinds of options, described in these sections:

- [“Location of Matrix Options” on page 179](#)
- [“Orientation Options” on page 180](#)

This panel also has the following buttons:

- **Back** — Returns you to the Select Assumptions panel.
- **Start** — Creates the correlation matrix according to the options you specify.

Location of Matrix Options

The Location Of Matrix options indicate whether to create the correlation matrix on the active worksheet or on a new worksheet. Available options include:

- **Create A Temporary Correlation Matrix On A New Worksheet** — Creates the matrix on a new worksheet. Use this option if you do not want to permanently alter your spreadsheet.

After filling in the matrix, click Load The Matrix to enter the coefficients into the model. This is the default matrix location.

- Create And Link To A Correlation Matrix On The Active Worksheet — Creates the matrix on the active worksheet and links it with cell references, so if you change the cells, the correlations update automatically. Select this option to embed the correlation matrix in your model. If you select this option, you must indicate where to put the matrix in the model using the Specify Upper Left Corner option.
- Specify Upper Left Corner — Enables you to select the origin cell for the top left corner of the matrix by either entering the cell reference in the field or clicking on the cell in your worksheet. This option is only available if you create the matrix on the active worksheet.
- Format Matrix — Adds borders and headings, and changes column widths to make the correlation matrix more readable. This option is only available if you create the matrix on the active worksheet. This option is selected by default.

Orientation Options

The Orientation options indicate whether to make the correlation matrix an upper triangular or a lower triangular matrix.

- Upper Triangular Matrix — Creates the matrix with cells to fill in above the diagonal. This is the default.
- Lower Triangular Matrix Creates the matrix with cells to fill in below the diagonal.

Running the Correlation Matrix Tool

- To run the Correlation Matrix tool when all settings are complete, click **Start**.

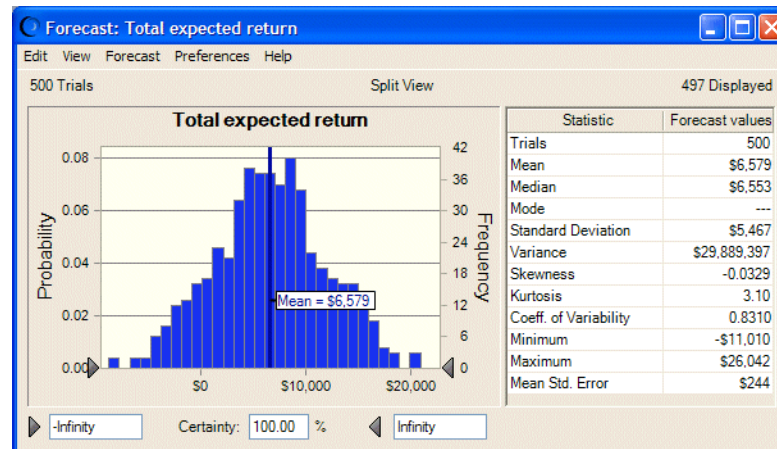
Correlation Matrix Example

In the Crystal Ball Examples folder, there is a Portfolio Allocation.xls workbook you can use to experiment with the Correlation Matrix tool. This spreadsheet calculates the total expected return for an investment model. In this example, you will run a simulation without correlations and then add the correlations and rerun the simulation for comparison.

- To start the Correlation Matrix tool:
 - 1 In Excel with Crystal Ball loaded, open the workbook Portfolio Allocation.xls.
 - 2 Set the following options in the **Run**, then **Run Preferences** dialog:
 - On the Trials tab, set Maximum Number Of Trials to 500.
 - On the Sampling tab, set Random Number Generation to Use Same Sequence Of Random Numbers and set an Initial Seed Value of 999.
 - Also on the Sampling tab, set Sampling Method to Monte Carlo.
 - 3 Run a simulation by selecting **Run**, then **Start Simulation**.

Choose View, then Statistics in the forecast chart. The forecast statistics for the simulation are similar to those shown in Figure 63, following.



Figure 63 Uncorrelated Simulation Statistics



- 4 Choose Run, then Reset to reset the simulation.
- 5 Select Run, then More Tools, then Correlation Matrix. (In Microsoft Excel 2007, select **More Tools** in the **Tools** group.)

The Select Assumptions panel opens.

- 6 Include all the assumptions in the correlation matrix by moving all the assumptions from the Available Assumptions list to the Selected Assumptions list using one of these alternatives:

- Double-click each assumption to move.
- Select each assumption to move and click the  to move it.
- Make an extended selection using the Shift or Ctrl keys and then click .

- 7 Click **Next**.

The Specify Options panel opens.

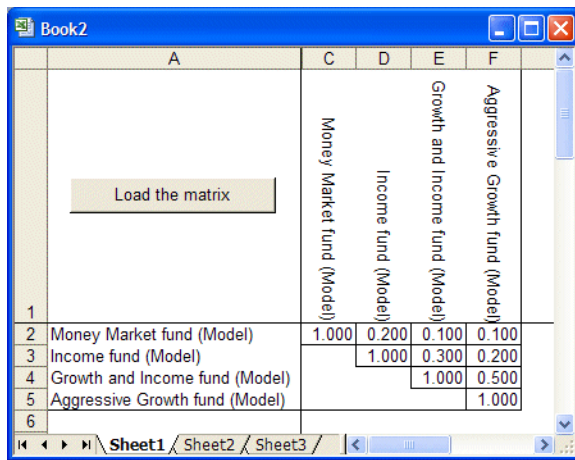
- 8 Select the following settings:

- Create A Temporary Correlation Matrix On A New Worksheet
- Upper Triangular Matrix

- 9 Click **Start**.

The tool creates a temporary matrix in a new workbook.

- 10 Enter the following correlation coefficients into the matrix.



Leaving a cell blank is not the same as entering a zero. Values that are not specified in the matrix will be filled in with estimates of appropriate values when the simulation runs.

11 Click Load The Matrix.

The tool loads the correlation coefficients from the matrix into your Crystal Ball model. Loading a full correlation matrix for all assumptions can take several minutes or even longer.

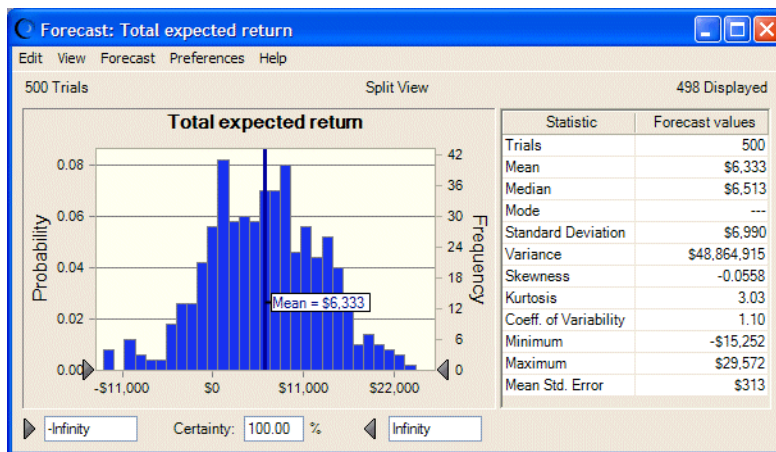
If a Matrix Successfully Loaded message is not displayed, press Tab or Return to exit the current cell and then click Load The Matrix again.

12 Reset the simulation.

13 Rerun the simulation.

The forecast statistics for the correlated simulation are shown in [Figure 64](#).

Figure 64 Correlated Simulation Statistics



The standard deviation is now much higher than the original simulation due to the correlations. The original model without the correlations ignored this risk factor and its effects.

Tornado Chart Tool

The Tornado Chart 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 183](#)
- [“Spider Chart” on page 185](#)

This method differs from the correlation-based sensitivity method built into Crystal Ball because this tool tests each assumption, decision variable, precedent, or 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 Chart tool is useful for:

- Measuring the sensitivity of variables that you have defined in Crystal Ball.
- Quickly pre-screening the variables in your 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. See for more information on precedents.

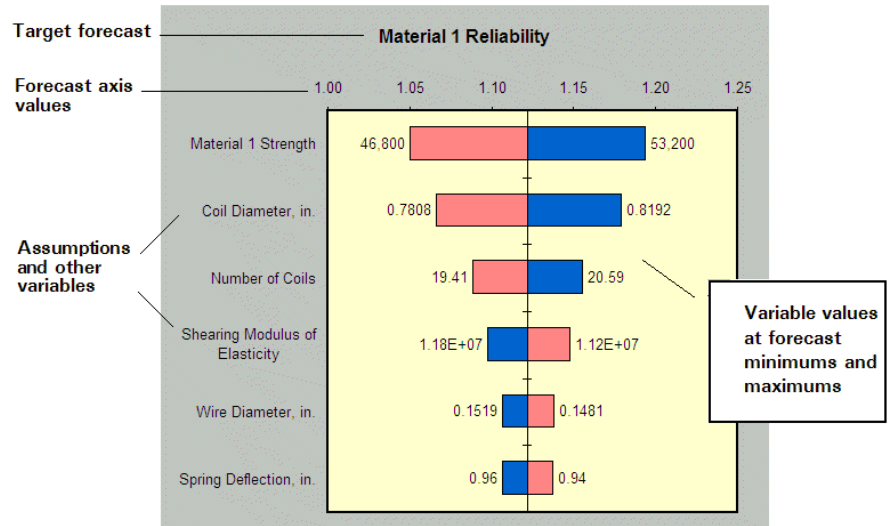
The following sections describe how to create and use tornado charts and spider charts:

- [“Using the Tornado Chart Tool” on page 185](#)
- [“Tornado Chart Example” on page 188](#)
- [“Limitations of the Tornado Chart Tool” on page 191](#)

Tornado Chart

The Tornado Chart 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 65](#)) 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.

Figure 65 Tornado Chart

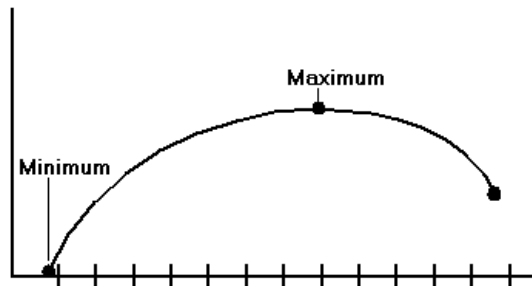


The bars next to each variable represent the forecast value range across the variable tested, as discussed above. Next to the bars are the values of the variables that produced the greatest swing in the forecast values. The bar colors indicate the direction of the relationship between the variables and 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 66).

Figure 66 A non-monotonic variable

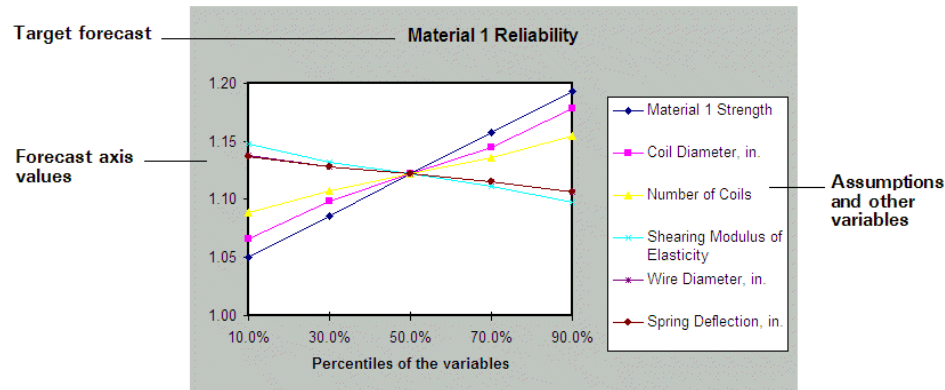


If one or more variables are non-monotonic, all the variable bars are the same color all the way across.

Spider Chart

The spider chart (Figure 67) 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 slopes of the lines also indicate whether a positive change in the variable has a positive or negative effect on the forecast.

Figure 67 Spider chart



A maximum of 250 variables can be displayed in these charts.

Using the Tornado Chart Tool

To use the Tornado Chart tool, start it, specify a target to analyze, specify input variables, set options, and run it as described in the following topics:

- “Starting the Tornado Chart Tool” on page 185
- “Specifying a Tornado Chart Analysis Target” on page 186
- “Specifying Tornado Chart Input Variables” on page 186
- “Specifying Tornado Chart Options” on page 187
- “Running the Tornado Chart Tool” on page 188

Also see “Tornado Chart Example” on page 188.

Starting the Tornado Chart Tool

- To start the Tornado Chart tool, select **Run, More Tools**, and then select **Tornado Chart**. (In Microsoft Excel 2007, select **More Tools** in the **Tools** group.)

The Specify Target panel opens.

Specifying a Tornado Chart Analysis Target

The Specify Target panel in the Tornado Chart tool indicates which forecast or formula cell to analyze. The Specify Target panel contains the following settings:

- 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 Enter Target Cell field. The first forecast is selected by default.
- Enter Target Cell — Describes the cell location of the selected forecast or formula. If you select a forecast from the list above, the cell information is automatically displayed in this field. You can use this field to select a formula cell instead of a forecast.
- Next — Opens the Specify Input Variables panel.

When settings are complete, click Next to open the Specify Input Variables panel.

Specifying Tornado Chart Input Variables

The Specify Input Variables panel of the Tornado Chart tool specifies the assumptions, decision variables, and precedents to include in the tornado and spider charts. You can include any value cell in your 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 the active spreadsheet that are referenced as part of the formula or a sub-formula of the target cell. Precedents for this tool are handled differently than standard Excel precedents in that they cannot trace beyond the active spreadsheet. Therefore, you can only use precedents on the active spreadsheet as input variables.

The Specify 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 — Lets you 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. You must click OK to accept the selected range.
- Remove — This button 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 Specify Target panel.
- Next — Opens the Specify Options panel.

When settings are complete, click Next to open the Specify Options panel.

Specifying Tornado Chart Options

The Specify Options panel of the Tornado Chart 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 187](#)
- [“Tornado Input Options” on page 187](#)
- [“Tornado Output Options” on page 187](#)

Other controls are:

- Back — Returns to the Specify Input Variables panel.
- Start — Starts the tool, generating the tornado and spider charts.

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.
- Percentage Deviations From The Base Case — 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 decision variables as continuous for this second method.

Tornado Input Options

The Tornado Input options include:

- Testing 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 Percentage Deviations From The Base Case). The default is 10% to 90% percentiles or -10% to 10% deviation.
- Testing Points — Defines how many values to test in the testing range. The testing points are evenly distributed across the testing range. Testing more points than just end points detects non-monotonic variable relationships. The default is five testing points.
- For Base Case Specifies whether to define the base case as either the existing cell values or the median values of the variables. If the tornado is based on a percentage deviation, only the cell values option is available. The default is the median cell values.

Tornado Output Options

The Tornado Output options are:

- Tornado Chart — Generates a tornado chart showing the sensitivity of the variables using range bars.
- Spider Chart — Generates a spider chart showing the sensitivity of the variables using sloping curves.
- Show Top Variables — Indicates how many variables to include in the tornado charts if there are a lot of variables. The charts can only clearly show about 20 variables.

Running the Tornado Chart Tool

- When all settings are complete, click Start to run the Tornado Chart tool and generate selected charts.

Tornado Chart Example

In the Crystal Ball Examples folder, there is a Reliability.xls workbook you can use to experiment with the Tornado Chart tool. This spreadsheet model predicts the reliability of a spring using three different construction materials. This section includes the following example topics:

- [“Generating Tornado and Spider Charts” on page 188](#)
- [“Interpreting Tornado and Spider Chart Results” on page 190](#)

Generating Tornado and Spider Charts

- To run the Tornado Chart tool:

- 1 In Excel with Crystal Ball loaded, open the workbook Reliability.xls.

If you have any other spreadsheets open, close them first, because the tool gathers all Crystal Ball definitions from all open workbooks.

- 2 Select **Run**, then **More Tools**, then **Tornado Chart**. (In Microsoft Excel 2007, select **More Tools** in the **Tools** group.)

The Specify Target panel opens. All of the forecasts from Reliability.xls are displayed in the list.

- 3 Select the **"Material 1 Reliability"** forecast.

- 4 Click **Next**.

The Specify Input Variables panel opens.

You can include any value cell in your tornado chart calculations, using cell names if available. However, the cells are usually defined as one of the following types:

- Assumptions — Cells defined as assumptions in Crystal Ball. For more information about assumptions, see [“About Assumptions and Probability Distributions” on page 38](#).
- Decision variables — Cells defined as decision variables in Crystal Ball. For more information about defining decision variables, see [“Defining Decision Variable Cells” on page 63](#).

- Precedents — All cells within the active worksheet that are referenced as part of the formula or a sub-formula of the target cell. Precedents for this tool are handled differently than standard Excel precedents in that they cannot trace beyond the active worksheet. Therefore, you can only use precedents on the active worksheet as input variables.

5 Click Add Assumptions.

Available assumptions are displayed in the panel.

6 Remove Material 2 Strength and Material 3 Strength.

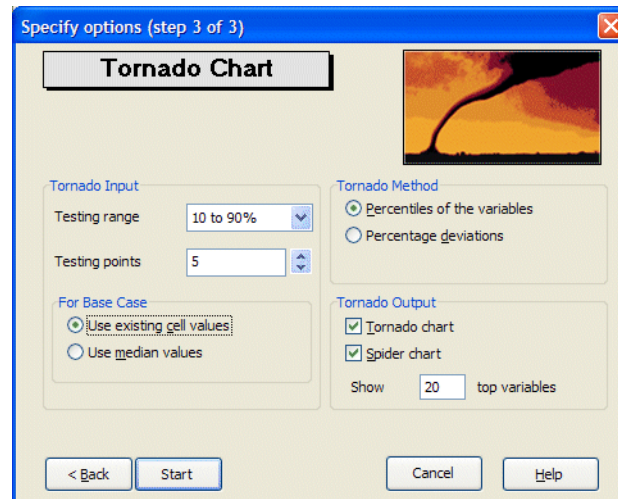
- Select an assumption to remove.
- Click **Remove**.
- Repeat steps 6a and 6b for the second assumption to remove.

The last two assumptions have no impact on the target forecast. If you leave them in the list, they will be displayed in the charts even though they are unrelated to the target forecast.

7 Click Next.

The Specify Options panel opens, similar to [Figure 68](#).

Figure 68 Specify Options panel, Tornado Chart tool



8 Set the following options as shown in [Figure 68](#):

- Testing Range = 10% to 90%.
- Testing Points = 5.
- For Base Case = Use Existing Cell Values.
- Tornado Method = Percentiles Of The Variables.
- Tornado Output = Tornado Chart and Spider Chart.
- Show __ Top Variables = 20.

9 Click Start.

The tool creates the tornado and spider charts in their own workbooks with data tables as shown in [Figure 69](#) and [Figure 70](#).

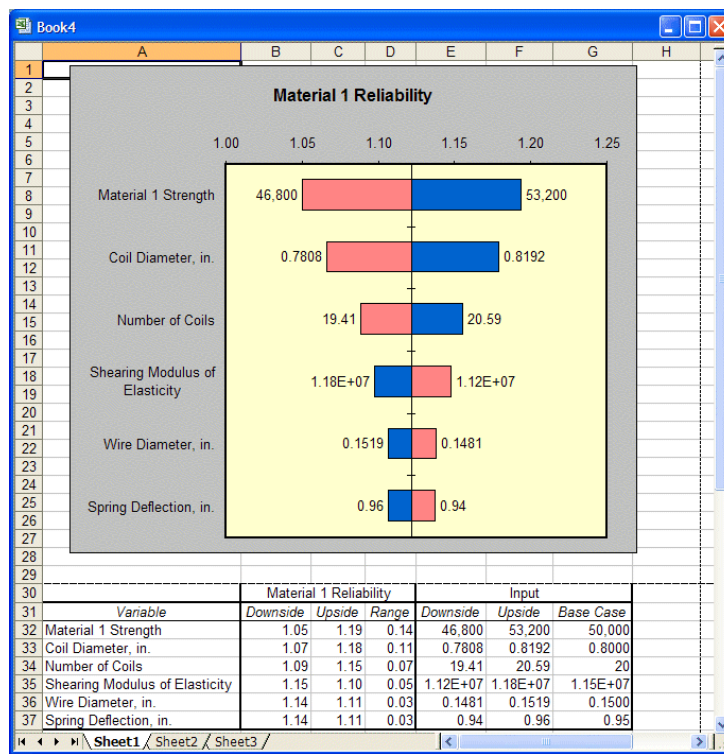
For more information about the Tornado Chart panels, click Help in a panel.

Interpreting Tornado and Spider Chart Results

In this example, six assumptions are listed in the tornado chart (Figure 69). 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.

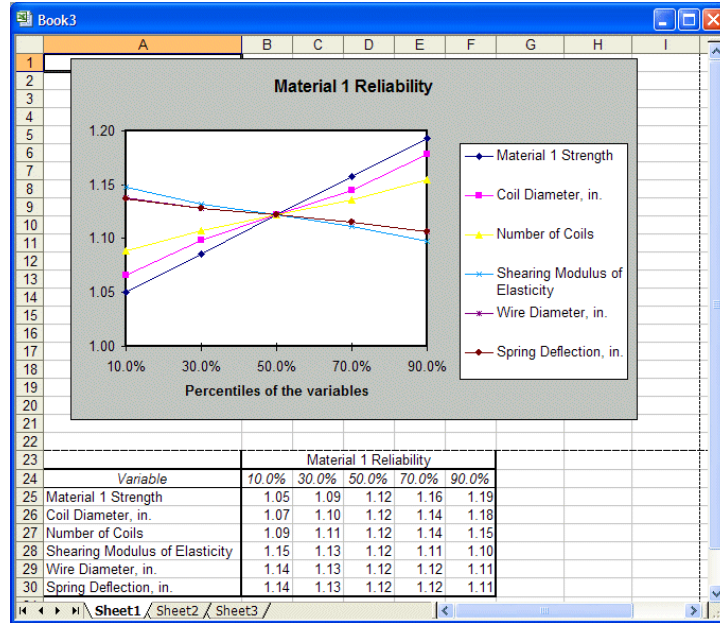
The last two assumptions, Wire Diameter and Spring Deflection, are the least influential assumptions. Since their effects on the Material 1 Reliability are very small, you might ignore their uncertainty or eliminate them from the spreadsheet.

Figure 69 Tornado Chart with Data



The spider chart shows similar information (Figure 70). Material 1, at the top of the tornado chart, has the steepest positive slope in the spider chart. Notice that more reliability values are given, one for each of five levels within the testing range.

Figure 70 Spider chart with Data



Limitations of the Tornado Chart Tool

While tornado and spider charts are useful, there are 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.

Bootstrap Tool

Bootstrap 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. These methods assume that the distribution of a sample statistic approaches a normal distribution, making the calculation of the statistic's standard error or confidence interval relatively easy. However, when a statistic's sampling distribution is not normally distributed or easily found, these classical methods are difficult to use or are invalid.

In contrast, bootstrapping analyzes sample statistics empirically by repeatedly sampling the data and creating distributions of the different statistics from each sampling. The term bootstrap

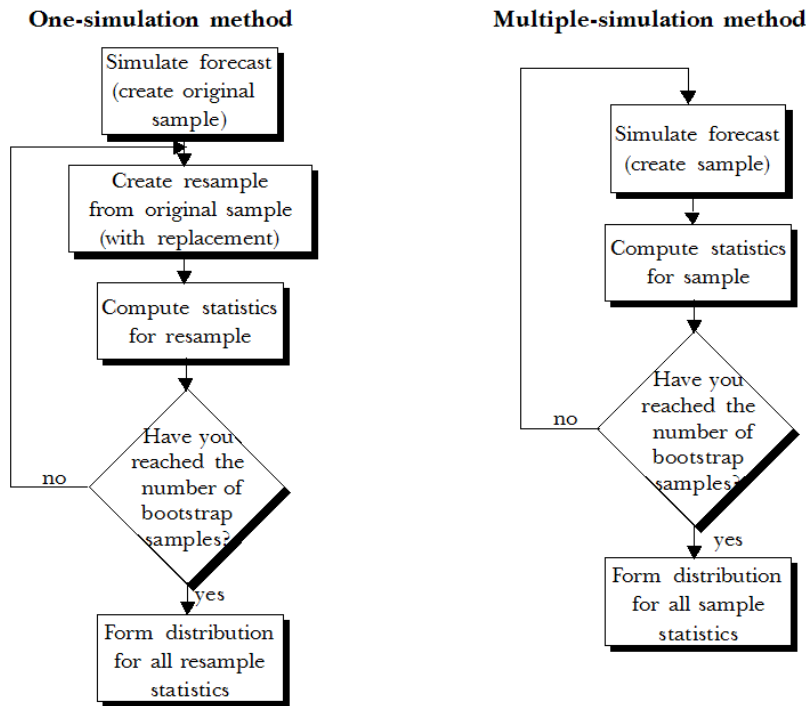
comes from the saying, "to pull oneself up by one's own bootstraps," since this method uses the distribution of statistics itself to analyze the statistics' accuracy.

There are two bootstrap methods 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 might 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 multi-simulation method is also called the parametric bootstrap.

Figure 71 Bootstrap simulation methods



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.

The following sections describe how to use the Bootstrap tool:

- [“Using the Bootstrap Tool” on page 193](#)
- [“Bootstrap Example” on page 195](#)

Using the Bootstrap Tool

To use the Bootstrap tool, you start it, define a target forecast or formula cell, choose a bootstrap method, set options, and then run the tool. The following sections describe these steps:

- [“Starting the Bootstrap Tool” on page 193](#)
- [“Using the Bootstrap Welcome Panel” on page 193](#)
- [“Specifying Forecasts to Analyze with the Bootstrap Tool” on page 194](#)
- [“Specifying a Bootstrap Tool Method” on page 194](#)
- [“Setting Bootstrap Options” on page 195](#)
- [“Running the Bootstrap Tool” on page 195](#)

Also see [“Bootstrap Example” on page 195](#).

Starting the Bootstrap Tool

- To start the Bootstrap tool, select **Run**, then **More Tools**, and then **Bootstrap**. (In Microsoft Excel 2007, 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 field. 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 field. You can use this field to select a formula cell instead of a forecast. If you choose 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.

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 [“Bootstrap Tool” on page 191](#). 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 field (between 0 and 100, exclusive) separated by commas.
- Back — Returns to 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** — Returns to 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 [“Interpreting Bootstrap Results” on page 197](#).

Bootstrap Example

In the Crystal Ball Examples folder, there is a Futura Apartments.xls workbook you can use to experiment with the Bootstrap tool. This spreadsheet model forecasts the profit and loss for an apartment complex.

The Bootstrap example includes the following sections:

- [“Generating Bootstrap Results” on page 195](#)
- [“Interpreting Bootstrap Results” on page 197](#)

Generating Bootstrap Results

- To start the Bootstrap tool:
 - 1 In Excel with Crystal Ball loaded, open the workbook Futura Apartments.xls.
 - 2 Select **Run**, then **More Tools**, then **Bootstrap**. (In Microsoft Excel 2007, select **More Tools** in the **Tools** group.)

The first time you run the Bootstrap tool, the Welcome panel opens.
 - 3 If the Welcome panel opens, click **Next**.

The Target Forecast panel opens.
 - 4 Set the target by selecting **Profit Or Loss** from the forecast list.

Instead, you could choose "Or, enter a data range:" and enter a range of spreadsheet data cells to be used for resampling.

5 Click Next.

The Method panel opens.

6 Make sure the one-simulation method and the statistics options are selected.

If you choose Percentiles and then choose Custom, you can select 0 or 100 as well as values between these.

7 Click Next.

The Options panel opens.

8 Set the following options:

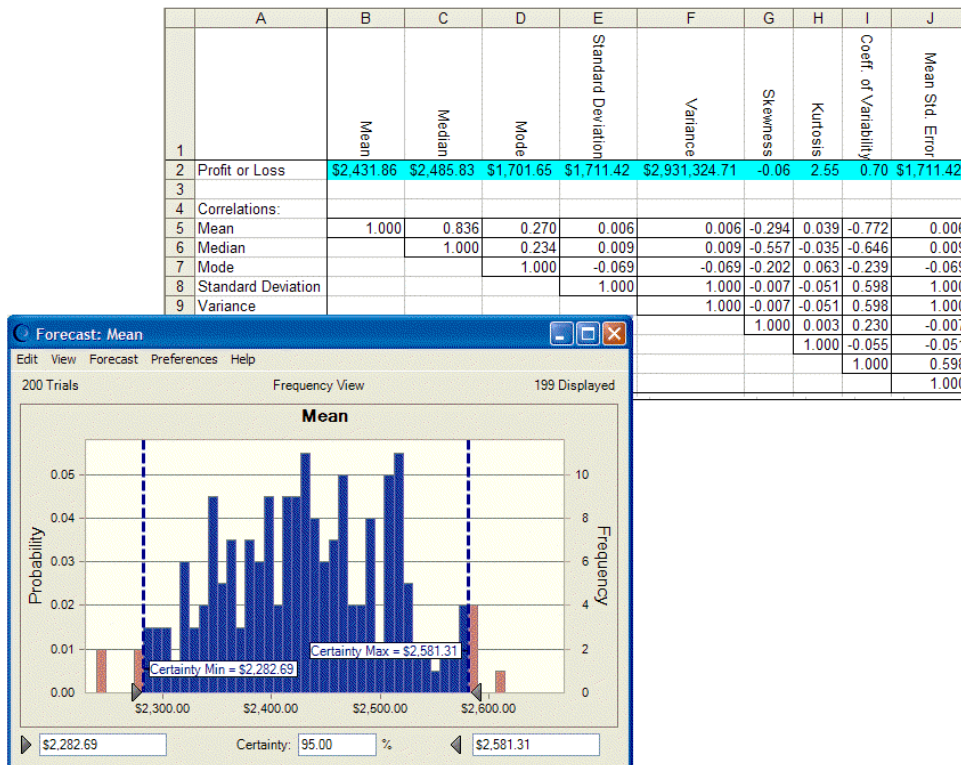
- Number Of Bootstrap Samples = 200
- Number Of Trials Per Sample = 500
- Show Only Target Forecast is selected

9 Click Run.

The Bootstrap tool displays a forecast chart of the distributions for each statistic and creates a workbook summarizing the data ([Figure 72](#)).

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.

Figure 72 Bootstrap Example Results



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.

Other statistics are also calculated, although they are not displayed.

Interpreting Bootstrap Results

The Bootstrap tool displays sampling distributions in forecast charts for the following statistics:

- Mean
- Median
- Mode
- Standard deviation
- Variance
- Skewness
- Kurtosis
- Coefficient of variability
- Mean standard error
- Process capability metrics, if these are set to display

When you use the multiple-simulation method, the tool also displays sampling distributions for these statistics:

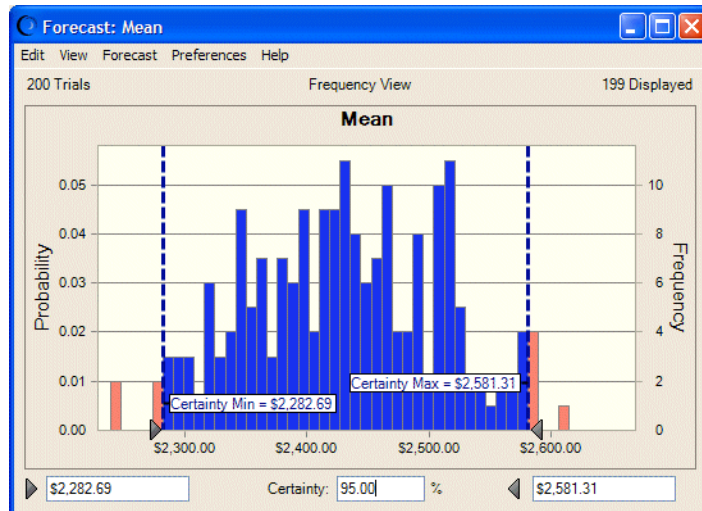
- Range minimum
- Range maximum
- Range width

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, 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 80](#)

The forecast charts visually indicate the accuracy of each statistic (Figure 73). A narrow and symmetrical distribution yields more precise statistics estimates than a wide and skewed distribution.

Figure 73 Bootstrap forecast distribution for the mean



The Statistics view (Figure 74) further lets you analyze the statistics’ sampling distribution. If the mean standard error or coefficient of variability is very large, the statistic might not be reliable and might 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.

Figure 74 Bootstrap forecast statistics for the mean

Statistic	Forecast values
Trials	200
Mean	\$2,431.86
Median	\$2,430.70
Mode	\$2,239.32
Standard Deviation	\$80.57
Variance	\$6,492.10
Skewness	0.0685
Kurtosis	2.61
Coeff. of Variability	0.0331
Minimum	\$2,239.32
Maximum	\$2,679.52
Mean Std. Error	\$5.70

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 Bibliography).

Decision Table Tool

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.

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 for Crystal Ball, if available.

OptQuest is a wizard-based program that enhances Crystal Ball by automatically finding optimal solutions to simulation models. This program is an option included with Crystal Ball Decision Optimizer.

Table 9 Comparison of Decision Table Tool and OptQuest

Aspect Compared	Decision Table tool	OptQuest
Process	Runs multiple Crystal Ball simulations for different values of decision variables	Same as Decision Table tool.
Results	All displayed in a table	Only the best solutions displayed

Aspect Compared	Decision Table tool	OptQuest
Optimization	No	Yes
Number of variables	One or two	Unlimited
Variable range	Small	Small to large

The following sections describe and show how to use the Decision Table tool:

- [“Using the Decision Table Tool” on page 200](#)
- [“Decision Table Example” on page 202](#)

Using the Decision Table Tool

To use the Decision Table tool, start the tool, select a target forecast, select decision variables, set options, and run the tool. The following sections describe these procedures:

- [“Starting the Decision Table Tool” on page 200](#)
- [“Using the Decision Table Welcome Panel” on page 200](#)
- [“Specifying a Target Forecast for Decision Table Analysis” on page 201](#)
- [“Selecting Decision Variables for Decision Table Testing” on page 201](#)
- [“Setting Decision Table Tool Options” on page 201](#)
- [“Running the Decision Table Tool” on page 202](#)

Also see [“Decision Table Example” on page 202](#).

Starting the Decision Table Tool

- To start the Decision Table tool, choose **Run** then, **More Tools** then, **Decision Table**. (In Microsoft Excel 2007, 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 202](#)
- [“While Running Options” on page 202](#)

Other controls include:

- Back — Returns to 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, that is., the product of the two numbers of test 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.

Results are generated as described in [“Interpreting Decision Table Results” on page 204](#).

Decision Table Example

In the Crystal Ball Examples folder, there is an Oil Field Development.xls workbook you can use to experiment with the Decision Table tool. 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 field.

The Decision Table example description contains the following sections:

- [“Generating Decision Table Results” on page 203](#)
- [“Interpreting Decision Table Results” on page 204](#)

Generating Decision Table Results

► To run the Decision Table tool:

1 In Excel with Crystal Ball loaded, open the workbook Oil Field Development.xls.

2 In the **Run**, then **Run Preferences**, then **Sampling** dialog:

- Set Random Number Generation to use the Same Sequence Of Random Numbers and an Initial Seed Value of 999.
- Select Monte Carlo simulation.

When using this tool, use these options to make the resulting simulations comparable.

3 In the Run Preferences dialog, click **OK**.

4 Select **Run**, then **More Tools**, then **Decision Table**. (In Microsoft Excel 2007, select **More Tools** in the **Tools** group.)

If this is the first time you have opened the Decision Table tool, the Welcome panel opens.

5 If the Welcome panel opens, click **Next**.

The Target Forecast panel opens.

6 Be sure the NPV forecast is selected and click **Next**.

The Decision Variables panel opens.

7 Move **Facility Size and Wells To Drill** to the Chosen Decision Variables list.

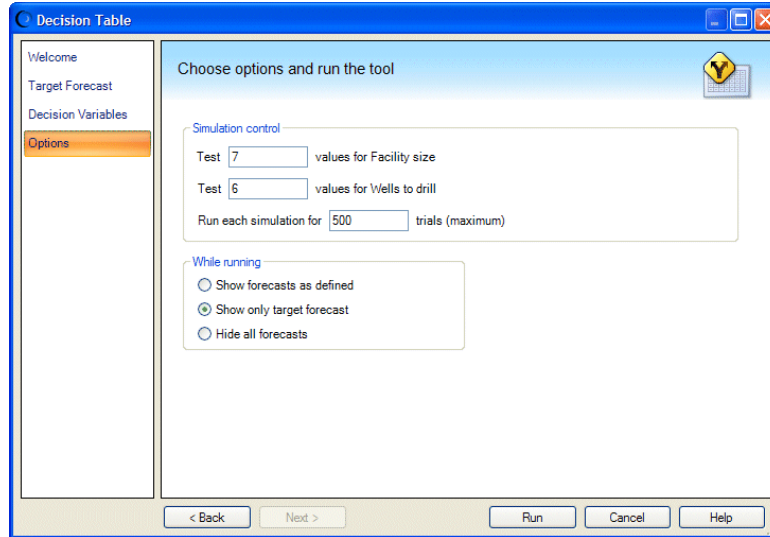
a. Press the **Ctrl** key and select **Facility Size and Wells To Drill** in the Available Decision Variables list.

b. Click .

8 Click **Next**.

The Options panel opens, similar to [Figure 75](#).

Figure 75 Options panel, Decision Table Tool



9 Set the following options as shown in Figure 75:

- 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.

10 Click Run.

The tool runs a simulation for each combination of decision variable values. It compiles the results in a table of forecast cells indexed by the decision variables.

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.

Interpreting Decision Table Results

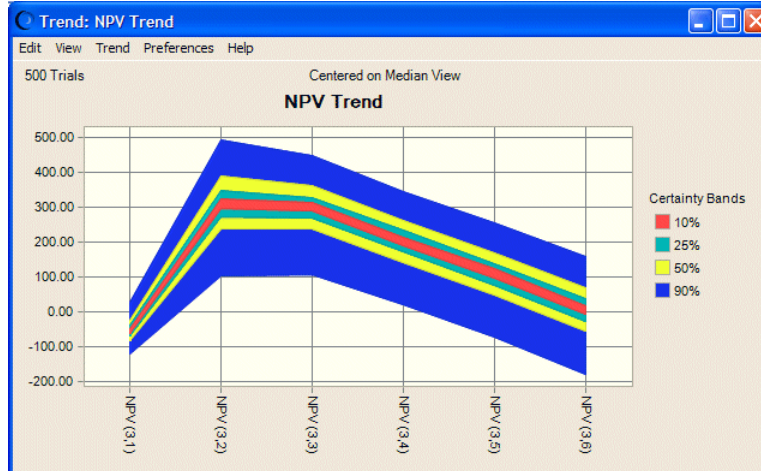
For this example, the Decision Table tool ran 42 simulations, one for each combination of wells to drill and facility sizes. The simulation that resulted in the best mean NPV was the combination of 12 wells and a facility size of 150 mbd (Figure 76).

Figure 76 Decision table for Oil Field Development Results

	A	B	C	D	E	F	G	H	I
	Trend Chart	Facility size (50,000)	Facility size (100,000)	Facility size (150,000)	Facility size (200,000)	Facility size (250,000)	Facility size (300,000)	Facility size (350,000)	
	Overlay Chart								
	Forecast Chart								
1									
2	Wells to drill (2)	57.67	-2.33	-52.33	-92.33	-122.33	-142.33	-152.33	1
3	Wells to drill (12)	152.22	296.31	308.35	273.93	243.93	223.93	213.93	2
4	Wells to drill (21)	60.01	222.04	291.94	289.13	263.11	243.17	233.17	3
5	Wells to drill (31)	-43.63	119.87	196.08	204.23	180.93	161.20	151.20	4
6	Wells to drill (40)	-136.92	26.98	103.75	113.09	90.69	71.04	61.04	5
7	Wells to drill (50)	-240.57	-76.64	0.65	10.04	-12.34	-32.00	-42.00	6
8		1	2	3	4	5	6	7	

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 77).

Figure 77 Trend chart of 150 mbd Forecasts



You can create the above trend chart (Figure 77) 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 80.

Scenario Analysis Tool

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 the Scenario Analysis tool on any Crystal Ball model. You simply 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.

Note: To help ensure the most accurate results, select Run, then Run Preferences, then Trials and be sure the Stop On Calculation Errors checkbox is checked before you use the Scenario Analysis tool. Because of the way it creates workbooks while it is running, the Scenario Analysis tool cannot be run in Extreme speed. When this tool runs, the

simulation part of the tool runs in Normal speed even if the Run Mode preference is set to Extreme Speed.

Using the Scenario Analysis Tool

To use the Scenario Analysis tool, start the tool, specify a target forecast or formula cell, specify options, and run the tool. The following sections describe these procedures:

- [“Starting the Scenario Analysis Tool” on page 206](#)
- [“Specifying a Scenario Analysis Target Cell” on page 206](#)
- [“Specifying Scenario Analysis Options” on page 206](#)
- [“Running the Scenario Analysis Tool” on page 207](#)

Also see [“Scenario Analysis Example” on page 207](#).

Starting the Scenario Analysis Tool

- To start the Scenario Analysis tool, select **Run**, then **More Tools**, then **Scenario Analysis**. (In Microsoft Excel 2007, select **More Tools** in the **Tools** group.)

The Specify Target panel opens.

Specifying a Scenario Analysis Target Cell

The Scenario Analysis tool analyzes the corresponding assumptions for a specified forecast or formula cell. The Specify Target panel indicates the forecast or cell to use as the “target.” The controls for this panel include:

- **Forecast List** — Lists all the forecast cells in all open spreadsheets. When you select a forecast from the list, its cell information automatically is displayed in the Enter Target Cell field. The first forecast is selected by default.
 - **Enter Target Cell** — Describes the cell location of the selected forecast or formula. If you select a forecast from the list above, the cell information is automatically displayed in this field. You can use this field to select a formula cell instead of a forecast.
 - **Next** — Opens the Specify Options panel for defining Scenario Analysis options.
- When the forecast or formula cell is selected, click **Next** to open the Specify Options panel.

Specifying Scenario Analysis Options

This panel indicates several Scenario Analysis option settings. You can specify the range of forecast values to analyze, which forecast charts to display while running the tool, and the number of trials to run for the analysis. Settings and other controls include:

- **Range Of Forecast Results** — Indicates whether to analyze a range of percentiles or a range of forecast values. All scenarios resulting in a forecast value that falls within the specified

range is displayed in the final table, along with their corresponding assumption values. For the percentile range, you must enter the lower and upper percentiles (both numbers between 0 and 100). For the forecast value range, you must enter the lower and upper limits for the values.

- 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..
- Simulation Control — Sets the number of Crystal Ball trials to run. This option temporarily overrides the setting in the Crystal Ball Run Preferences dialog.
- Back — Returns to the Specify Target panel.
- Start — Runs the Scenario Analysis tool and generates results.

➤ When options are complete, click **Start** to run the Scenario Analysis tool.

Running the Scenario Analysis Tool

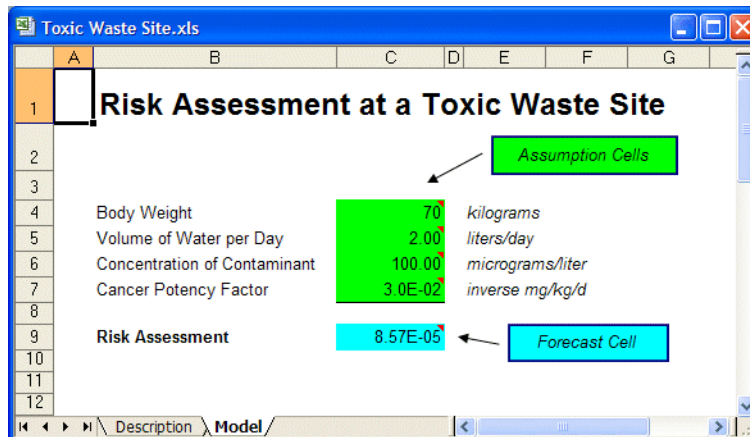
➤ To run the Scenario Analysis tool, click **Start** in the Specify Options panel.

Results are displayed, as described in “[Interpreting Scenario Analysis Results](#)” on page 209.

Scenario Analysis Example

In the Crystal Ball Examples folder there is a Toxic Waste Site.xls workbook you can use to experiment with the Scenario Analysis tool. This spreadsheet model predicts the cancer risk to the population from a toxic waste site. This spreadsheet has four assumptions and one forecast.

Figure 78 Toxic Waste Site spreadsheet



The screenshot shows a spreadsheet window titled "Toxic Waste Site.xls". The spreadsheet content is as follows:

	A	B	C	D	E	F	G
1		Risk Assessment at a Toxic Waste Site					
2							
3							
4		Body Weight	70		kilograms		
5		Volume of Water per Day	2.00		liters/day		
6		Concentration of Contaminant	100.00		micrograms/liter		
7		Cancer Potency Factor	3.0E-02		inverse mg/kg/d		
8							
9		Risk Assessment	8.57E-05				
10							
11							
12							

Annotations in the image:

- A green box labeled "Assumption Cells" points to the cells containing 70, 2.00, 100.00, and 3.0E-02.
- A blue box labeled "Forecast Cell" points to the cell containing 8.57E-05.

Generating Scenario Analysis Results

► To run the Scenario Analysis tool:

- 1 In Excel with Crystal Ball loaded, open the workbook Toxic Waste Site.xls.
- 2 Select **Run**, then **More Tools**, then **Scenario Analysis**. (In Microsoft Excel 2007, select **More Tools** in the **Tools** group.)

The Specify Target panel opens.

- 3 Select the Risk Assessment forecast.
- 4 Click **Next**.

The Specify Options panel opens.

- 5 In the Range Of Forecast Results section, specify a percentile range from 95 to 100 percent.
- 6 In the While Running section, select **Show Only Target Forecast**.
- 7 In the Simulation Control section, enter **1000** as the maximum number of trials to run.
- 8 Click **Start**.

The tool creates a table of all the forecast values within the range specified in [step 5](#), along with the corresponding value of each assumption as shown in [Figure 79](#).

Note: Even if you have Stop On Calculation Errors turned off in the Run Preferences, then Trials 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. Your original setting is restored when the Scenario Analysis tool is closed.

Figure 79 Scenario Analysis results for Toxic Waste Site

	A	B	C	D	E	F
1	Paste Selected Scenario				Concentration of Contaminant in Water	
	Paste Next Scenario			Volume of Water per Day		
	Paste Previous Scenario	Risk Assessment	Body Weight			
	Reset Original Values					OPF
4	95.00%	2.06E-04	69.87490755	3.54	111.43	3.6E-02
5	95.10%	2.06E-04	62.70645667	3.21	109.68	3.7E-02
6	95.20%	2.08E-04	61.96110005	2.64	115.19	4.2E-02
7	95.30%	2.08E-04	65.27839119	3.71	110.18	3.3E-02
8	95.40%	2.09E-04	60.08305465	2.25	90.27	6.2E-02
9	95.50%	2.10E-04	48.17095135	3.69	116.02	2.4E-02
10	95.60%	2.10E-04	72.23222708	2.78	104.42	5.2E-02
11	95.70%	2.11E-04	70.34865898	3.91	114.58	3.3E-02
12	95.80%	2.11E-04	57.59735483	2.44	99.77	5.0E-02
13	95.90%	2.15E-04	59.59421316	3.41	117.92	3.2E-02
14	96.00%	2.15E-04	58.43870157	2.94	111.36	3.8E-02
15	96.10%	2.17E-04	67.10438161	3.13	111.70	4.2E-02

Note: For the next few steps, you might want to arrange the windows in Excel vertically, so that you can see the results next to the original workbook.

9 Select the row with the 98.00% (assuming default percentile settings).

10 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.

11 Click **Paste Next Scenario**.

In the workbook, the assumption and forecast values change to the values for the next scenario (for 98.10%).

12 Click **Reset Original Values**.

The original assumption and forecast values are displayed in the workbook.

Interpreting Scenario Analysis Results

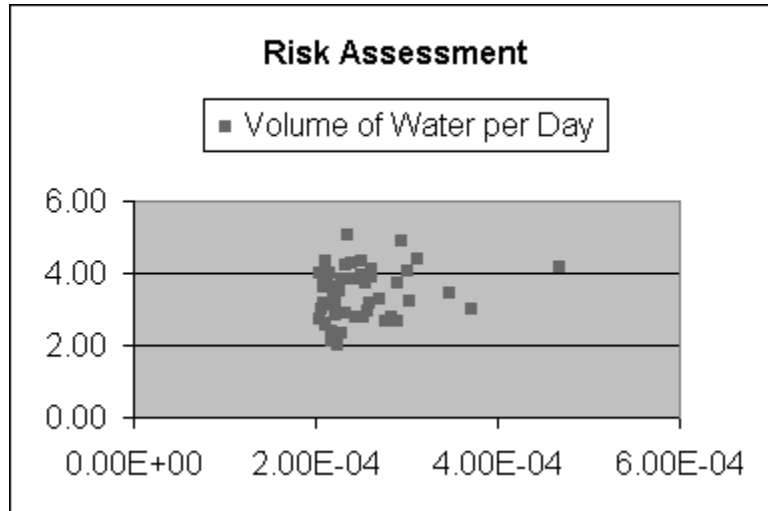
In this example, the simulation generated 1,000 forecast values. Since you selected to analyze the percentiles from 95 to 100, the resulting table lists 51 forecast values, or the top 5% of the forecast range, including the endpoints. The table sorts the values from lowest to highest value and also includes the assumption values that Crystal Ball generated for each trial.

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%.

One way to analyze the Scenario Analysis results is to identify a particular forecast value and see what assumption values created that forecast value.

Another way to analyze the Scenario Analysis results is to generate a scatter chart with the data. For example, you might create a scatter chart comparing the risk assessment with the CPF, as shown below.

Figure 80 Scatter Chart of Risk Assessment and CPF



2D Simulation Tool

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.

The following sections describe and show how to use the 2D Simulation tool and its results:

- [“Using the 2D Simulation Tool” on page 211](#)
- [“2D Simulation Example” on page 213](#)
- [“Second-Order Assumptions” on page 218](#)

Using the 2D Simulation Tool

To use the 2D Simulation tool, start the tool, select a forecast to analyze, sort assumptions into Uncertainty and Variability groups, set options, and run the tool. The following sections describe these procedures:

- [“Starting the 2D Simulation Tool” on page 211](#)
- [“Using the 2D Simulation Welcome Panel” on page 211](#)
- [“Specifying a 2D Simulation Target Forecast” on page 212](#)
- [“Sorting Assumptions for 2D Simulation Analysis” on page 212](#)
- [“Setting 2D Simulation Options” on page 212](#)
- [“Running the 2D Simulation Tool” on page 213](#)

Also see [“2D Simulation Example” on page 213](#).

Starting the 2D Simulation Tool

- ▶ To start the 2D Simulation tool, select **Run**, then **More Tools**, then **2D Simulation**. (In Microsoft Excel 2007, 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 your 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 Uncertainty 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.
- When 2D Simulation tool settings are complete, click **Run** to run the tool and generate results, as shown in “[Interpreting 2D Simulation Results](#)” on page 214.

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, as described in “[Interpreting 2D Simulation Results](#)” on page 214.

2D Simulation Example

In the Crystal Ball Examples folder there is a Toxic Waste Site.xls workbook you can use to experiment with the 2D Simulation tool. This spreadsheet model predicts the cancer risk to the population from a toxic waste site. This spreadsheet has two variability assumptions and two uncertainty assumptions.

The 2D Simulation tool example contains the following sections:

- “[Interpreting 2D Simulation Results](#)” on page 214
- “[Interpreting 2D Simulation Results](#)” on page 214

Generating 2D Simulation Results


- To run the 2D Simulation tool:
- 1 In Excel with Crystal Ball loaded, open the workbook Toxic Waste Site.xls.
 - 2 In the **Run**, then **Run Preferences**, then **Sampling** dialog:
 - Set Random Number Generation to use the Same Sequence Of Random Numbers and An Initial Seed Value of 999.
 - Select Monte Carlo simulation.

When using this tool, use these options to make the resulting simulations comparable.
 - 3 Select **Run**, then **More Tools**, then **2D Simulation**. (In Microsoft Excel 2007, select **More Tools** in the **Tools** group.)
- If this is the first time you have opened the 2D Simulation tool, the Welcome panel opens.
- 4 If the Welcome panel opens, click **Next**.
- The Target Forecast panel opens.
- 5 Be sure the Risk Assessment forecast is selected.

6 Click Next.

The Assumption Types panel opens.

7 Move Body Weight and Volume Of Water Per Day to the Variability list.

- a. Select **Body Weight**.
- b. Press **Ctrl** and then click **Volume Of Water Per Day**.
- c. Click  .

This separates the assumptions into the two types: Uncertainty and Variability.

8 Click Next.

The Options panel opens. The default number of trials for the outer (uncertainty) simulation is 50. The default for the inner (variability) simulation is the number of trials currently set on the Trials tab of the Run Preferences dialog.

9 Set the following options.

- Run outer (uncertainty) simulation for 100 trials
- Run inner (variability) simulation for 1,000 trials
- Show Only Target Forecast is selected.

Use the default settings in the Report Options group.

10 Click Run.

The simulations start. The 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.

Interpreting 2D Simulation Results

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 81](#)).

Figure 81 2D Simulation ResultsTable

	A	B	C	D	E	F	G	H	
1		Summary	Risk Assessment(21)	Risk Assessment(10)	Risk Assessment(95)	Risk Assessment(37)	Risk Assessment(53)	Risk Assessment(14)	
2			4.55E-05	4.84E-05	5.09E-05	5.32E-05	5.39E-05	5.55E-05	
3	Assumptions:								
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	
9	Median	8.97E-05	4.39E-05	4.67E-05	4.91E-05	5.13E-05	5.20E-05	5.35E-05	
10	Standard Deviation	4.35E-05	2.13E-05	2.27E-05	2.38E-05	2.49E-05	2.52E-05	2.60E-05	
11	Variance	2.07E-09	4.53E-10	5.14E-10	5.67E-10	6.20E-10	6.36E-10	6.75E-10	
12	Skewness	0.56	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	3.43	
14	Coeff. of Variability	0.47	0.47	0.47	0.47	0.47	0.47	0.47	
15	Minimum	9.87E-09	4.82E-09	5.14E-09	5.40E-09	5.64E-09	5.72E-09	5.89E-09	
16	Maximum	2.66E-04	1.30E-04	1.39E-04	1.46E-04	1.52E-04	1.54E-04	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	
18									
19	Percentiles:								
20	0%	9.87E-09	4.82E-09	5.14E-09	5.40E-09	5.64E-09	5.72E-09	5.89E-09	
21	5%	2.79E-05	1.36E-05	1.45E-05	1.53E-05	1.59E-05	1.62E-05	1.66E-05	
22	10%	3.81E-05	1.86E-05	1.98E-05	2.08E-05	2.18E-05	2.21E-05	2.27E-05	

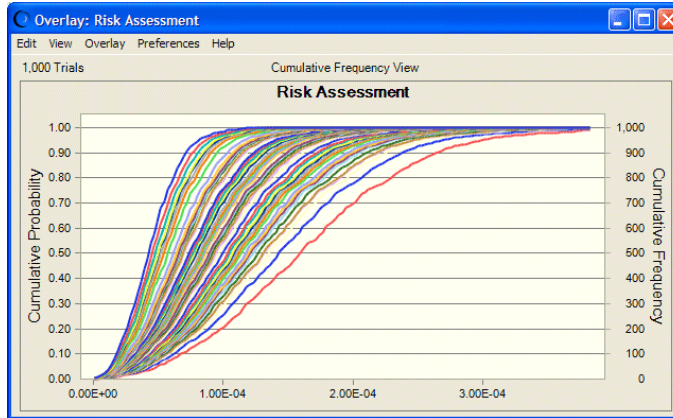
The tool also graphs the results of the two-dimensional simulations on an overlay chart and a trend chart.

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 choose 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 82 shows that most of the risk curves are clustered densely toward the center while a few outlier curves are scattered to the right, showing the small probability of having a much greater risk.

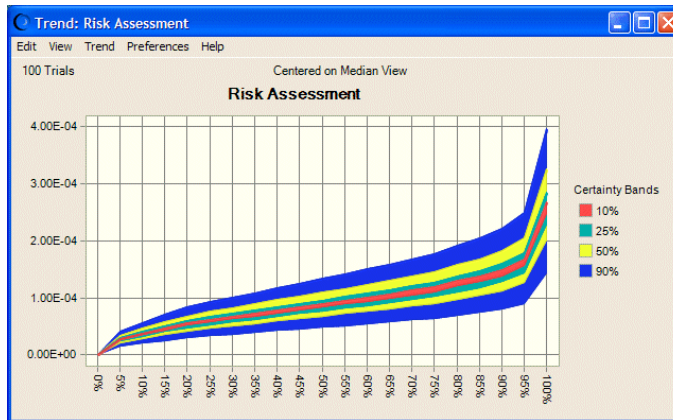
In risk analysis literature, the curves are often called the alternate realizations of the population risk assessment.

Figure 82 Overlay chart of risk curves



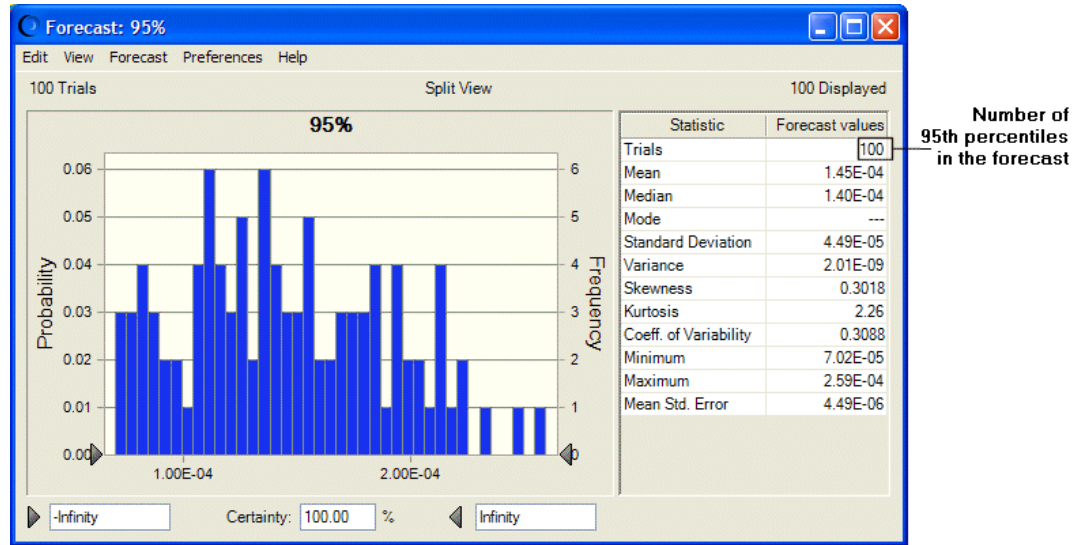
The trend chart (Figure 83) shows certainty bands for the percentiles of the risk curves. The band width shows the amount of uncertainty at each percentile level for all the distributions.

Figure 83 Trend chart of 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 84. For example, this figure shows 100 trials, the number of 95th percentiles in the forecast.

Figure 84 95th percentiles forecast statistics

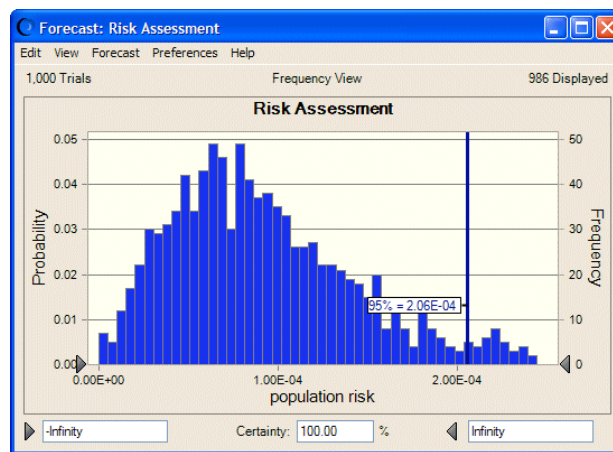


If you have the Probability Above A Value option selected in the Run Preferences, then Options panel, the percentiles will be reversed in meaning, so that the 1st percentile represents the uppermost 1% and the 99th percentile represents the lowest 1%. For more information, see [“Setting Statistics Preferences” on page 80.](#)

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 85,](#) following .

The mean of the 95th percentiles in [Figure 84,](#) 1.45E-4, is lower than the 95th percentile risk of the one-dimensional simulation shown in [Figure 85](#) 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 85 Forecast chart for one-dimensional simulation



Second-Order Assumptions

Some assumptions contain elements of both uncertainty and variability. For instance, an assumption might describe the distribution of body weights in a population, but the parameters of the distribution might 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:

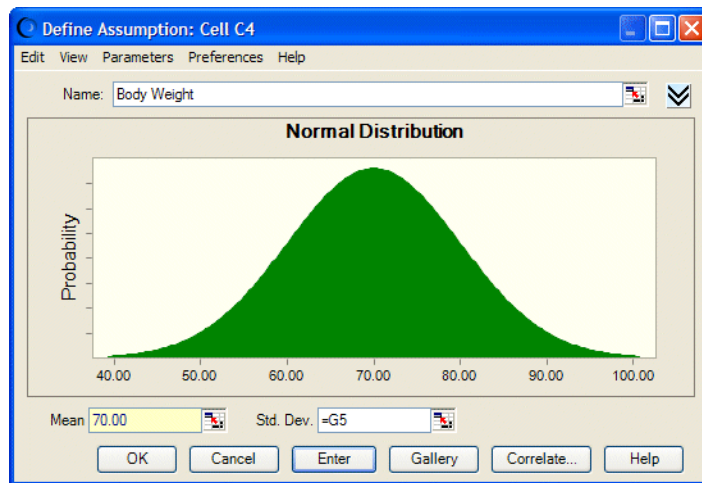
- 1 Enter the values **70** and **10** into cells **G4** and **G5**, respectively.

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.

For an example, see [Figure 86](#), following.

Figure 86 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.

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 your 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.

Data Analysis Tool

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, your data series must be contiguous (in adjacent rows or columns) in either rows or columns.

The following sections describe and show how to use the Data Analysis tool:

- [“Using the Data Analysis Tool” on page 219](#)
- [“Data Analysis Example” on page 221](#)

Using the Data Analysis Tool

The following sections describe procedures for starting and using the Data Analysis tool:

- [“Starting the Data Analysis tool” on page 219](#)
- [“Specifying Data Analysis Input Data” on page 220](#)
- [“Setting Data Analysis Options” on page 220](#)
- [“Running the Data Analysis Tool” on page 221](#)

Starting the Data Analysis tool

- To start the Data Analysis tool, choose **Run**, then **More Tools**, then **Data Analysis**. (In Microsoft Excel 2007, 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 chooses possible data for fitting. This information is displayed in the Location Of Data Series field and the illustration at the right side of the panel. You can choose different data if necessary. The controls in this panel include:

- Location Of Data Series — Indicates the cells that contain data to analyze. If your data has headers or labels at the beginning of the rows or columns of data, include them in your selection and select the appropriate Headers setting(s). The data must be in adjacent rows or columns.
- Orientation — Sets whether your 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 your data has headers and/or labels and whether they are located in the top row or the left header (varies with orientation). Checked items are used in the output: Top Row Has Headers/Labels includes text in the top row in your selection; Left Column Has Labels/Headers includes text in the left column in your selection.
- Back — Returns to 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 checked, 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 checked, shows a chart in the left pane and statistics in the right pane.
- Fit A Probability Distribution To The Data — When checked, 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 checked, 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 checked, 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 — Returns to 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

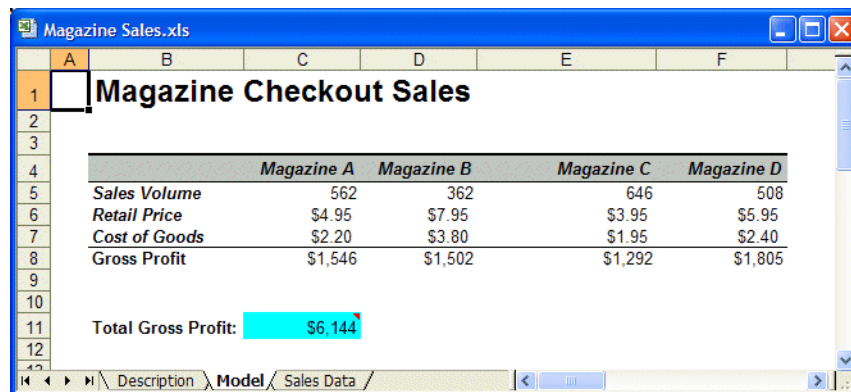
- To run the Data Analysis tool, confirm that all required settings are complete and then click Run.

For more information, see [“Generating Data Analysis Results” on page 222](#).

Data Analysis Example

You can use the Magazine Sales.xls workbook, provided in the Crystal Ball Examples folder, to experiment with the Batch Fit tool. This model shows the estimated gross profit resulting from newsstand sales of four of the company’s most popular magazines ([Figure 87](#)).

Figure 87 Magazine Sales workbook



The screenshot shows a spreadsheet window titled "Magazine Sales.xls". The main heading is "Magazine Checkout Sales". Below this, there is a table with four columns: Magazine A, Magazine B, Magazine C, and Magazine D. The rows represent different metrics: Sales Volume, Retail Price, Cost of Goods, and Gross Profit. The total gross profit is highlighted in red and shows a value of \$6,144.

	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 of Goods	\$2.20	\$3.80	\$1.95	\$2.40
Gross Profit	\$1,546	\$1,502	\$1,292	\$1,805
Total Gross Profit:	\$6,144			

This model shows sales figures for four magazines. The accompanying Sales Data worksheet contains historical data for each magazine. For this example, you will import the data into the Data Analysis tool, automatically create a forecast for each magazine, run a simulation, display the simulated data as forecast charts, correlate the forecasts for each magazine, and produce other charts using buttons in the new DataAnalysisOutput worksheet generated by the tool.

Generating Data Analysis Results

► To run the Data Analysis tool:

- 1 In Excel with Crystal Ball loaded, open the workbook Magazine Sales.xls.
- 2 Click the **Sales Data** tab to select and display it.
- 3 Choose **Run**, then **More Tools**, then **Data Analysis**. (In Microsoft Excel 2007, select **More Tools** in the **Tools** group.)

If this is the first time you have opened the Data Analysis tool, the Welcome panel opens.

- 4 If the Welcome panel opens, click **Next**.

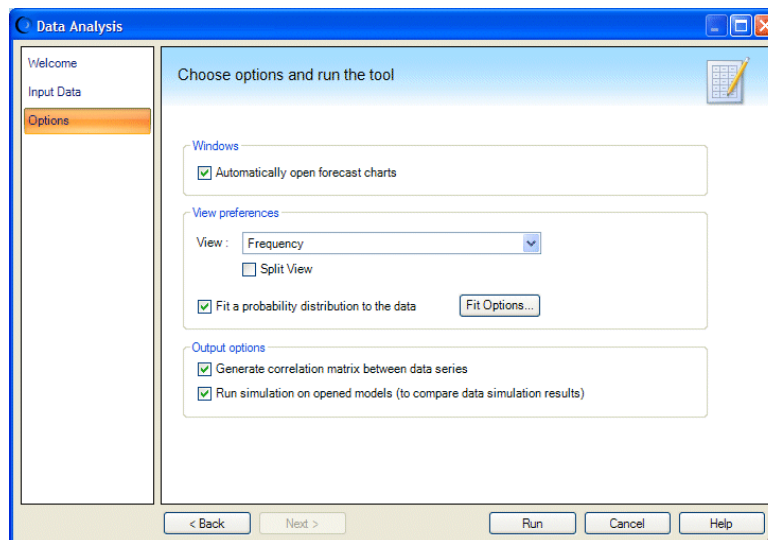
The Input Data panel opens.

The Data Analysis data selector attempts to select relevant data and indicate its orientation.

The Input Data panel shows a cell range with four data series and 360 rows of data. The tool determined that the data is in columns with headers in the top row. There are no labels in the left column.

- 5 Examine the Sales Data tab of the Magazine Sales workbook to confirm that this information is correct.
- 6 Click **Next** to display the Options panel, similar to [Figure 88](#).

Figure 88 Options panel, Data Analysis Tool



- 7 Confirm that the settings are as shown in [Figure 88](#). Change them if necessary:
 - Check "Automatically open forecast charts."
 - Set View to Frequency.
 - Check "Fit a probability distribution to the data."
 - Check "Generate correlation matrix between data series."
 - Check "Run simulation on opened models..."
- 8 Click **Fit Options** to specify which distributions and ranking statistics to use for fitting.

The Fit Options panel opens.

9 Choose AutoSelect for both Distributions To Fit and Rank By Goodness-of-Fit Statistic.

Note: If you know location, shape, or other parameter values that might help create a more accurate fit with certain distributions, check Lock Parameters and enter appropriate values in the Lock Parameters dialog. For details, see “[Locking Parameters When Fitting Distributions](#)” on page 47.

10 Click OK to return to the Options panel.

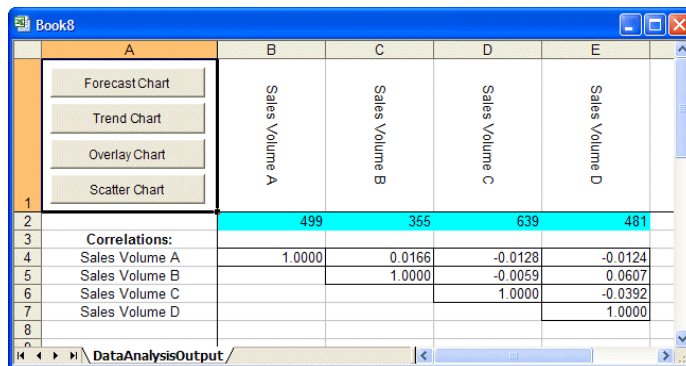
11 Click Run.

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.

The new worksheet is similar to [Figure 89](#).

Figure 89 Data Analysis Output worksheet



- 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.

12 Select all four forecast cells in row 2 and click the Forecast Chart button.

A chart is displayed for each forecast, in Frequency view. You can customize them as usual, changing the view or setting other chart preferences as described in Chapter 6.

To see which type of distribution fit best, select a chart and choose View, then Goodness of Fit.

13 Experiment with the other chart buttons as well. Select two or more forecasts and click a button. You can create new charts of the selected type just as if you used the Analyze command or clicked a chart icon.



Selecting and Using Probability Distributions

In This Appendix

Introduction.....	225
Understanding Probability Distributions	225
Selecting Probability Distributions.....	229
Probability Distribution Descriptions	231
Using the Custom Distribution	265
Truncating Distributions.....	280
Comparing Distributions.....	281
Distribution Parameter Summary.....	282
Using Probability Functions	284
Sequential Sampling with Custom Distributions	285

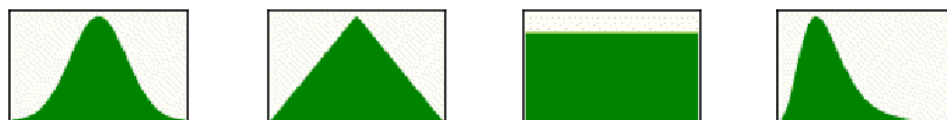
Introduction

This appendix explains probability and probability distributions. Understanding these concepts will help you select the right probability distribution for your 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 left to right in [Figure 90](#): normal, triangular, uniform, and lognormal

Figure 90 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 226, 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 228. For suggestions about using the best distribution when defining an assumption, see “[Selecting Probability Distributions](#)” on page 229. “[Probability Distribution Descriptions](#)” on page 231 describes the properties and uses of each distribution available in Crystal Ball.

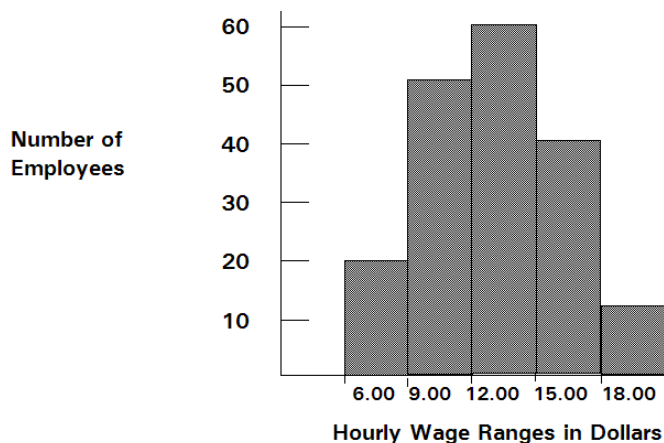
A Probability Example

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 91](#) 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.

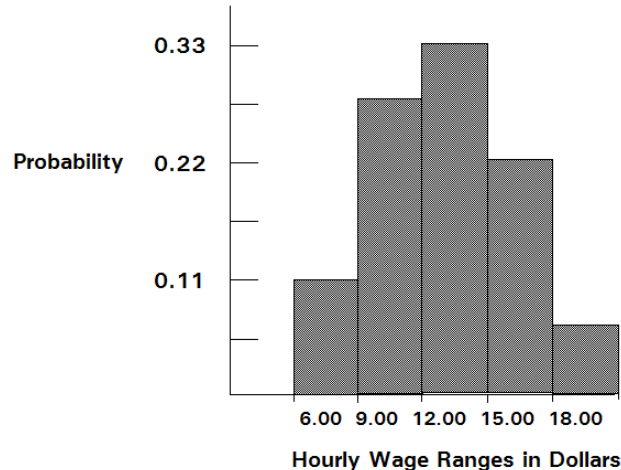
Figure 91 Raw frequency data for a probability distribution



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.

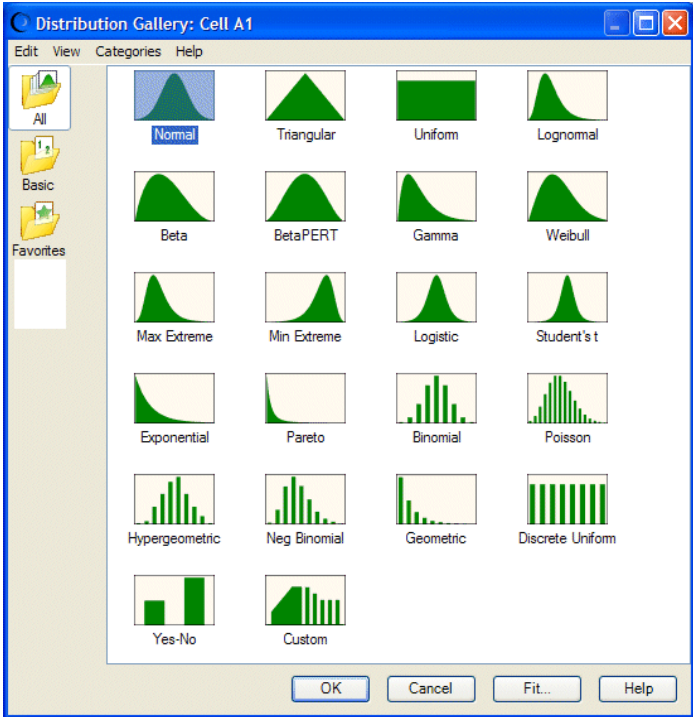
The chart illustrated in [Figure 92](#) shows you the number of employees in each wage group as a fraction of all employees; you can estimate the likelihood or probability that an employee drawn at random from the whole group earns a wage within a given interval. For example, assuming the same conditions 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.

Figure 92 Probability distribution of wages



Compare the probability distribution in the example above to the probability distributions in Crystal Ball ([Figure 93](#)).

Figure 93 Distribution Gallery Dialog



The probability distribution in the example in [Figure 92](#) 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 your probability distribution, then read about those distributions in this chapter to find the correct distribution.

For information about the similarities between distributions, see [“Comparing Distributions” on page 281](#). For a complete discussion of probability distributions, refer to the sources listed in the bibliography.

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 93](#). A discrete distribution, for example, might 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 120](#).

The following sections list continuous and discrete distributions available in Crystal Ball:

- [“Continuous Probability Distributions” on page 228](#)
- [“Discrete Probability Distributions” on page 229](#)

Note: Custom distributions can be defined as continuous, discrete, or both. For more information, see [“Custom Distribution” on page 236](#).

Continuous Probability Distributions

The following sections describe continuous distributions available in Crystal Ball:

- “Beta Distribution” on page 231
- “BetaPERT Distribution” on page 233
- “Exponential Distribution” on page 238
- “Gamma Distribution” on page 240
- “Logistic Distribution” on page 247
- “Lognormal Distribution” on page 248
- “Maximum Extreme Distribution” on page 250
- “Minimum Extreme Distribution” on page 251
- “Normal Distribution” on page 253
- “Pareto Distribution” on page 255
- “Student’s t Distribution” on page 258
- “Triangular Distribution” on page 259
- “Uniform Distribution” on page 261
- “Weibull Distribution” on page 262

Discrete Probability Distributions

The following sections describe discrete distributions available in Crystal Ball:

- “Binomial Distribution” on page 235
- “Discrete Uniform Distribution” on page 237
- “Geometric Distribution” on page 243
- “Hypergeometric Distribution” on page 245
- “Negative Binomial Distribution” on page 252
- “Poisson Distribution” on page 256
- “Yes-No Distribution” on page 264
- “Triangular Distribution” on page 259
- “Uniform Distribution” on page 261
- “Weibull Distribution” on page 262

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 your 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 might be able to gather valuable information about the uncertain variable from historical data. If historical data are not available, use your own 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 333](#). 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 231](#) 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 235](#):

- 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 check the "patients cured" variable in Tutorial 2 in the *Crystal Ball Getting Started Guide* against the conditions of the binomial distribution:

- There are two possible outcomes: 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 your data.

Crystal Ball can automatically select the probability distribution that most closely approximates your data's distribution. The feature is described in detail in [“Fitting Distributions to Data” on page 44](#). You can also populate a custom distribution with your 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, there are two parameters for the binomial distribution: 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 choose from alternate parameter sets, which substitute percentiles for one or more of the standard parameters. For more information on alternate parameters, see [“Alternate Parameter Sets” on page 43](#).

Probability Distribution Descriptions

This section contains descriptions of all the Crystal Ball probability distributions, listed in alphabetical order.

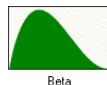
The following sections list continuous and discrete distributions described below:

- [“Continuous Probability Distributions” on page 228](#)
- [“Discrete Probability Distributions” on page 229](#)

See [“Custom Distribution” on page 236](#) 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 menubar to specify different combinations of parameters. For more information, see [“Alternate Parameter Sets” on page 43](#).

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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Beta Distribution Parameters” on page 231](#)
- [“Beta Distribution Conditions” on page 232](#)
- [“Beta Distribution Example” on page 232](#)

Beta Distribution Parameters

Minimum, Maximum, Alpha, Beta

Beta Distribution 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. After analyzing the empirical data, the company knows that it can use the beta distribution to describe the reliability of the devices if the parameters are alpha = 10 and beta = 2.

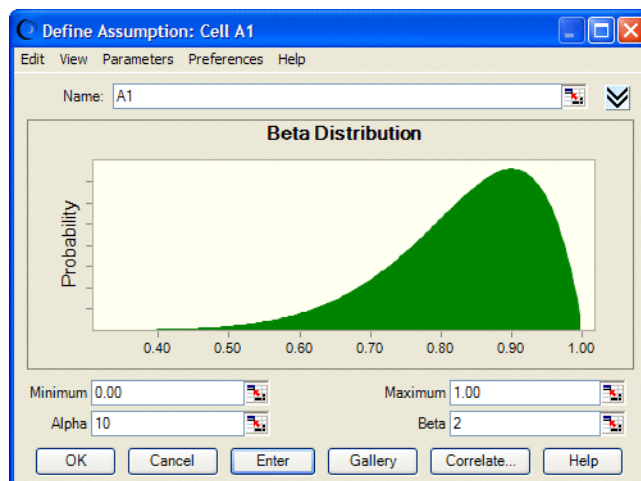
The first step in selecting a probability distribution is matching your data with a distribution's conditions. Checking the beta distribution:

- The reliability rate is a random value somewhere between 0 and 1.
- The shape of the distribution can be specified using two positive values: 10 and 2.

These conditions match those of the beta distribution.

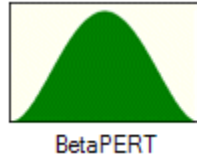
Figure 94 shows the beta distribution with the alpha parameter set to 10, the beta parameter set to 2, and Minimum and Maximum set to 0 and 1. The reliability rate of the devices will be x .

Figure 94 Beta distribution



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.

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 259](#), 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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“BetaPERT Parameters” on page 233](#)
- [“BetaPERT Conditions” on page 233](#)
- [“BetaPERT Example” on page 233](#)

BetaPERT Parameters

Minimum, Likeliest, Maximum

BetaPERT Conditions

The betaPERT distributions 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

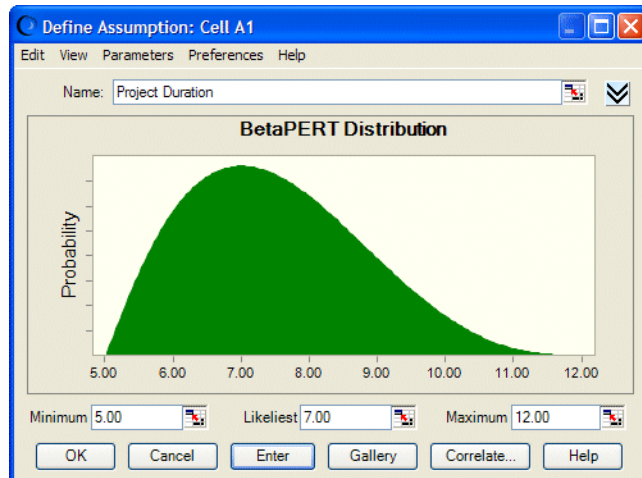
A project manager wants to estimate the time (number of days) required for completion of a project. From the manager's past experience, similar projects typically take 7 days to finish, but can be finished in 5 days given favorable conditions, and can take as long as 12 days if things do not happen as expected. The project manager wants to estimate the probability of finishing within 9 days.

The first step in selecting a probability distribution is matching available data with a distribution's conditions. Checking the betaPERT distribution for this project:

- The minimum number of days for completion is 5.
- The maximum number of days for completion is 12.
- The most likely number of days for completion is 7, which is between 5 and 12.

These conditions match those of the betaPERT distribution shown in [Figure 95](#).

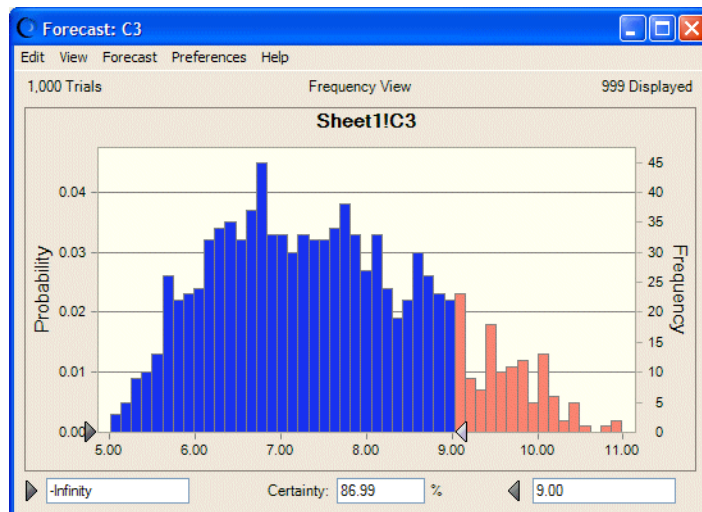
Figure 95 BetaPERT distribution



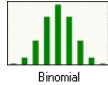
If that distribution is located in cell A1 and a forecast with formula =A1 is created, simulation results show there is about an 87% probability of the project completing within 9 days.

If the same forecast is calculated using a triangular distribution instead of a betaPERT, the probability of completing within 9 days is about 74% ([Figure 96](#)).

Figure 96 Project duration based on betaPERT distribution



Binomial Distribution



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 be used for Boolean logic (true/false or on/off).

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Binomial Parameters” on page 235](#)
- [“Binomial Conditions” on page 235](#)
- [“Binomial Example 1” on page 235](#)
- [“Binomial Example 2” on page 236](#)

Binomial Parameters

Probability, Trials

Binomial 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 1

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.

The first step in selecting a probability distribution is matching your data with a distribution's conditions. Checking the binomial distribution:

- There are only two possible outcomes: the manufactured item is either good or defective.
- The trials (50) are independent of one another. Any given manufactured item is either defective or not, independent of the condition of any of the others.
- The probability of a defective item (7%) is the same each time an item is tested.

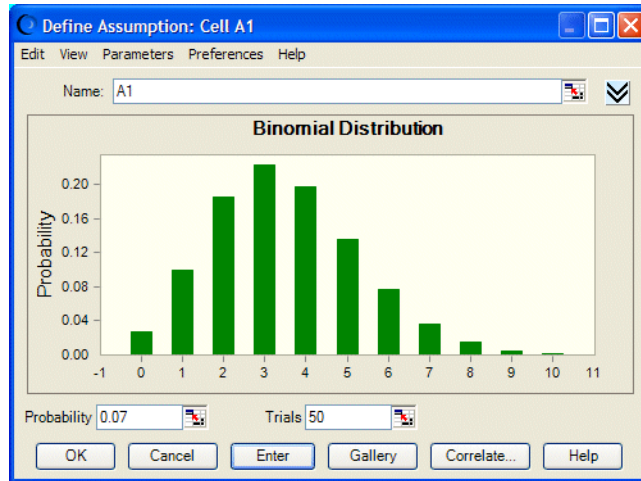
These conditions match those of the binomial distribution.

The parameters for the binomial distribution are Probability and Trials. In example one, the values for these parameters are 50 (Trials) and 0.07 (7% Probability of producing defective

items). You would enter these values to specify the parameters of the binomial distribution in Crystal Ball.

The distribution illustrated in [Figure 97](#) shows the probability of producing x number of defective items.

Figure 97 Binomial Distribution

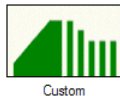


Binomial Example 2

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 and determined that 60% prefer the company's product over the competitor's.

Again, the conditions fit the binomial distribution with two important values: 100 (trials) and 0.6 (60% probability of success). These values specify the parameters of the binomial distribution in Crystal Ball. The result would be a distribution of the probability that x number of people prefer the company's product.

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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Custom Parameters” on page 237](#)
- [“Custom Conditions” on page 237](#)

Also see [“Using the Custom Distribution” on page 265](#).

Custom Parameters

Variable, see [“Using the Custom Distribution” on page 265](#).

Custom 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 339](#)). Also see [“Using the Custom Distribution” on page 265](#).

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 261](#)).

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Discrete Uniform Parameters” on page 237](#)
- [“Discrete Uniform Conditions” on page 237](#)
- [“Discrete Uniform Example” on page 238](#)

Discrete Uniform Parameters

Minimum, Maximum

Discrete Uniform 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

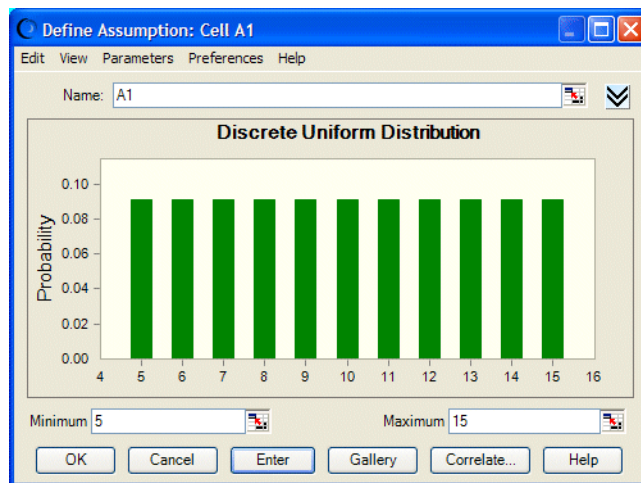
A manufacturer determines that he must receive 10% over production costs—or a minimum of \$5 per unit—to make the manufacturing effort worthwhile. He also wants to set the maximum price for the product at \$15 per unit, so that he can gain a sales advantage by offering the product for less than his nearest 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.

The first step in selecting a probability distribution is matching your data with a distribution's conditions. Checking the uniform distribution:

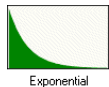
- The minimum value is \$5 per unit.
- The maximum value is \$15 per unit.
- All integer values between \$5 and \$15 are equally possible.

You would enter these values in Crystal Ball to produce a discrete uniform distribution showing that all whole dollar values from \$5 to \$15 occur with equal likelihood. Figure 98 illustrates this scenario.

Figure 98 Discrete uniform distribution



Exponential Distribution



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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Exponential Parameter” on page 239](#)
- [“Exponential Conditions” on page 239](#)
- [“Exponential Example 1” on page 239](#)
- [“Exponential Example 2” on page 240](#)

Exponential Parameter

Rate

Exponential 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. This same example was used for the Poisson distribution to describe the number of calls arriving every 10 minutes.

The first step in selecting a probability distribution is matching your data with a distribution’s conditions. Checking the exponential distribution:

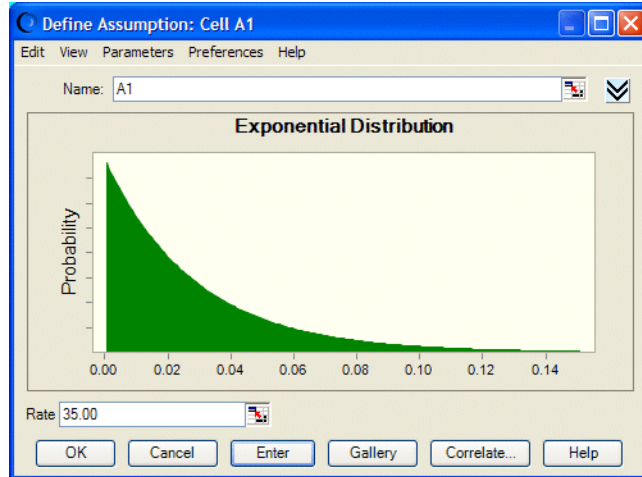
- The travel agency wants to describe the time between successive telephone calls.
- The phone calls are not affected by previous history. The probability of receiving 35 calls every 10 minutes remains the same.

The conditions in this example match those of the exponential distribution.

The exponential distribution has only one parameter: rate. The conditions outlined in this example include the value for this parameter: 35 (calls) every 10 minutes or a rate of 35. Enter this value to set the parameter of the exponential distribution in Crystal Ball.

The distribution in [Figure 99](#) shows the probability that x number of time units (10 minutes in this case) will pass between calls.

Figure 99 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.

Checking the exponential distribution:

- The car dealer wants to describe the time between successive customer drop-ins.
- The probabilities of customer drop-ins remain the same from hour to hour.

These conditions fit the exponential distribution.

The resulting distribution would show the probability that x number of hours will pass between customer visits.

Gamma Distribution



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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Gamma Parameters” on page 241](#)
- [“Gamma Conditions” on page 241](#)

- “Gamma Example 1” on page 241
- “Gamma Example 2” on page 242
- “Chi-square and Erlang Distributions” on page 242

Gamma Parameters

Location, Scale, Shape

Gamma 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.

Checking the conditions of the gamma distribution:

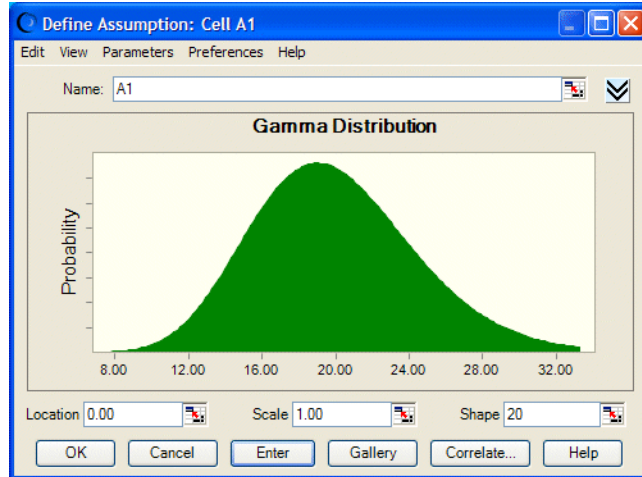
- The number of possible customers demanding to buy the computer system is unlimited.
- The decisions of customers to buy the system are independent.
- The demand remains constant from week to week.

These conditions match those of the gamma distribution. (Note that in this example the dealership has made several simplifying assumptions about the conditions. In reality, the total number of computer purchasers is finite, and some might have influenced the purchasing decisions of others.)

The shape parameter is used to specify the r th occurrence of the Poisson 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 100](#) illustrates the gamma distribution.

Figure 100 Gamma distribution



Gamma Example 2

Suppose a particular mechanical system fails after receiving exactly 5 shocks to it from an external source. The total time to system failure, defined as the random time occurrence of the 5th shock, follows a gamma distribution with a shape parameter of 5.

Some characteristics of the gamma distribution:

- When shape = 1, gamma becomes a scalable exponential distribution.
- The sum of any two gamma-distributed variables is a gamma variable.
- If you have historical data that you believe fits the conditions of a gamma distribution, computing the parameters of the distribution is easy. First, compute the mean and variance of your historical data:

Parameter	Symbol
mean =	(\bar{x})
variance =	(s^2)

Then compute the distribution's parameters:

Parameter	Symbol
shape =	\bar{x}^2/s^2
scale =	s^2/\bar{x}

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

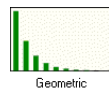
distributions with parameters N and S , where N = number of degrees of freedom and S = scale, set the parameters as follows:

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



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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Geometric Parameter” on page 243](#)
- [“Geometric Conditions” on page 243](#)
- [“Geometric Example 1” on page 244](#)
- [“Geometric Example 2” on page 244](#)

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

If you are drilling for oil and want to describe the number of dry wells you would drill before the next producing well, you would use the geometric distribution. Assume that in the past you have hit oil about 10% of the time.

The first step in selecting a probability distribution is matching your data with a distribution's conditions. Checking the geometric distribution:

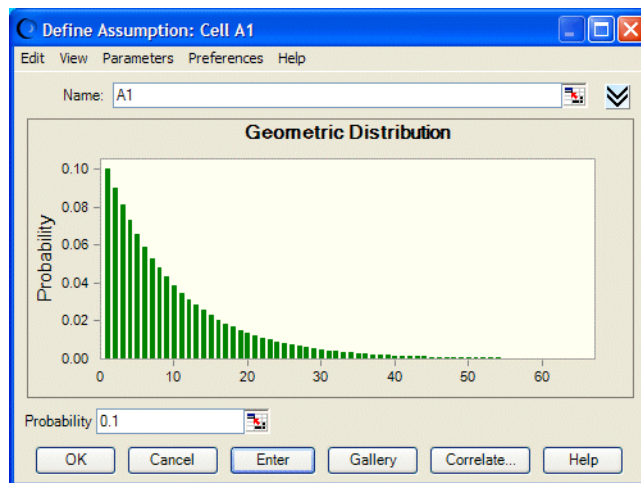
- The number of trials (dry wells) is unlimited.
- You continue to drill wells until you hit the next producing well.
- The probability of success (10%) is the same each time you drill a well.

These conditions match those of the geometric distribution.

The geometric distribution has only one parameter: Probability. In this example, the value for this 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.

The distribution illustrated in [Figure 101](#) shows the probability of x number of wells drilled before the next producing well.

Figure 101 Geometric Distribution

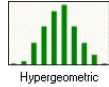


Geometric Example 2

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.

Again, identify and enter the parameter values for the geometric distribution in Crystal Ball. In this example, the conditions show one important value: a 0.06 (6%) probability of receiving that "major" claim. The result would be a distribution showing the probability of x number of claims occurring between "major" claims.

Hypergeometric Distribution



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).

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Hypergeometric Parameters” on page 245](#)
- [“Hypergeometric Conditions” on page 245](#)
- [“Hypergeometric Example 1” on page 245](#)
- [“Hypergeometric Example 2” on page 246](#)

Hypergeometric Parameters

Success, Trials, Population

Hypergeometric 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.

The first step in selecting a probability distribution is matching your data with a distribution's conditions. Checking the hypergeometric distribution:

- The population size (40) is fixed.
- The sample size (20 consumers) represents a portion of the population.
- Initially, 30 of 40 consumers preferred Brand X so the initial success rate is 30. This rate changes each time you question one of the 20 consumers, depending on the preference of the previous consumer.

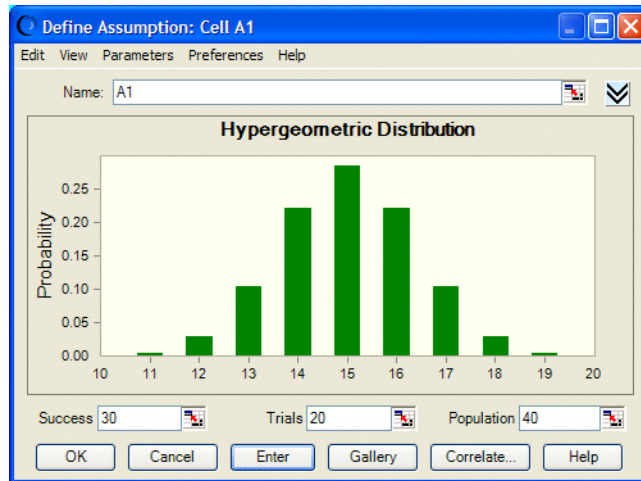
The conditions in this example match those of the hypergeometric distribution.

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% ($.75 \times 40 = 30$ and $30/40 = .75$).

The three parameters of this distribution are initial Success, number of Trials, and Population size. The conditions outlined in this example contain the values for these parameters: a population Size of 40, sample size (Trials) of 20, and initial Success of 30 (30 of 40 consumers will prefer Brand X). You would enter these values as the parameters of the hypergeometric distribution in Crystal Ball.

The distribution illustrated in [Figure 102](#) shows the probability that x number of consumers prefer Brand X.

Figure 102 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.

Check the data against the conditions of the hypergeometric distribution. The parameter values for the hypergeometric distribution in Crystal Ball are the population size of 1,000, sample size of 200, and an initial success rate of 100 out of 1,000 (or a probability of 10% — 0.1 — of finding tagged horses). The result would be a distribution showing the probability of observing x number of tagged horses.

If you used this distribution in a model created in Crystal Ball 2000.x, you might notice slight data changes when running that model in the current version of Crystal Ball. This is because

some rounding might occur when converting the probability parameter used in previous releases to the success parameter used in this version of Crystal Ball.

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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Logistic Parameters” on page 247](#)
- [“Logistic Conditions” on page 247](#)
- [“Calculating Logistic Parameters” on page 247](#)

Logistic Parameters

Mean, Scale

Logistic Conditions

The logistic distribution is used under these conditions:

- Conditions and parameters are complex. See: Fishman, G. *Springer Series in Operations Research*. NY: Springer-Verlag, 1996.

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.

Calculating Logistic Parameters

There are two standard parameters for the logistic distribution: mean and scale. 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. The scale parameter’s symbol is:

α

To calculate a more exact scale, you can estimate the variance and use the equation:

$$\alpha = \sqrt{\frac{3 \cdot \text{variance}}{\pi^2}}$$

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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Lognormal Parameters” on page 248](#)
- [“Lognormal Conditions” on page 248](#)
- [“Lognormal Example” on page 248](#)
- [“Lognormal Parameter Sets” on page 249](#)

Lognormal Parameters

Location, Mean, Standard Deviation

Lognormal 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

The lognormal distribution can be used to model the price of a particular stock. 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, your losses are limited to your original investment, but your gains are unlimited.

Using historical data, you can determine that the standard deviation of the stock’s price is \$12.

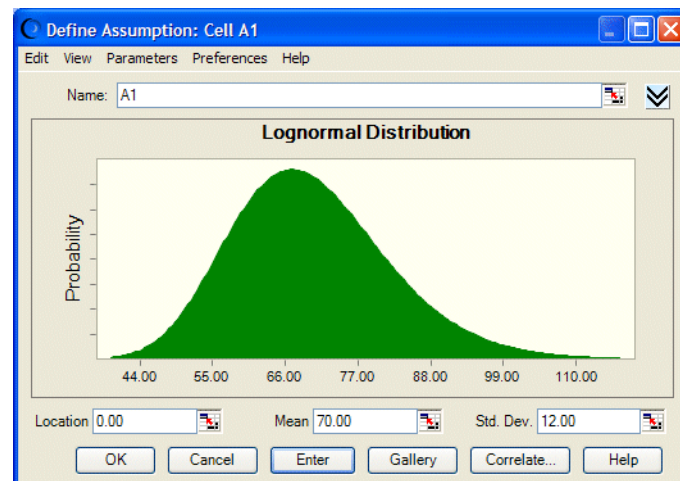
Note: If you have historical data available with which to define a lognormal distribution, it is important to calculate the mean and standard deviation of the logarithms of the data and then enter these log parameters using the Parameters menu (Location, Log Mean, and Log Standard Deviation). Calculating 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 Data”](#) on page 44.

The first step in selecting a probability distribution is matching your data with a distribution’s conditions. Checking the lognormal distribution:

- The price of the stock is unlimited at the upper end but cannot drop below \$0.
- The distribution of the stock price is positively skewed.
- The natural logarithm of the stock price yields a normal distribution.

These conditions match those of the lognormal distribution ([Figure 103](#)).

Figure 103 Lognormal distribution



In the lognormal distribution, 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.

Lognormal Parameter Sets

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 menubar. Note that the location parameter is always in the arithmetic space.

For more information on these alternate parameters, see "Lognormal distribution" in the "Equations and Methods" chapter of the online *Oracle Crystal Ball Statistical Guide*. For more information about this menu, see [“Alternate Parameter Sets”](#) on page 43.

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."

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Maximum Extreme Parameters” on page 250](#)
- [“Maximum Extreme Conditions” on page 250](#)
- [“Calculating Maximum Extreme Parameters” on page 250](#)

Maximum Extreme Parameters

Likeliest, Scale

Maximum Extreme Conditions

The maximum extreme distribution is used under these conditions:

- Conditions and parameters are complex. See: Castillo, Enrique. *Extreme Value Theory in Engineering*. London: Academic Press, 1988.

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.

Calculating Maximum Extreme Parameters

There are two standard parameters for the maximum extreme value distribution: Likeliest and Scale. The Likeliest parameter is the most likely value for the variable (the highest point on the probability distribution, or mode).

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.

The Scale parameter symbol is:

α

To calculate a more exact scale, you can estimate the mean and use the equation:

$$\alpha = \left| \frac{\text{mean} - \text{mode}}{0.57721} \right|$$

Or estimate the variance and use the equation:

$$\alpha = \sqrt{\frac{6 \cdot \text{variance}}{\pi^2}}$$

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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Minimum Extreme Parameters” on page 251](#)
- [“Minimum Extreme Conditions” on page 251](#)
- [“Calculating Minimum Extreme Parameters” on page 251](#)

Minimum Extreme Parameters

Likeliest, Scale

Minimum Extreme Conditions

The minimum extreme distribution is used under these conditions:

- Conditions and parameters are complex. See: Castillo, Enrique. *Extreme Value Theory in Engineering*. London: Academic Press, 1988.

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.

Calculating Minimum Extreme Parameters

There are two standard parameters for the minimum extreme value distribution: Likeliest and Scale. The Likeliest parameter is the most likely value for the variable (the highest point on the probability distribution, or mode).

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.

The Scale parameter symbol is:

α

To calculate a more exact scale, you can estimate the mean and use the equation:

$$\alpha = \left| \frac{\text{mean} - \text{mode}}{0.57721} \right|$$

Or estimate the variance and use the equation:

$$\alpha = \sqrt{\frac{6 \cdot \text{variance}}{\pi^2}}$$

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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Negative Binomial Parameters” on page 252](#)
- [“Negative Binomial Conditions” on page 252](#)
- [“Negative Binomial Example” on page 252](#)

Negative Binomial Parameters

Probability, Shape

Negative Binomial 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.

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.

Matching these conditions with the negative binomial distribution:

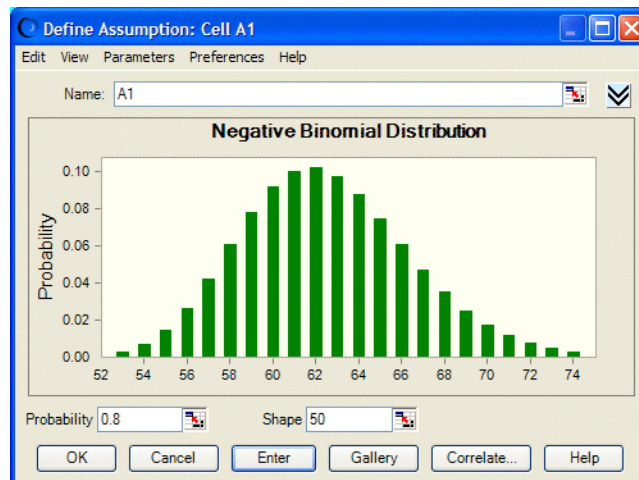
- The number of turbines to produce (trials) is not fixed.

- The manufacturer will continue to produce turbines until the 50th one has passed the spin test.
- The probability of success (80%) is the same for each test.

These conditions match those of the negative binomial distribution.

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 104).

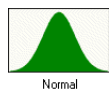
Figure 104 Negative Binomial Distribution



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 your worksheet.

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.

The following sections describe the parameters, conditions, and other features of this distribution:

- “Normal Parameters” on page 254
- “Normal Conditions” on page 254
- “Normal Example” on page 254

Normal Parameters

Mean, Standard Deviation

Normal 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.

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.

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%.

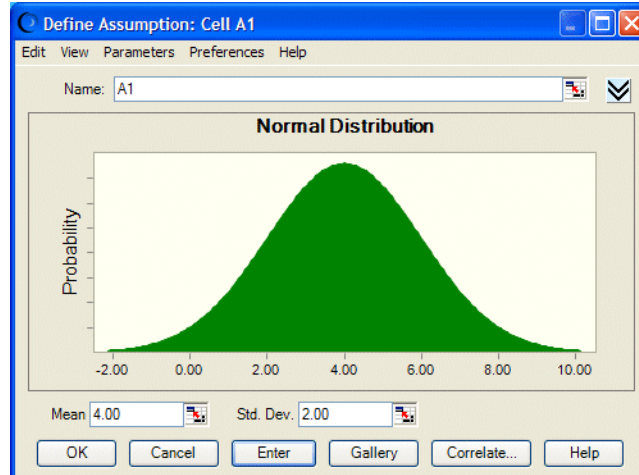
The first step in selecting a probability distribution is matching your data with a distribution's conditions. Checking the normal distribution:

- The mean inflation rate is 4%.
- The inflation rate could as likely be above or below 4%.
- The inflation rate is more likely to be close to 4% than far away. In fact, there is approximately a 68% chance that the rate will lie within 2% of the mean rate of 4%.

These conditions match those of the normal distribution.

The normal distribution uses two parameters: Mean and Standard Deviation. [Figure 105](#) 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 105 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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Pareto Parameters” on page 255](#)
- [“Pareto Conditions” on page 255](#)
- [“Calculating Pareto Parameters” on page 256](#)

Pareto Parameters

Location, Shape

Pareto Conditions

The Pareto distribution is used under these conditions:

- Conditions and parameters are complex. See: Fishman, G. *Springer Series in Operations Research*. NY: Springer-Verlag, 1996.

Note: **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 is displayed.

Calculating Pareto Parameters

There are two standard parameters for the Pareto distribution: Location and Shape. 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 is displayed.

The Shape parameter symbol is (β).

The Location parameter symbol is L .

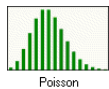
To calculate a more exact shape, you can estimate the mean and use the equation (for shapes greater than 1):

$$\text{mean} = \frac{\beta \cdot L}{\beta - 1}$$

Or estimate the variance and use the following equation (for shapes greater than 2):

$$\text{variance} = \frac{\beta \cdot L^2}{(\beta - 2)(\beta - 1)^2}$$

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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Poisson Parameter” on page 256](#)
- [“Poisson Conditions” on page 257](#)
- [“Poisson Example 1” on page 257](#)
- [“Poisson Example 2” on page 258](#)

Poisson Parameter

Rate

Poisson 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 first step in selecting a probability distribution is matching your data with a distribution's conditions. Checking the Poisson distribution:

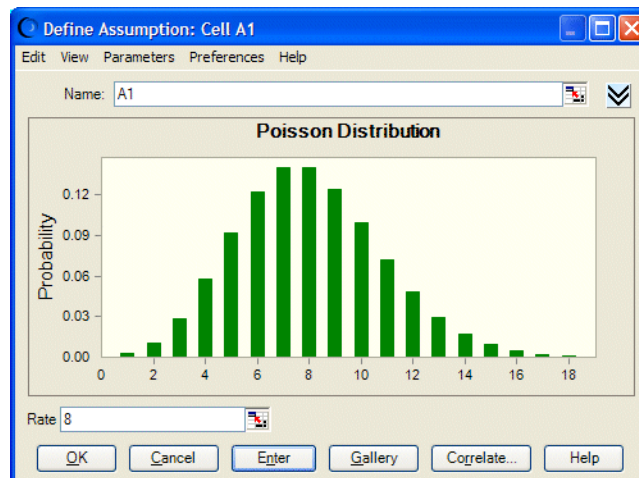
- Any number of defects is possible within 100 square yards.
- The occurrences are independent of one another. The number of defects in the first 100 square yards does not affect the number of defects in the second 100 square yards.
- The average number of defects (8) remains the same for each 100 square yards.

These conditions match those of the Poisson distribution.

The Poisson distribution has only one parameter: Rate. In this example, the value for this parameter is 8 (defects). You would enter this value to specify the parameter of the Poisson distribution in Crystal Ball.

The distribution illustrated in [Figure 106](#) shows the probability of observing x number of defects in 100 square yards of the carbon fiber material.

Figure 106 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 your spreadsheet formulas.

Poisson Example 2

A travel agency wants to describe the number of calls it receives in 10 minutes. The average number of calls in 10 minutes is about 35.

Again, you begin by identifying and entering the values to set the parameters of the Poisson distribution in Crystal Ball. In this example, the conditions show one important value: 35 calls or a rate of 35. The result would be a distribution showing the probability of receiving x number of calls in 10 minutes.

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. For sets of data larger than 30, you can use the normal distribution instead.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Student's \$t\$ Parameters” on page 258](#)
- [“Student's \$t\$ Conditions” on page 258](#)
- [“Student's \$t\$ Example” on page 259](#)

Student's t Parameters

Midpoint, Scale, Degrees of Freedom

Student's t Conditions

The Student's t distribution is used under these conditions:

- Midpoint value is most likely.
- It is symmetrical about the mean.
- Approximates the Normal distribution when degrees of freedom are equal to or greater than 30.

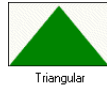
Note: **Note:** The Midpoint parameter is the central location of the distribution (also mode), the x -axis value where you want to place the peak of the distribution. The Degrees of Freedom parameter controls the shape of the distribution. Smaller values result in thicker tails and less mass in the 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.

Student's *t* Example

For examples, see “[Normal Distribution](#)” on page 253. The uses are the same except that the sample degrees of freedom will be < 30 for the Student's *t* distribution.

Triangular Distribution



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.

The following sections describe the parameters, conditions, and other features of this distribution:

- “[Triangular Parameters](#)” on page 259
- “[Triangular Conditions](#)” on page 259
- “[Triangular Example 1](#)” on page 259
- “[Triangular Example 2](#)” on page 260

Triangular Parameters

Minimum, Likeliest, Maximum

Triangular 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 first step in selecting a probability distribution is matching your data with a distribution's conditions. Checking the triangular distribution:

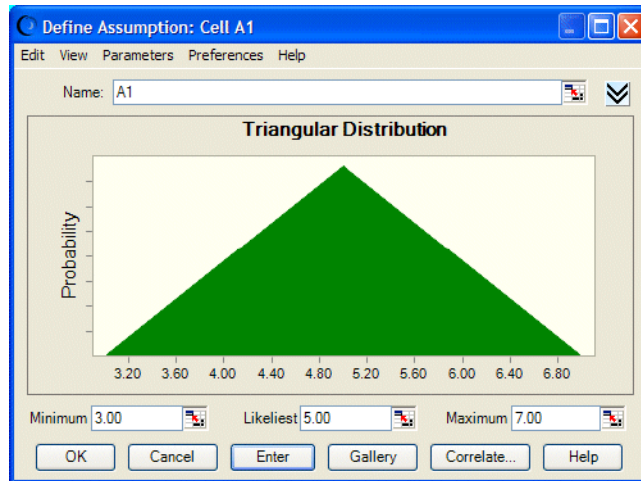
- The minimum number of gallons is 3,000.
- The maximum number of gallons is 7,000.
- The most likely number of gallons (5,000) falls between 3,000 and 7,000, forming a triangle.

These conditions match those of the triangular distribution.

The triangular distribution has three parameters: Minimum, Likeliest, and Maximum. The conditions outlined in this example contain the values for these parameters: 3,000 (Minimum), 5,000 (Likeliest), and 7,000 (Maximum). You would enter these values as the parameters of the triangular distribution in Crystal Ball.

The following triangular distribution (Figure 107 on page 260) shows the probability of x number of gallons being sold per week.

Figure 107 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, always keep inventory at 10 items or more, and prevent inventory from ever rising above 30 items.

Check the triangular distribution conditions:

- The minimum inventory is 10 items.
- The maximum inventory is 30 items.
- The ideal level most frequently on the shelf is 25 items.

These conditions match those of the triangular distribution.

The result would be a distribution showing the probability of x number of items in inventory.

Uniform Distribution



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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Uniform Parameters” on page 261](#)
- [“Uniform Conditions” on page 261](#)
- [“Uniform Example 1” on page 261](#)
- [“Uniform Example 2” on page 262](#)

Uniform Parameters

Minimum, Maximum

Uniform 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 1

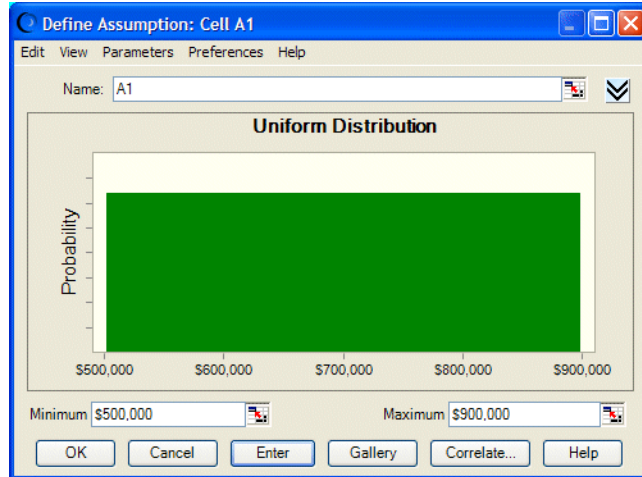
An investment company interested in purchasing a parcel of prime commercial real estate wants to describe the appraised value of the property. The company expects an appraisal of at least \$500,000 but not more than \$900,000. They believe that all values between \$500,000 and \$900,000 have the same likelihood of being the actual appraised value.

The first step in selecting a probability distribution is matching your data with a distribution’s conditions. In this case:

- The minimum value is \$500,000.
- The maximum value is \$900,000.
- All values between \$500,000 and \$900,000 are equally possible.

These conditions match those of the uniform distribution. The uniform distribution has two parameters: the Minimum (\$500,000) and the Maximum (\$900,000). You would enter these values as the parameters of the uniform distribution in Crystal Ball ([Figure 108](#)).

Figure 108 Uniform Distribution



The distribution in Figure 108 shows that all values between \$500,000 and \$900,000 are equally possible.

Uniform Example 2

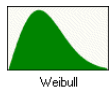
A manufacturer determines that he must receive 10% over production costs—or a minimum of \$3 per unit—to make the manufacturing effort worthwhile. He also wants to set the maximum price for the product at \$6 per unit, so that he can gain a sales advantage by offering the product for less than his nearest competitor. All values between \$3 and \$6 per unit have the same likelihood of being the actual product price.

The first step in selecting a probability distribution is matching your data with a distribution's conditions. Checking the uniform distribution:

- The minimum value is \$3 per unit.
- The maximum value is \$6 per unit.
- All values between \$3 and \$6 are equally possible.

You would enter these values in Crystal Ball to produce a uniform distribution showing that all values from \$3 to \$6 occur with equal likelihood.

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.

The following sections describe the parameters, conditions, and other features of this distribution:

- [“Weibull Parameters” on page 263](#)
- [“Weibull Conditions” on page 263](#)
- [“Weibull Example” on page 263](#)
- [“Calculating Weibull Parameters” on page 263](#)

Weibull Parameters

Location, Scale, Shape

Weibull Conditions

The Weibull distribution is used under these 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 might 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 gas-powered, self-propelled lawn mowers. 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.

Calculating Weibull Parameters

There are three standard parameters for the Weibull distribution: Location, Scale, and Shape. The Location parameter is the lower bound for the variable.

The Shape parameter is a number greater than 0, usually a small number less than 10. When the Shape parameter is less than 3, the distribution becomes more and more positively skewed until it starts to resemble an exponential distribution (shape < 1). At a shape of 3.25, the distribution is symmetrical, and above that value, the distribution becomes more narrow and negatively skewed.

After you select the Location and Shape parameter, you can estimate the Scale parameter. The larger the scale, the larger the width of the distribution.

To calculate a more exact scale, estimate the mean and use the equation:

$$\alpha = \frac{\text{mean} - L}{\Gamma\left(1 + \frac{1}{\beta}\right)}$$

where (alpha) is the scale, (beta) is the shape, L is the location, and (gamma) is the gamma function. You can use the Excel GAMMALN function and Excel Solver to help you calculate this parameter.

For this distribution, there is a 63% probability that x falls between a and a+L.

Or estimate the mode and use the equation:

$$\alpha = \frac{\text{mode} - L}{\left(1 - \frac{1}{\beta}\right)^{\frac{1}{\beta}}}$$

where (alpha) is the scale, (beta) is the shape, and L is the location.

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:

- [“Yes-No Parameters” on page 264](#)
- [“Yes-No Parameters” on page 264](#)
- [“Yes-No Example” on page 265](#)

Yes-No Parameters

Probability of Yes (1)

Yes-No Conditions

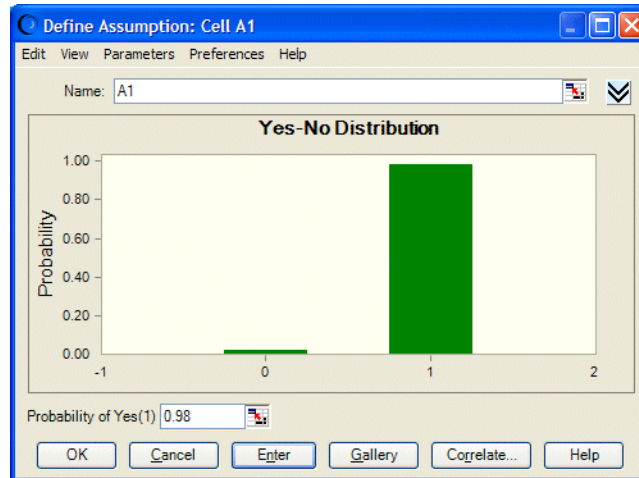
The yes-no distribution is used under these conditions:

- 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 ($0 < p < 1$).
- Trials are independent. Probability is the same from trial to trial.
- The Yes-No distribution is equivalent to the Binomial distribution with one trial.

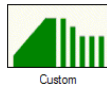
Yes-No Example

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 109](#) shows the probability that the part is good.

Figure 109 Probability of Pulling a Good Part



Using the Custom Distribution



If none of the provided distributions fits your data, you can use the custom distribution to define your own. 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 might want to start Crystal Ball and use it to follow the examples. To follow the custom distribution examples, first create a new Excel workbook then select cells as specified.

The following sections show how to use the custom distribution:

- [“Custom Distribution Example 1” on page 266](#)
- [“Custom Distribution Example 2” on page 268](#)
- [“Custom Distribution Example 3 — Loading Data” on page 271](#)
- [“Entering Tables of Data into Custom Distributions” on page 274](#)
- [“Changes from Crystal Ball 2000.x \(5.x\)” on page 279](#)
- [“Other Important Custom Distribution Notes” on page 279](#)

For summaries of the data entry rules used in the examples plus additional rules, see [“Entering Tables of Data into Custom Distributions”](#) on page 274 and [“Other Important Custom Distribution Notes”](#) on page 279.

Custom Distribution Example 1

► Before beginning example one, open the Custom Distribution dialog as follows:

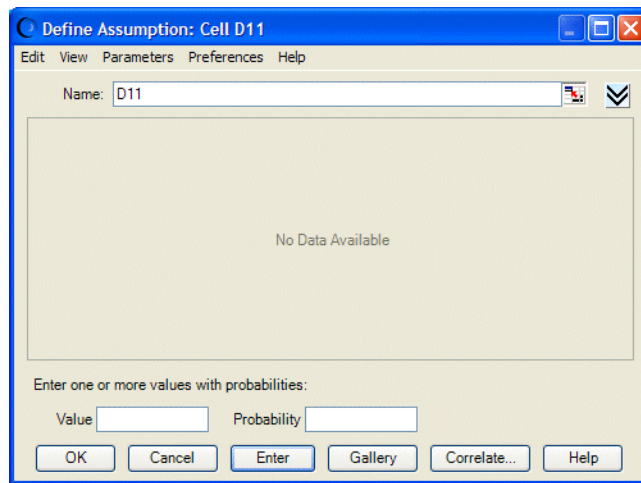
- 1 Click cell **D11**.
- 2 Select **Define**, then **Define Assumption**.

The Distribution Gallery dialog opens.

- 3 Click the **All** category to select it.
- 4 Scroll to find the custom distribution, then click it.
- 5 Click **OK**.

Crystal Ball displays the Define Assumption dialog.

Figure 110 Define Assumption Dialog for Custom Distributions



Using the custom distribution, a company can describe the probable retail cost of a new product. The company decides the cost could be \$5, \$8, or \$10. In this example, you will use the custom distribution to describe a series of single values.

► To enter the parameters of this custom distribution:

- 1 Type **5** in the **Value** field and click **Enter**.

Since you do not specify a probability, Crystal Ball defaults to a relative probability of 1.00 for the value 5. A single value bar displays the value 5.00.

Relative probability means that the sum of the probabilities does not have to add up to 1. So the probability for a given value is meaningless by itself; it makes sense only in relation to the total

relative probability. For example, if the total relative probability is 3 and the relative probability for a given value is 1, the value has a probability of 0.33.

2 Type 8 in the Value field.

3 Click Enter.

Since you did not specify a probability, Crystal Ball defaults to a relative probability of 1.00 (displayed on the scale to the left of the Custom Distribution dialog) for the value 8. A second value bar represents the value 8.

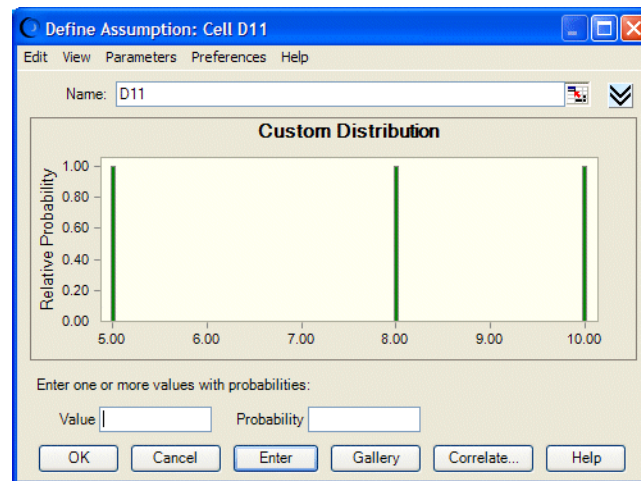
4 Type 10 in the Value field.

5 Click Enter.

Crystal Ball displays a relative probability of 1.00 for the value 10. A third single value bar represents the value 10.

Figure 111 shows the value bars for the values 5, 8, and 10, each with a relative probability of 1.00.

Figure 111 Single Values



Now, each value has a probability of 1. However, when you run the simulation, their total relative probability becomes 1.00 and the probability of each value is reset to .3333.

► To reset their probabilities before you run the simulation, follow these steps:

1 Click the bar with a value of 5.00.

Its value is displayed in the Value field.

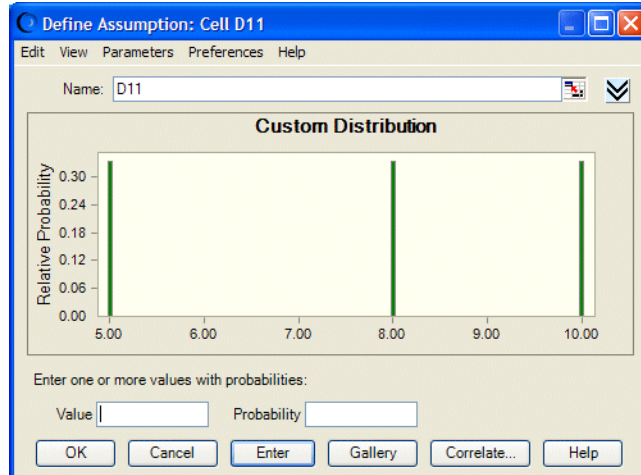
2 Type the probability as the formula =1/3 in the Probability field and click Enter.

You could also enter a decimal — for example, 0.333333 — but the formula is more exact.

3 Follow steps 6 and 7 for the other two bars.

Crystal Ball rescales each value to a relative probability of 0.33 on the left side of the screen (Figure 112).

Figure 112 Single Values with Adjusted Probabilities



Custom Distribution Example 2

► Before beginning example two, clear the values entered in example one as follows:

- 1 Right-click in the chart and choose **Clear Distribution** from the right-click menu.

In this example, you will use the custom distribution to describe a continuous range of values, since the unit cost can take on any value within the specified intervals.

- 2 Choose **Parameters**, then **Continuous Ranges** to enter value ranges.

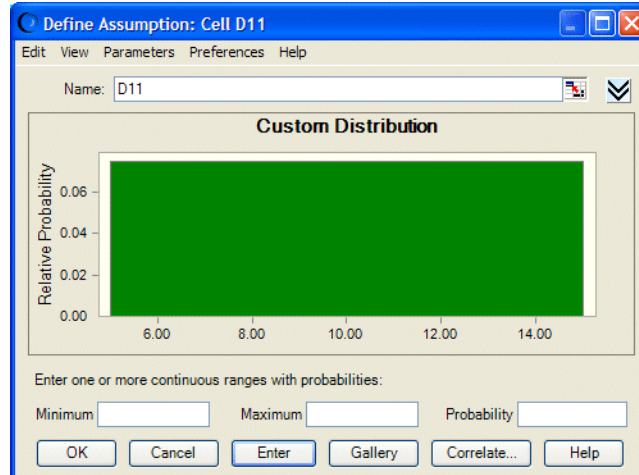
- 3 Enter the first range of values:

- Type 5 in the **Minimum** field.
- Type 15 in the **Maximum** field.
- Type .75 in the **Probability** field. This represents the total probability of all values within the range.

- 4 Click **Enter**.

Crystal Ball displays a continuous value bar for the range 5.00 to 15.00, as in [Figure 113](#), and returns the Crystal Ball cursor to the Minimum field. Notice that the height of the range is 0.075. This represents the total probability divided by the width (number of units) in the range, 10 ([Figure 113](#)).

Figure 113 A Continuous Custom Distribution

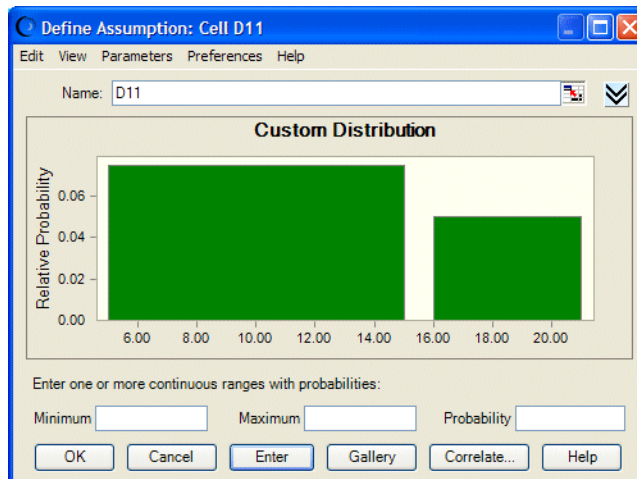


5 Enter the second range of values:

- Type 16 in the **Minimum** field.
- Type 21 in the **Maximum** field.
- Type .25 in the **Probability** field.
- Click **Enter**.

Crystal Ball displays a continuous value bar for the range 16.00 to 21.00. Its height is .050, equal to .25 divided by 5, the number of units in the range. Both ranges now are displayed in the Custom Distribution dialog (Figure 114).

Figure 114 Custom Distribution with Two Continuous Ranges



► You can change the probability and slope of a continuous range, as described in the following steps:

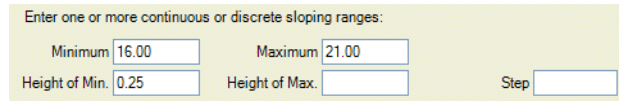
1 Click anywhere on the value bar for the range 16 to 21.

The value bar changes to a lighter shade.

2 Choose Parameters, then Sloping Ranges.

Additional parameters are displayed in the Custom Distribution dialog (Figure 115).

Figure 115 Sloping Range Parameters, Custom Distribution Dialog



3 Set the Height of Min. and Height of Max. equal to what currently is displayed in the chart, 0.05.

This can be an approximate value. The Height of Min. is the height of the range Minimum and the Height of Max. is the height of the range Maximum.

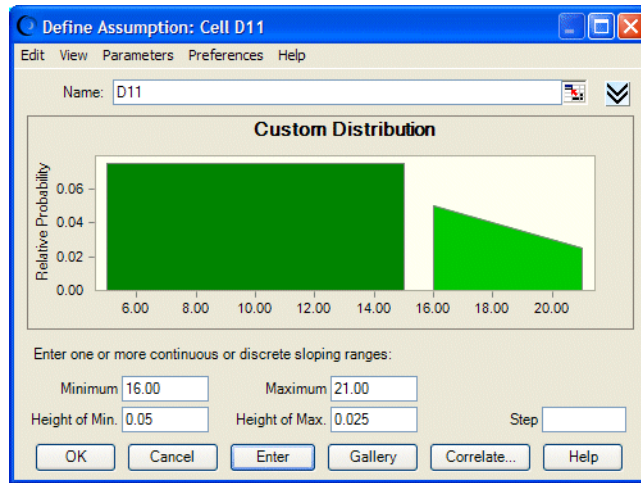
4 Click Enter.

The range returns to its original color and its height is displayed unchanged.

5 Click in the range again to select it and set the Height of Max. to 0.025. Then, click Enter.

The right side of the range drops to half the height of the left, as shown in Figure 116. The range is selected to show its parameters after the change.

Figure 116 Sloping Continuous Value Range

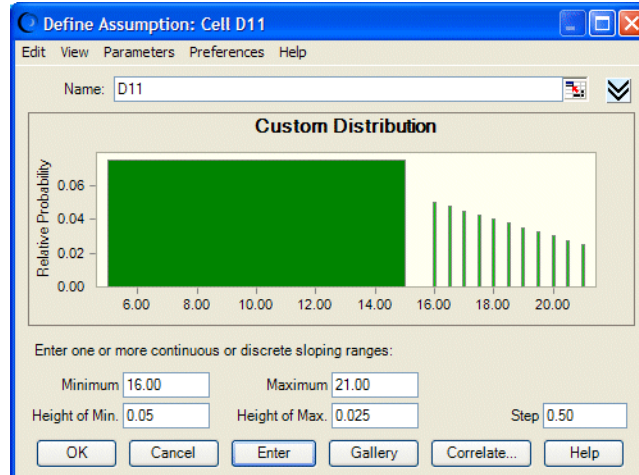


6 Optional: Change the range from continuous to discrete values by adding a step value. Type .5 in the Step field and click Enter.

The sloped range is now discrete. Separate bars are displayed at the beginning and end of the range and every half unit in between (16, 16.5, 17, 17.5 and so on until 21), as shown in Figure 117. If the discrete range represented money, it could only include whole dollars and 50-cent increments.

You can enter any positive number in the Step field. If you entered 1 in this example, the steps would fall on consecutive integers, such as whole dollars. Leave the Step parameter blank for continuous ranges.

Figure 117 A Sloped Discrete Range with Steps of .5



Although the bars have spaces between them, their heights and the width of the range they cover are equal to the previous continuous sloped range and the total probability is the same.

While a second continuous range could have extended from 15 to 20, the second range in this example starts at 16 rather than 15 to illustrate a discrete range because, unlike continuous ranges, discrete ranges cannot touch other ranges.

With Crystal Ball, you can enter single values, discrete ranges, or continuous ranges individually. You also can enter any combination of these three types in the same Custom Distribution dialog as long as you follow these guidelines: ranges and single values cannot overlap one another; however, the ending value of one continuous range can be the starting value of another continuous range.

Custom Distribution Example 3 – Loading Data

This example describes a special feature on the Custom Distribution dialog: the Load Data button, which lets you pull in numbers from a specified cell range (grouped data) on the worksheet. This example is not a hands-on exercise, but the illustrations will guide you through the procedure. After you read this section, you can experiment with your own data by pulling in numbers from specified cell ranges on your worksheet.

In this example, the same company decides that the unit cost of the 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 118](#).

Figure 118 Four-column Custom Data Range

	A	B	C	D	E	F	G
1	Minimum	Maximum	Prob.	Step			
2	\$10	\$20	0.2			Continuous	
3	\$20	\$30	0.1			Continuous	
4	\$40	\$50	0.3			Continuous	
5	\$60	\$80	0.3	1		Discrete	
6	\$90		0.05			Single Value	
7	\$100		0.05			Single Value	
8							

In this case, discrete ranges have the most parameters. So, you can create an assumption, choose Custom Distribution, and then choose Parameters, then Discrete Ranges before loading the data.

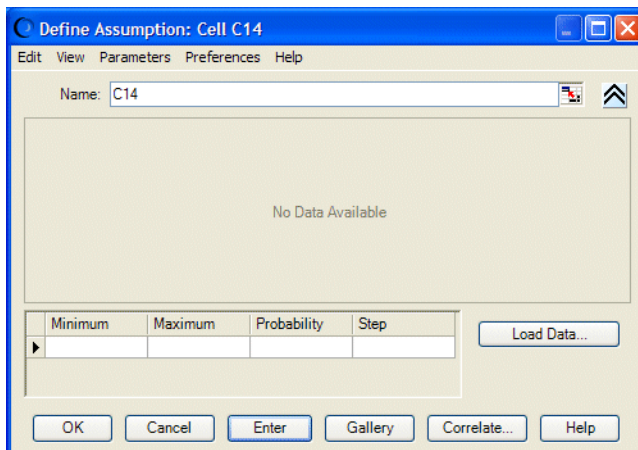
If your data also included discrete sloping ranges, you could choose Parameters, then Sloping Ranges before loading the data. The data table would then have five columns and could accommodate all data types.

► To complete the data load after the Parameters setting has been made:

- 1 Click the **More** button to the right of the **Name** field.

The Custom Distribution dialog expands to include a data table, as shown in [Figure 119](#).

Figure 119 Custom Distribution with Data Table

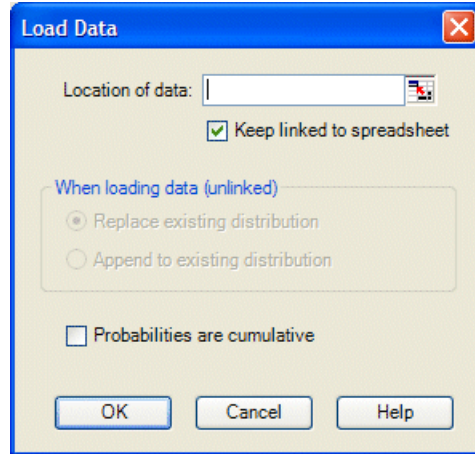


A column is displayed for each parameter in the current set (selected using the Parameters menu). Parameters, then Discrete Ranges was set before viewing the data table, so there is a column in the data table for each discrete range parameter. Because the single value and continuous ranges have subsets of the same group of parameters, their parameters will also fit into the table.

- 2 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, as shown in [Figure 120](#).

Figure 120 Load Data Dialog, Custom Distribution

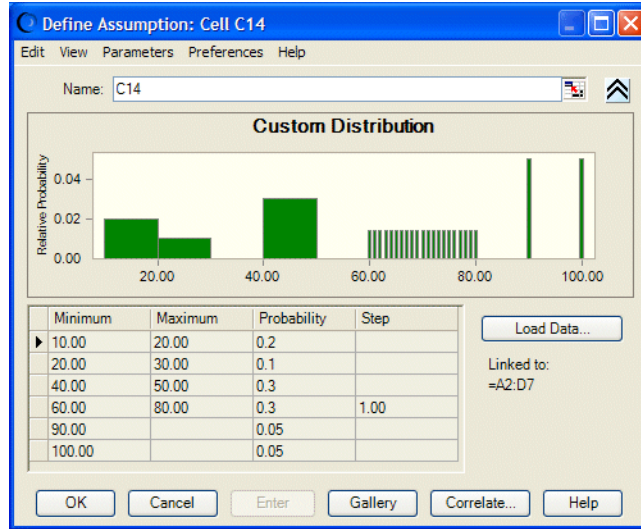


The default settings are appropriate for most purposes, but the following other options are available:

- 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, you can check 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 will need to choose View, then Cumulative Probability to display the data cumulatively in the assumption chart.
- 3** Enter a location range for your data, in this case A2:D7. If the range has a name, you can enter the name preceded by an = sign.
 - 4** 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 121](#).

Figure 121 Custom Data from Worksheet



Entering Tables of Data into Custom Distributions

Follow the rules in this section for loading data. If a data range has been named, you can enter the name (preceded by the = sign) in the range field of the Load Data dialog.

The following sections show how to enter tables of data into custom distributions:

- “Unweighted Values” on page 274
- “Weighted Values” on page 275
- “Mixed Single Values, Continuous Ranges, and Discrete Ranges” on page 276
- “Mixed Ranges, Including Sloping Ranges” on page 276
- “Connected Series of Ranges (Sloping)” on page 277
- “Connected Series of Continuous Uniform Ranges (Cumulative)” on page 278
- “Other Data Load Notes” on page 278

Unweighted Values

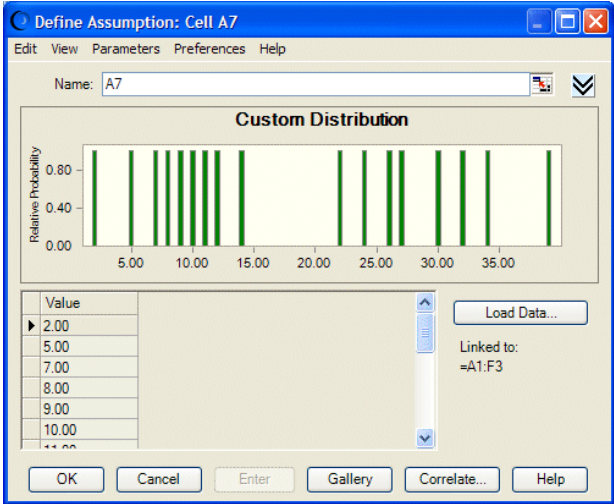
Single values are values that do not define a range. Each value stands alone. For a series of single values with the same probabilities (unweighted values), use a one-column format or more than five columns (Figure 122). The values go in each cell and the relative probabilities are all assumed to be 1.0. Choose Parameters, then Unweighted Values to enter these.

Figure 122 Single Values with the Same Probability

	A	B	C	D	E	F	G
1	2	8	9	22	24	32	
2	5	10	12	26	34	27	
3	7	11	30	14	39		
4							

Figure 123 shows the custom distribution created by loading the unweighted values illustrated in Figure 122.

Figure 123 Unweighted Values Loaded in a Custom Distribution



Weighted Values

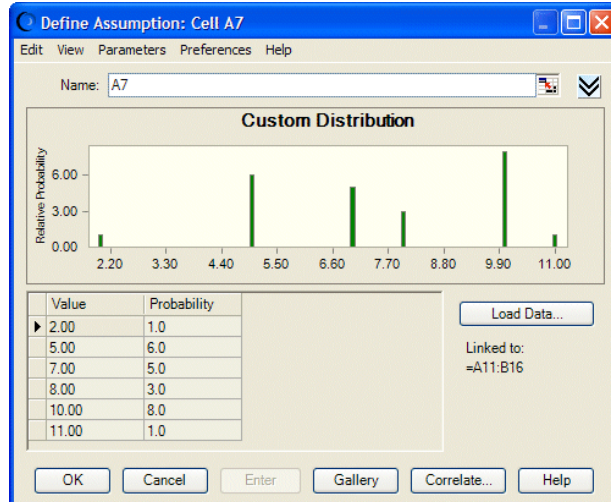
For a series of single values all with different probabilities, use a two-column format. The first column contains single values, the second column contains the probability of each value (Figure 124).

Figure 124 Single Values with Different Probabilities (Weighted Values)

	A	B
10	Value	Weight or Probability
11	2	1
12	5	6
13	7	5
14	8	3
15	10	8
16	11	1

Figure 125 shows the custom distribution created by loading the values illustrated in Figure 124.

Figure 125 Weighted Values Loaded in a Custom Distribution



Mixed Single Values, Continuous Ranges, and Discrete Ranges

For any mixture of single values and continuous ranges, use a three-column format, obtained by choosing Parameters, then Continuous ranges. The three-column format is the same as using the first three columns shown in [Figure 119](#), [Figure 120](#), and [Figure 121](#).

If the mix includes uniform (non-sloping) discrete ranges, use a four-column format, as in the first four columns of [Figure 126](#) and [Figure 127](#). To obtain four columns, choose Parameters, then Discrete Ranges.

Mixed Ranges, Including Sloping Ranges

If sloping ranges are included in a mix of ranges, choose Parameters, then Sloping Ranges to display a five-column data table. The first column contains the range Minimum value, the second column contains the range Maximum value, the third column contains Height of Min. (the relative probability — height — at the Minimum value), the fourth column contains Height of Max. (the relative probability at the Maximum value), and the fifth column contains the Step value for discrete sloping ranges. For continuous sloping ranges the fifth column (Step) is left blank.

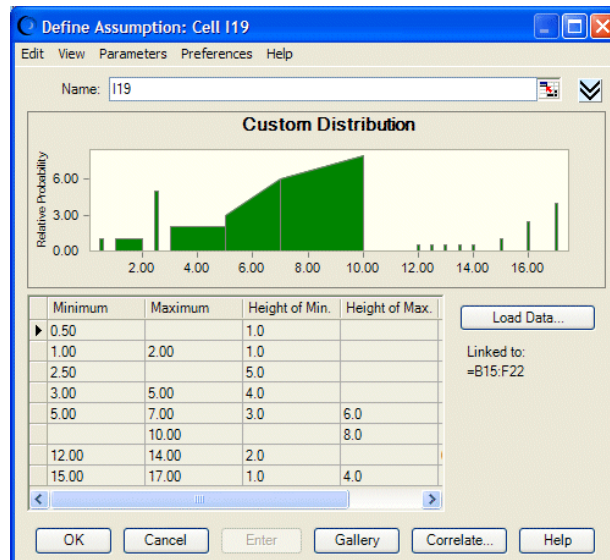
Note that if there are uniform discrete ranges, their first three columns contain the Minimum, Maximum, and Probability as in a four-column format but the fourth column is left blank and Step is entered in the fifth column ([Figure 126](#)).

Figure 126 Mixed Ranges, Including Sloping Ranges

	A	B	C	D	E	F
14	Custom Value Description	Minimum	Maximum	Height of Min.	Height of Max.	Step
	Discrete Value = 0.5, Probability = 1.0	0.5				
15	Continuous Range = 1-2, Uniform Probability = 1.0	1	2			
16	Discrete Value = 2.5, Probability = 5	2.5		5		
17	Continuous Range = 3-5, Uniform Probability = 4	3	5	4		
18	Continuous Range = 5-7, Sloping Probability = 3-6	5	7	3	6	
19	Continuous Connected Range = 7-10, Sloping Probability = 6-8		10		8	
20	Discrete Range = 12-14, Uniform Probability = 2, Step = 0.5	12	14	2		0.5
21	Discrete Range = 15-17, Sloping Probability = 1-4, Step = 1	15	17	1	4	1
22						

Figure 127 shows the custom distribution created by loading the values illustrated in Figure 126.

Figure 127 Mixed Ranges Loaded in a Custom Distribution



Connected Series of Ranges (Sloping)

For a connected series of sloping continuous ranges, choose Parameters, then Sloping Ranges to use a five-column format. The first column contains the lowest Minimum value of the right-most range, the second column contains the Maximum value of each connected range, the third column contains the Height of Min. (relative probability of the Minimum value) if it differs from the previous Height of Max. (otherwise it is left empty), and the fourth column contains Height of Max. (relative probability of the Maximum value) for that range. The fifth column is left blank for continuous ranges but a fifth column is necessary to indicate that these are sloping ranges.

For example, row 20 in [Figure 126](#) shows a connected continuous sloping range. The Minimum cell is blank because the Minimum value is equal to 7, the previous Maximum. The Height of Min. is blank because it is equal to 6, the previous Height of Max.

Connected Series of Continuous Uniform Ranges (Cumulative)

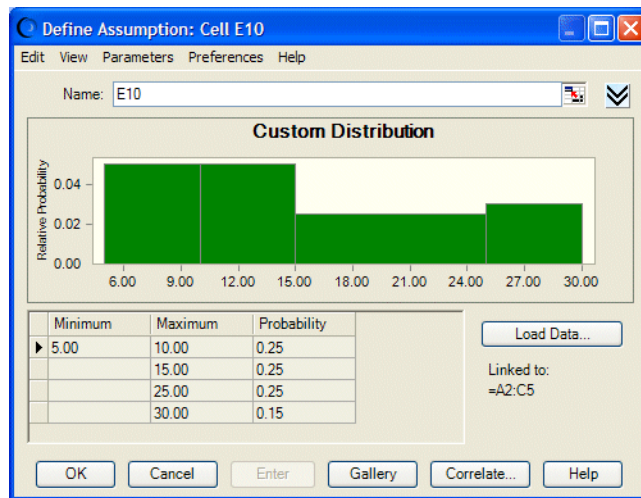
For a connected series of continuous uniform ranges specified using cumulative probabilities, use a three-column format with the common endpoints of the ranges in the second column and the cumulative probabilities in the third column. The first column is left blank except for the minimum value of the first range, beside the maximum in the second column ([Figure 128](#)). Be sure to check Probabilities Are Cumulative in the Load Data dialog.

Figure 128 Connected Continuous Uniform Ranges

	A	B	C
1	Minimum of First Range	Maximums of Continuous Ranges	Cumulative Probabilities
2	5	10	0.25
3		15	0.50
4		25	0.75
5		30	0.90

[Figure 129](#) shows the custom distribution created by loading the data illustrated in [Figure 128](#).

Figure 129 Connected Continuous Uniform Ranges After Loading



Other Data Load Notes

You can load each type of range separately or you can specify the range type with the greatest number of parameters and load all types together. Other rules are.

- Cumulative probabilities are supported for all but sloping ranges.
- Blank probabilities are interpreted as a relative probability of 1.0.

- Ranges or values with 0 probabilities are removed. Sloping ranges with Height of Min. and Height of Max. equal to 0 are also removed.
- For continuous connected ranges, for either endpoint values or probabilities, if the starting cell is blank, the previous end value is used as the start for this range.
- When you load a discrete value that exists in the table already, its probability is incremented by 1. For continuous ranges, this is not allowed; an error message about overlapping ranges opens.


Changes from Crystal Ball 2000.x (5.x)

In versions of Crystal Ball earlier than version 7.0, discrete values with the same probability could be entered in ranges with five columns or more. Now, they cannot be entered in ranges with five columns but can only be entered in single columns or ranges with six or more columns (to distinguish them from sloping ranges).

In versions of Crystal Ball earlier than version 7.0, continuous uniform ranges with cumulative probabilities could be entered in a two-column format. Now a three-column format is required, discussed in [“Connected Series of Continuous Uniform Ranges \(Cumulative\)”](#) on page 278.

The three-column sloping range format used in previous versions of Crystal Ball has been replaced by a five-column format, described in [“Mixed Ranges, Including Sloping Ranges”](#) on page 276 and the section that follows it, [“Connected Series of Ranges \(Sloping\)”](#) on page 277

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, , 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 choose Delete Row.
- To clear all data rows, right-click within the data table and choose 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
 - Choose Edit, then Delete Row or right-click and choose Delete Row.
- Statistics for custom distributions are approximate.

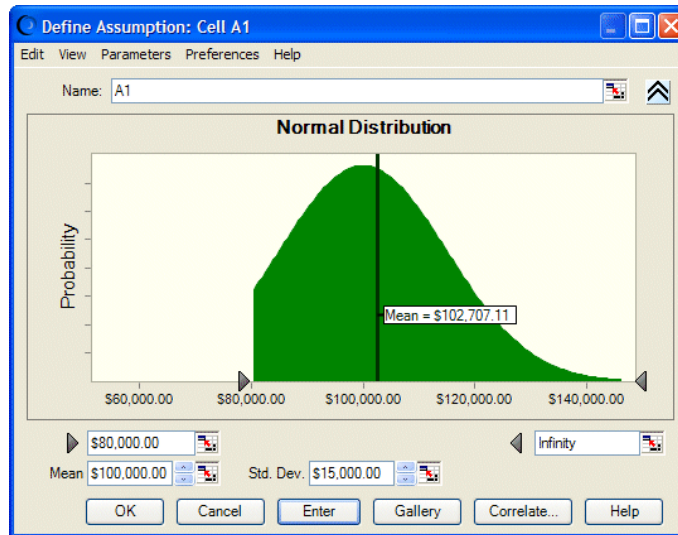
Truncating Distributions

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" the distribution. You can also exclude a middle area of a distribution by crossing over the truncation grabbers to "white out" the portion to exclude.

Note: To display the truncation grabbers, open an assumption in the Define Assumption dialog and click the More button to the right of the assumption name field.

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 would specify the mean as 100,000 and the standard deviation as 15,000 and then move the left grabber to set the limit of 80,000. The grabber "whites out" the portion to exclude, as shown in [Figure 130](#).

Figure 130 Truncated distribution example



Be Aware...

Each adjustment changes the characteristics of the probability distribution. For example, the truncated normal distribution in [Figure 130](#) 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 might differ from the Mean parameter field. The mean line shows the actual mean of the truncated distribution while the Mean parameter field shows the mean of the complete distribution.

Comparing Distributions

Many of the distributions discussed in this chapter are related to one another in various ways. For example, the geometric distribution is related to the binomial distribution. The geometric distribution represents the number of trials until the next success while the binomial represents the number of successes in a fixed number of trials. Similarly, the Poisson distribution is related to the exponential distribution. The exponential distribution represents the amount of time until the next occurrence of an event while the Poisson distribution represents the number of times an event occurs within a given period of time.

In some situations, as when the number of trials for the binomial distribution becomes very large, the normal and binomial distributions become similar. For these two distributions, as the number of binomial trials approaches infinity, the probabilities become identical for any given interval. For this reason, you can use the normal distribution to approximate the binomial distribution when the number of trials becomes too large for Crystal Ball to handle (more than 1000 trials). You also can use the Poisson distribution to approximate the binomial distribution when the number of trials is large, but there is little advantage to this since Crystal Ball takes a comparable amount of time to compute both distributions.

Likewise, the normal and Student's t distributions are related. With Degrees of Freedom, then 30, Student's t closely approximates the normal distribution.

The binomial and hypergeometric distributions are also closely related. As the number of trials and the population size increase, the hypergeometric trials tend to become independent like the binomial trials: the outcome of a single trial has a negligible effect on the probabilities of successive observations. The differences between these two types of distributions become important only when you are analyzing samples from relatively small populations. As with the Poisson and binomial distributions, Crystal Ball requires a similar amount of time to compute both the binomial and hypergeometric distributions.

The yes-no distribution is simply the binomial distribution with Trials = 1.

The Weibull distribution is flexible. Actually, it consists of a family of distributions that can assume the properties of several distributions. When the Weibull shape parameter is 1.0, the Weibull distribution is identical to the exponential distribution. The Weibull 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 might find this effect useful in describing part failures during a burn-in period. When the shape parameter is equal to 2.0, a special form of the Weibull distribution, called the Rayleigh distribution, results. A researcher might find the Rayleigh distribution useful for analyzing noise problems in communication systems or for use in reliability studies. When the shape parameter is set to 3.25, the Weibull distribution approximates the shape of the normal distribution; however, for applications when the normal distribution is appropriate, use it instead of the Weibull distribution.



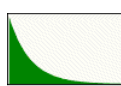
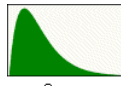

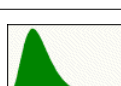
The gamma distribution is also a flexible family of distributions. When the shape parameter is 1.0, the gamma distribution is identical to the exponential distribution. When the shape parameter is an integer greater than one, a special form of the gamma distribution, called the Erlang distribution, results. The Erlang distribution is especially useful in the areas of inventory control and queueing theory, where events tend to follow Poisson processes. Finally, when the shape parameter is an integer plus one half (e.g., 1.5, 2.5, etc.), the result is a chi-square distribution, useful for modeling the effects between the observed and expected outcomes of a random sampling.

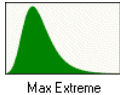


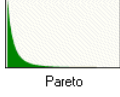



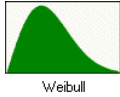
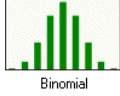

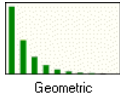
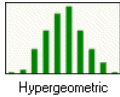
When no other distribution seems to fit your historical data or accurately describes an uncertain variable, you can use the custom distribution to simulate almost any distribution. The Load Data button on the Custom Distribution dialog lets you read a series of data points or ranges from value cells in your worksheet. If you like, you can use the mouse to individually alter the probabilities and shapes of the data points and ranges so that they more accurately reflect the uncertain variable.

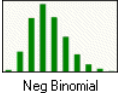
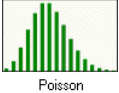

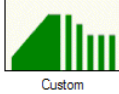
Distribution Parameter Summary

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 Statistical Guide* lists defaults for each parameter value.

Table 10 Distributions and Their Parameters

Distribution		Type	Parameter 1	Parameter 2	Parameter 3	Parameter 4
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		continuous	minimum value	likeliest value	maximum value	N/A
Exponential		continuous	rate (greater than 0)	N/A	N/A	N/A
Gamma		continuous	location	scale (greater than 0)	shape (greater than 0.05 and less than 1000)	N/A
Logistic		continuous	mean value	scale (greater than 0)	N/A	N/A
Lognormal		continuous	location	mean value	standard deviation value	N/A

Distribution		Type	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 0 and 1)	trials (a whole number greater than 0 and less than 1000)	N/A	N/A
Discrete Uniform	 Discrete Uniform	discrete	minimum (integer)	maximum (integer)	N/A	N/A
Geometric	 Geometric	discrete	probability (between 0 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		Type	Parameter 1	Parameter 2	Parameter 3	Parameter 4
Negative binomial		discrete	probability (between 0 and 1)	shape (whole number greater than 0 and less than 1000)	N/A	N/A
Poisson		discrete	rate value (between 0 and 1000)	N/A	N/A	N/A
Yes-No		discrete	probability (between 0 and 1)	N/A	N/A	N/A
Custom		custom	See Appendix A of the current <i>Oracle Crystal Ball User's Guide</i> .	N/A	N/A	N/A

Using Probability Functions

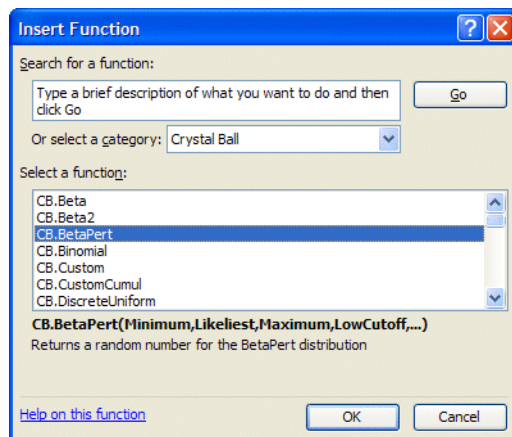
For each of the Crystal Ball distributions, there is an equivalent Excel function. You can enter these functions in your spreadsheet directly instead of defining distributions using the Define Assumption command. Be aware, though, that there are a number of limitations in using these functions. For details, see “[Limitations of Probability Functions](#)” on page 285.

Also see “[Probability Functions and Random Seeds](#)” on page 285 for information about setting a random seed so probability functions can have comparable values.

- To view these functions and their parameters, choose **Insert**, then **Function** in Excel, and then be sure the category is set to Crystal Ball (Figure 131, following).

(In Excel 2007, choose Formulas, then Insert Function.)

Figure 131 Crystal Ball Functions in Excel



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.

Probability Functions and Random Seeds

“[Setting Sampling Preferences](#)” on page 77 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, 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 might 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 “[Sequential Sampling with SIPs](#)” on page 402; Savage, S. et al, 2006).

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:

- “Creating Custom SIP Distributions” on page 286
- “Running Simulations with SIPs” on page 287

Creating Custom SIP Distributions

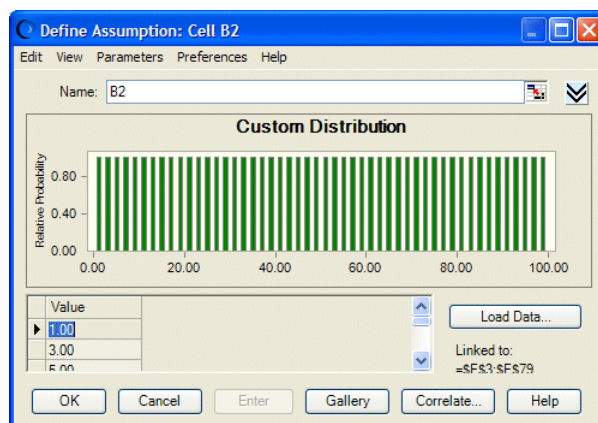
The easiest way to load a SIP or similar set of values into Crystal Ball is to organize the data in a single column in Excel.

- Then, define an assumption in Crystal Ball using a custom distribution:
- 1 Select a cell and choose Define, then Define Assumption.
 - 2 Looking at the list of All distributions in the Distribution Gallery, scroll to the Custom distribution and double-click it.
 - 3 In the Define Assumption dialog, choose Parameters, then Sample Sequentially. This also switches the parameter set to Unweighted Values.
 - 4 Click the More button, , to expand the dialog.
 - 5 Click Load Data and enter the range of data in the Location of Data field.

You can click the cell selector icon to select the range, or you can enter a range name if one has been defined. Be sure Sample Sequentially (instead of randomly) is still checked and click OK.

The distribution is displayed in the Define Assumption dialog, as shown in [Figure 132](#), following.

Figure 132 A SIP loaded into the Define Assumption dialog



Now, you can choose Edit, then Add to Gallery to add the SIP to a custom library (Category) in the Distribution Gallery. You can also use Publish and Subscribe on the Distribution Gallery Categories menu to share the library of SIPs with others.

Running Simulations with SIPs

To run a simulation with one or more SIPs, define assumptions in your model as usual, pulling in SIPs from a library (Category) in the Distribution Gallery as needed. When the simulation runs, Crystal Ball samples the SIP values sequentially instead of randomly. If the simulation has more trials than there are values in the SIP, sampling wraps around to the first value of the distribution. If you are using several SIPs with different numbers of values, a warning is displayed. You can either continue, knowing that mismatched values will be sampled together after sampling wraps for one SIP but not the other, or you can cancel the simulation and correct the problem. You can also run fewer trials so that sampling doesn't need to wrap for any SIP.

Correlations are not allowed for assumptions defined as SIPs, since the correlation structures are implicitly defined for them. Warnings are displayed if correlations are defined for them.

Two Crystal Ball Developer Kit calls, `CB.DefineAssumND` and `CB.GetAssum`, support the new parameter for sequential sampling. The Developer Kit constant is called `cbAsmIsSequential`, a Boolean type.



Accessibility

In This Appendix

Introduction.....	289
Enabling Accessibility for Crystal Ball.....	289
Using the Tab and Arrow Keys in the Crystal Ball User Interface.....	289
Toolbar and Menu Commands: Excel 2003 or Earlier.....	290
Using Crystal Ball in Excel 2007.....	301

Introduction

This appendix describes the accessibility features of Crystal Ball, including keyboard equivalents for application commands.

Enabling Accessibility for Crystal Ball

You do not need to enable accessibility specifically for Crystal Ball; it is always in accessible mode. Crystal Ball output can be extracted to Excel spreadsheets and pasted into PowerPoint slides, which are accessible through Microsoft Office. For information about Excel or PowerPoint accessibility, refer to Microsoft Office product documentation.

Using the Tab and Arrow Keys in the Crystal Ball User Interface

The main Crystal Ball menubar and menu commands are accessed with shortcut keys. After a menu is open, the Tab key or Down Arrow key highlights commands in a circular sequence (tabbing from the last item moves focus to the first item). Using Shift+Tab or the Up Arrow highlights commands in the opposite direction.

Default tab order in the Crystal Ball dialogs flows from left to right, top to bottom. Tab can be used to access the first item of a subwindow in a dialog, but then arrow keys are needed to move to additional items. For example, in the Distribution Gallery, Alt+b displays six basic distributions and places the focus on one of them. Using one of the arrow keys moves focus to an adjacent distribution. Tab moves focus to the OK button at the bottom of the dialog.

Toolbar and Menu Commands: Excel 2003 or Earlier

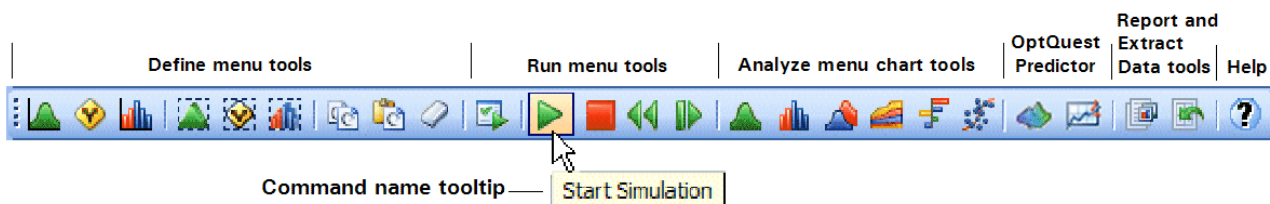
This section describes the Crystal Ball toolbar and associated menu commands for Crystal Ball used with Excel 2003 or earlier supported versions.

Note: The information in this appendix is for those using Crystal Ball with Excel 2003 or earlier. If you are using Crystal Ball with Excel 2007, see [“Using Crystal Ball in Excel 2007” on page 301](#) instead.

Crystal Ball Toolbar

As you point to each of the Crystal Ball toolbar buttons, a tool tip identifies it, as shown in [Figure 133](#).

Figure 133 Crystal Ball Toolbar



Crystal Ball Menus

When Crystal Ball is open in Excel, the following special menus are added to the standard Excel menus:

- Define menu — lets you 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, Correlation Matrix, Tornado Chart, 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, see the tables later in this appendix or view Help from within Crystal Ball using the Help menu or icon.

Distribution Gallery Menus

The Distribution Gallery has the following menus:







- Edit menu — lets you copy, paste, modify, and delete, and print distributions.
- View menu — determines how distributions are displayed in the right pane of the Distribution Gallery and shows or hides the Description pane.
- Categories menu — lets you create, modify, delete, reorder, and share distribution categories.
- Help menu — displays help for the Distribution Gallery or the active distribution.

Shortcut key Combinations in Excel 2003 or Earlier

Use the following Alt+key combinations in Excel 2003 or earlier supported versions of Excel to execute Crystal Ball's Define, Run, Analyze, and Help menu commands and chart windows commands without using the mouse. For shortcut keys in Excel 2007, see [“Shortcut key Combinations in Excel 2003 or Earlier”](#) on page 291.

Note: Oracle tries to avoid keyboard shortcut conflicts; if a key combination is the same as one on an Excel menu, you can use the down arrow key to access the command you want. Commands are listed in the same order in which they are displayed in menus.

Table 11 Define Menu Commands

Button	Command	Command Action	Keystrokes
	Define Assumption	Opens the Define Assumption dialog to define a Crystal Ball assumption cell	Alt+n, a
	Define Decision	Opens the Define Decision Variable dialog to define a Crystal Ball decision variable cell	Alt+n, d
	Define Forecast	Opens the Define Forecast dialog to define a Crystal Ball forecast cell	Alt+n, f
	Select All Assumptions	Selects all assumption cells on the active worksheet	Alt+n, m
	Select All Decisions	Selects all decision variable cells on the active worksheet	Alt+n, i
	Select All Forecasts	Selects all forecast cells on the active worksheet	Alt+n, r
n/a	Select	Selects specified Crystal Ball data cells	Alt+n, s











Button	Command	Command Action	Keystrokes
n/a	Freeze	Excludes specified Crystal Ball data cells from a simulation	Alt+n, z
	Copy Data	Copies Crystal Ball cell definitions to specified cells	Alt+n, c
	Paste Data	Pastes copied Crystal Ball cell definitions into specified cells	Alt+n, p
	Clear Data	Removes Crystal Ball cell definitions from specified cells	Alt+n, e
n/a	Cell Preferences	Opens the Cell Preferences dialog	Alt+n, l

Table 12 Run Menu Commands

Button	Command	Command Action	Keystrokes
	Start Simulation	Begins running a Crystal Ball simulation	Alt+r, s
	Continue Simulation	Resumes a stopped simulation	Alt+r, c
	Reset Simulation	Clears generated simulation data (Crystal Ball data cells remain defined)	Alt+r, r
	Stop Simulation	Stops a simulation	Alt+r, s
	Single Step	Steps through a simulation one trial at a time	Alt+r, i
	OptQuest	Starts OptQuest for results optimization (if available)	Alt+r, o
	Predictor	Starts Predictor for time series analysis	Alt+r, p
n/a	More Tools	Offers the Crystal Ball general and integration tools for additional analysis and charting	Alt+r, t
n/a	Batch Fit (general)	Automatically fits selected continuous probability distributions to multiple data series	Alt+r, t, f
n/a	Bootstrap (general)	Addresses the reliability and accuracy of forecast statistics	Alt+r, t, b
n/a	Correlation Matrix (general)	Rapidly defines and automates correlations of assumptions	Alt+r, t, c




Button	Command	Command Action	Keystrokes
n/a	Data Analysis (general)	Loads data from spreadsheets directly into Crystal Ball forecast charts	Alt+r, t, y
n/a	Decision Table (general)	Evaluates the effects of alternate decisions in a simulation model	Alt+r, t, d
n/a	Scenario Analysis (general)	Displays what inputs created particular outputs	Alt+r, t, s
n/a	Tornado Chart (general)	Individually analyzes the impact of each model variable on a target outcome	Alt+r, t, t
n/a	2D Simulation (general)	Independently addresses uncertainty and variability using a two-dimensional simulation	Alt+r, t, 2
n/a	Enterprise Performance Management (integration)	If available, enables Crystal Ball to run simulations on Enterprise Performance Management data using Smart View	Alt+r, t, m
n/a	Strategic Finance (integration)	If available, opens the Strategic Finance Setup wizard for setting up a workbook that allows Crystal Ball to run with Strategic Finance data	Alt+r, t, e
n/a	Compare Run Modes	Compares simulation run time in Normal and Extreme speed	Alt+r, t, r
n/a	Save Results	Saves current simulation results for later display and analysis	Alt+r, v
n/a	Restore Results	Restores saved results files for display and analysis	Alt+r, e
	Run Preferences	Opens the Run Preferences dialog for setting trials, sampling, and other run preferences	Alt+r, u

Table 13 Analyze Menu Commands

Button	Command	Command Action	Keystrokes
	Assumption Charts	Opens the Assumption Charts dialog so you can display or manage assumption charts	Alt+a, a
	Forecast Charts	Opens the Forecast Charts dialog so you can display or manage forecast charts	Alt+a, f




Button	Command	Command Action	Keystrokes
	Overlay Charts	Opens the Overlay Charts dialog so you can display existing or create new overlay charts	Alt+a, o
	Trend Charts	Opens the Trend Charts dialog so you can display existing or create new trend charts	Alt+a, t
	Sensitivity Charts	Opens the Sensitivity Charts dialog so you can display existing or create new sensitivity charts	Alt+a, s
	Scatter Charts	Opens the Scatter Charts dialog so you can display existing or create new scatter charts	Alt+a, s
	OptQuest Charts	If OptQuest is available, displays OptQuest charts following an optimization	Alt+a, q
	Predictor Charts	If Predictor is available, displays Predictor charts following a time series forecast	Alt+a, p
n/a	Open Selected Cells	Opens associated charts for selected cells	Alt+a, n
n/a	Cascade	Arranges open charts for easier viewing	Alt+a, c
n/a	Close All	Closes all open charts	Alt+a, l
	Create Report	Opens the Create Report dialog so you can create a report with data and charts for your simulation and results	Alt+a, r
	Extract Data	Copies selected simulation data to a worksheet for additional analysis	Alt+a, d

Table 14 Help Menu Commands

Button	Command	Command Action	Keystrokes
n/a	Technical Support	Displays the main Crystal Ball Web page with a link to Crystal Ball technical support	Alt+h, b, t
n/a	Oracle Technology Network	Opens the OTN download index for software and documentation	Alt+h, b, o
	Crystal Ball Help	Displays online help for Crystal Ball	Alt+h, b, h

Button	Command	Command Action	Keystrokes
n/a	Crystal Ball Documentation	Displays a list of available online documentation for Crystal Ball	Alt+h, b, c
n/a	Oracle EPM Documentation	Displays the OTN index for Oracle Enterprise Performance Management documentation, including Crystal Ball	Alt+h, b, d
n/a	Examples Guide	Displays a list of available example models so you can load your choice into Crystal Ball	Alt+h, b, e
n/a	Welcome Screen	Displays a Welcome screen that lets you automatically activate the process capability features for quality programs such as Six Sigma or set percentile preferences frequently used in the oil and gas industry	Alt+h, b, w
n/a	Licensing	Displays the Activate a License dialog so you can enter a serial number and activate a Crystal Ball license	Alt+h, b, l
n/a	About Crystal Ball	Offers version and other information about the current Crystal Ball release including the username	Alt+h, b, b

Table 15 General chart menu commands

Command	Command Action	Keystrokes
Bring Crystal Ball to front	A Microsoft Windows shortcut for switching between applications	Alt+Tab, then Oracle Crystal Ball
Edit, then Copy Chart	Copies the active Crystal Ball chart to the clipboard	Alt+e, c
Edit, then Page Setup	Defines margins, paper size, orientation, and other layout information for printing	Alt+e, u
Edit, then Print Preview	Displays the active chart as it will print with the current Page Setup settings	Alt+e, v
Edit, then Print	Prints the current chart to the specified printer or file	Alt+e, p
View, then Frequency	If available, sets the current chart to show the number or frequency of values occurring in a given interval (bin)	Alt+v, f
View, then Cumulative [Frequency]	If available, sets the current chart to show the number or proportion (percentage) of values less than or equal to a given amount	Alt+v, c

Command	Command Action	Keystrokes
View, then Reverse Cumulative [Frequency]	If available, sets the current chart to show the number or proportion (percentage) of values greater than or equal to a given amount	Alt+v, r
View, then Statistics	If available, sets the current chart to show a set of descriptive statistics for charted values	Alt+v, s
View, then Percentiles	If available, sets the current chart to show percentile information, in 10% increments	Alt+v, p
View, then Goodness Of Fit	If available, sets the current chart to show goodness-of-fit statistics for all fitted distributions	Alt+v, g
View, then Capability Metrics	If available, sets the current forecast chart to show a set of process capability metrics based on the specification limit(s) set for that forecast	Alt+v, a
View, then Split View	If available, sets the current chart to show data, such as statistics, beside the associated chart	Alt+v, l
Preferences, then Chart Preferences	Open the Chart Preferences dialog for changing chart appearance settings	Alt+p, c

Table 16 Assumption-specific chart menu commands

Command	Command Action	Keystrokes
Edit, then Add To Gallery	Adds the active assumption to the Distribution Gallery in the specified category	Alt+e, a
Parameters, then Show Cell References	Shows cell references instead of values when cell references are entered into parameter fields	n/a
Preferences, then Assumption	Opens the Assumption Preferences dialog for choosing a view and controlling chart display	Alt+p, a
Help, then Assumption Help	Displays online help about assumptions	Alt+h, a

Table 17 Forecast-specific chart menu commands

Command	Command Action	Keystrokes
Forecast, then Open Sensitivity Chart	Creates or displays a sensitivity chart for the active forecast	Alt+f, s
Forecast, then Fit Probability Distribution	Uses the default or currently selected distributions and ranking method to fit a distribution to the active forecast chart	Alt+f, f

Command	Command Action	Keystrokes
Preferences, then Forecast	Opens the Forecast Preferences dialog for controlling chart display, distribution fitting specifications, and more	Alt+p, f
Help, then Forecast Help	Displays online help about the forecast chart	Alt+h, f

Table 18 Overlay-specific chart menu commands

Command	Command Action	Keystrokes
Overlay, then Choose Forecasts	Displays the Choose Forecasts dialog to add or remove forecasts from the active overlay chart	Alt+o, c
Overlay, then Remove All	Removes all forecasts from the active overlay chart	Alt+o, r
Overlay, then Fit Probability Distribution	Uses the default or currently selected distributions and ranking method to fit a distribution to all forecasts on the active overlay chart	Alt+o, f
Preferences, then Overlay	Opens the Overlay Preferences dialog for controlling chart display and distribution fitting specifications	Alt+p, o
Help, then Overlay Help	Displays online help about the overlay chart	Alt+h, o

Table 19 Sensitivity-specific chart menu commands

Command	Command Action	Keystrokes
View, then Contribution To Variance Chart	Displays the sensitivity chart in terms of percentage of variance contributed by each assumption	Alt+v, c
View, then Rank Correlation Chart	Displays the sensitivity chart in terms of rank correlation of the assumptions in their effect on the forecast	Alt+v, r
View, then Sensitivity Data	Displays contribution to variance and rank correlation sensitivity measures for each assumption	Alt+v, s
Sensitivity, then Choose Target Forecast	Opens the Choose Forecast dialog so you can choose a forecast for sensitivity analysis	Alt+s, t
Sensitivity, then All Assumptions	Uses all assumptions in creating the sensitivity chart	Alt+s, a
Sensitivity, then Choose Assumptions	Displays the Choose Assumptions dialog so you can choose one or more assumptions for the sensitivity chart	Alt+s, c

Command	Command Action	Keystrokes
Sensitivity, then Open Scatter Chart	Opens a scatter chart using the current target forecast and assumptions	Alt+s, s
Preferences, then Sensitivity	Opens the Sensitivity Preferences dialog for choosing a view, controlling chart display, and more	Alt+p, s
Help, then Sensitivity Help	Displays online help about the sensitivity chart	Alt+h, s

Table 20 Trend-specific chart menu commands

Command	Command Action	Keystrokes
View, then Centered On Median	Displays certainty bands centered on the median of each forecast value	Alt+v, m
View, then Cumulative	Displays certainty bands anchored at the lower end of the forecast range; shows the certainty that the forecast values will be at or below a given value	Alt+v, c
View, then Reverse Cumulative	Displays certainty bands anchored at the higher end of the forecast range; shows the certainty that the forecast values will be at or above a given value	Alt+v, r
Trend, then Choose Forecasts	Opens the Choose Forecasts dialog so you can choose forecasts to use in the trend chart	Alt+t, f
Trend, then Remove All	Removes all forecasts from the active trend chart	Alt+t, r
Preferences, then Trend	Opens the Trend Preferences dialog for choosing a view and controlling chart display	Alt+p, t
Help, then Trend Help	Displays online help about the trend chart	Alt+h, t

Table 21 Scatter-specific chart menu commands

Command	Command Action	Keystrokes
View, then Scatter View (1xN)	Plots selected assumptions and/or forecasts against a target assumption or forecast	Alt+v, s
View, then Matrix View (NxN)	Plots selected assumptions and/or forecasts against each other	Alt+v, m
Scatter, then Choose Data	Opens the Choose Data dialog so you can choose assumptions and forecasts to use in the scatter chart	Alt+s, d

Command	Command Action	Keystrokes
Scatter, then Remove All	Removes all assumptions and forecasts from the active scatter chart	Alt+s, r
Preferences, then Scatter	Opens the Scatter Preferences dialog for choosing a view and controlling chart display	Alt+p, s
Help, then Scatter Help	Displays online help about the scatter chart	Alt+h, t

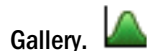
Distribution Gallery Shortcut Keys

Note: In Excel 2007, 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 icon, a list of All, Basic, or Favorite distributions opens, depending on the active category in the Distribution Gallery.

You can use the keyboard to select distributions in the Distribution Gallery.

► To do this:

- 1 Choose **Define**, then **Define Assumption** or click the **Define Assumption** button to open the **Distribution Gallery**.



- 2 Type the first letter of the name of the target distribution, for example **n** for **normal**.

If more than one distribution starts with that letter, keep pressing to cycle through the distributions.

- 3 When the target distribution is highlighted, type **Alt+o** (for **OK**) to open its **Define Assumption** dialog.

Or, you can press **Alt+f** to fit a distribution to it or **Alt+c** to cancel the selection and close the dialog.

► To apply a shortcut key to a custom category:

- 1 Open the **Crystal Ball Gallery**.

- 2 Edit the category name:

For a new category, select **Categories**, then **New**. In the **Name** field, enter an ampersand (&) before a letter in your category name. That letter becomes the shortcut key. Click **OK** to save.

For an existing category, select **Categories**, then **Properties**, add the ampersand to the existing name, and click **OK** to save.

Each category should use a unique shortcut key. The shortcut keys for the default categories are: **Alt+b** for the **Basic** category, **Alt+a** for **All**, and **Alt+i** for **Favorites**.

Chart Preference Shortcut Keys

Double-clicking in a chart area opens the Chart Preferences dialog.

Table 22 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 theoretical probability distribution for assumptions, and the generated values for forecasts and overlay charts.

Table 22 Shortcut Keys for Chart Preferences

Shortcut key	Command Equivalent	Description
Ctrl+d	View menu; Preferences, then <i>chartname</i> , then <i>chartname</i> Window, then View	Cycles through chart views – Frequency, Cumulative Frequency, Reverse Cumulative Frequency (for assumption and forecast charts)
Ctrl+b; Ctrl+g	Preferences, then Chart, then General, then Density	Cycles through bins or group interval values to adjust the number of data bins used to create the chart
Ctrl+l	Preferences, then Chart, then General, then Gridlines	Cycles through gridline settings: None, Horizontal, Vertical, Both
Ctrl+t	Preferences, then Chart, 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+3	Preferences, then Chart, then General, then 3D Chart	Cycles between two-dimensional and three-dimensional chart display
Ctrl+m	Preferences, then Chart, then Chart Type, then Marker Lines	Cycles through central tendency marker lines: None, Mean, Median, Mode (except for sensitivity and trend charts)
Ctrl+n	Preferences, then Chart, then General, then Legend	Toggles the legend display on and off
Ctrl+p	Preferences, then Chart, then Chart Type, then Marker Lines, then Percentiles	Cycles through percentile markers: None, 10%, 20%,...90%
Spacebar	View menu; Preferences, then <i>chartname</i> , then <i>chartname</i> Window, then View	Cycles through window views when Excel is not in Edit mode: Chart, Statistics, Percentiles, Goodness Of Fit (if distribution fitting is selected – except for trend charts), and Capability Metrics (if process capability features are activated)

Using Crystal Ball in Excel 2007

Introduction

This section describes the Crystal Ball ribbon for those who are using Crystal Ball with Excel 2007. If you are using an earlier version of Excel, see [“Toolbar and Menu Commands: Excel 2003 or Earlier” on page 290](#) instead.

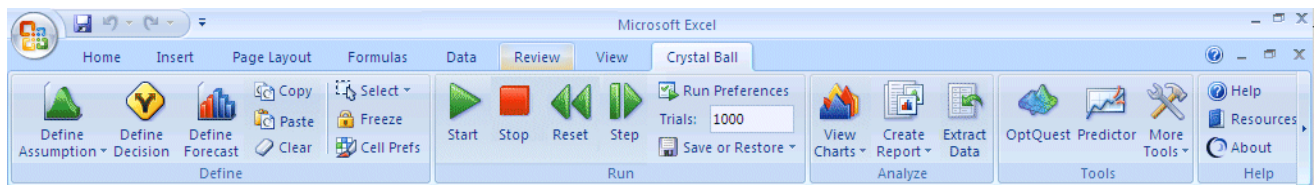
See [“Compatibility and File Conversion Issues” on page 308](#) for important information about using Crystal Ball models created in earlier versions of Excel with Excel 2007 or the Excel 2007 Compatibility Pack.

Crystal Ball Ribbon in Excel 2007

[“Toolbar and Menu Commands: Excel 2003 or Earlier” on page 290](#) describes the Crystal Ball toolbar and menus in Excel 2003 and earlier versions of Excel. While Crystal Ball’s functionality is the same in Excel 2007, the command structure or interface is different.

In earlier versions of Excel, including Excel 2003, Crystal Ball adds three menus to the Excel menubar. Many menu commands are also accessible through icons on the Crystal Ball toolbar. In Excel 2007, there is a single Crystal Ball ribbon that contains all the commands. The ribbon is a combination menubar and toolbar. It contains both menus and tool icons. [Figure 134](#) shows the Crystal Ball ribbon in Excel 2007.

Figure 134 Crystal Ball Ribbon in Excel 2007



The Crystal Ball ribbon contains five groups, described in the following sections:

- [“Define Commands” on page 301](#)
- [“Run Commands” on page 302](#)
- [“Analyze Commands” on page 302](#)
- [“Tools Commands” on page 302](#)
- [“Help Commands” on page 302](#)

Define Commands

The Define commands specify settings for the three types of Crystal Ball data cells: assumptions, decision variables, and forecasts.

You can also:

- 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

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

Analyze Commands

You can use the Analyze commands to:

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

Tools Commands

You can use the Tools commands to access the Crystal Ball tools, Predictor, and OptQuest with an appropriate license.

Help Commands

The Help commands display online help, online documents, example models, the Crystal Ball About Box, and more.

Shortcut Key Combinations in Excel 2007

The following tables list Alt+key combinations in Excel 2007 so you can use the Define, Run, Analyze, and Help commands in the Crystal Ball ribbon without using the mouse:

- [Table 23 on page 303](#)
- [Table 24 on page 304](#)
- [Table 25 on page 304](#)
- [Table 27 on page 307](#)

For shortcut keys in Excel 2003, see [“Shortcut key Combinations in Excel 2003 or Earlier” on page 291](#).

Note: Oracle tries to avoid keyboard shortcut conflicts; if a key combination is the same as one on an Excel menu, you can use the down arrow key to access the command you want.

Table 23 Define Commands

Button	Command	Command Action	Keystrokes
	Define Assumption	Opens the Define Assumption dialog to define a Crystal Ball assumption cell	Alt+c, a
	Define Decision	Opens the Define Decision Variable dialog to define a Crystal Ball decision variable cell	Alt+c, d
	Define Forecast	Opens the Define Forecast dialog to define a Crystal Ball forecast cell	Alt+c, f
	Copy	Copies Crystal Ball cell definitions to specified cells	Alt+c, c
	Paste	Pastes copied Crystal Ball cell definitions into specified cells	Alt+c, p
	Clear	Removes Crystal Ball cell definitions from specified cells	Alt+c, e
	Select	Offers the Select menu, to select assumption, decision variable, and forecast cells	Alt+c, l
	Select All Assumptions	Selects all assumption cells on the active worksheet	Alt+c, l, a
	Select All Decisions	Selects all decision variable cells on the active worksheet	Alt+c, l, d
	Select All Forecasts	Selects all forecast cells on the active worksheet	Alt+c, l, f
n/a	Select Some...	Selects specified Crystal Ball data cells	Alt+c, l, s
	Freeze	Excludes specified Crystal Ball data cells from a simulation	Alt+c, g
	Cell Prefs	Opens the Cell Preferences dialog to change the appearance and other properties of Crystal Ball data cells	Alt+c, y

Table 24 Run Commands












Button	Command	Command Action	Keystrokes
	Start	Begins running a Crystal Ball simulation and resumes a stopped simulation.	Alt+c, s
	Stop	Stops a simulation	Alt+c, o
	Reset	Clears generated simulation data (Crystal Ball data cells remain defined)	Alt+c, r
	Step	Steps through a simulation one trial at a time	Alt+c, i
n/a	Save Results	Saves current simulation results for later display and analysis	Alt+c, w, v
n/a	Restore Results	Restores saved results files for display and analysis	Alt+c, w, e
	Run Preferences	Opens the Run Preferences dialog for setting trials, sampling, and other run preferences	Alt+c, u

Table 25 Analyze Commands

Button	Command	Command Action	Keystrokes
	View Charts	Offers a gallery of charts and chart window management commands; use the Down arrow (↓) to choose a specific chart	Alt+c, v
	Assumption Charts	Opens the Assumption Charts dialog so you can display or manage assumption charts	Alt+c, v
	Forecast Charts	Opens the Forecast Charts dialog so you can display or manage forecast charts	Alt+c, v
	Sensitivity Charts	Opens the Sensitivity Charts dialog so you can display existing or create new sensitivity charts	Alt+c, v
	Overlay Charts	Opens the Overlay Charts dialog so you can display existing or create new overlay charts	Alt+c, v
	Trend Charts	Opens the Trend Charts dialog so you can display existing or create new trend charts	Alt+c, v

Button	Command	Command Action	Keystrokes
	Scatter Charts	Opens the Scatter Charts dialog so you can display or manage scatter charts	Alt+c, v
	OptQuest Charts	If OptQuest is available, opens OptQuest charts following an optimization	Alt+c, v
	Predictor Charts	Opens Predictor charts following a time series forecast	Alt+c, v
n/a	Open Selected Cells	Opens associated charts for selected cells	Alt+c, v, n
n/a	Cascade	Arranges open charts for easier viewing	Alt+c, v, c
n/a	Close All	Closes all open charts	Alt+c, v, l
	Create Report	Lets you create a report of simulation results by choosing from a gallery of predefined and custom report types	Alt+c, m
	Assumptions Report	Creates a report of only assumption results	Alt+c, m, a
	Decision Variables Report	Creates a report of only decision variable results	Alt+c, m, d
	Forecasts Report	Creates a report of only forecast results	Alt+c, m, f
	Full Report	Creates a report of all simulation results	Alt+c, m, r
	Index Report	Creates a report of only Crystal Ball data cell names and locations	Alt+c, m, i
	OptQuest Report	If OptQuest is available, creates a report of selected OptQuest results following an optimization	Alt+c, m, o
	Predictor Report	Creates a report of selected Predictor results following a time series forecast	Alt+c, m
	Custom Report	Creates a report with only selected simulation results	Alt+c, m, c
n/a	Report Preferences	Sets various report options	Alt+c, m, p


Button	Command	Command Action	Keystrokes
	Extract Data	Copies selected simulation data to a worksheet for additional analysis	Alt+c, x

Table 26 Tools Commands

Button	Command	Command Action	Keystrokes
	OptQuest	Starts OptQuest for results optimization	Alt+c, q
	Predictor	Starts Predictor for time series analysis	Alt+c, t, p
	More Tools	Offers the Crystal Ball general tools and integration tools for additional analysis and charting	Alt+c, t
	Batch Fit (general)	Automatically fits selected continuous probability distributions to multiple data series	Alt+c, t, f
	Bootstrap (general)	Addresses the reliability and accuracy of forecast statistics	Alt+c, t, b
	Correlation Matrix (general)	Rapidly defines and automates correlations of assumptions	Alt+c, t, c
	Data Analysis (general)	Imports data directly from spreadsheets into Crystal Ball forecasts for further analysis	Alt+c, t, a
	Decision Table (general)	Evaluates the effects of alternate decisions in a simulation model	Alt+c, t, d
	Scenario Analysis (general)	Displays what inputs created particular outputs	Alt+c, t, s
	Tornado Chart (general)	Individually analyzes the impact of each model variable on a target outcome	Alt+c, t, t
	2D Simulation (general)	Independently addresses uncertainty and variability using a two-dimensional simulation	Alt+c, t, 2
	Enterprise Performance Management (integration)	If available, enables Crystal Ball to run simulations on Enterprise Performance Management data using Smart View	Alt+c, t, m






Button	Command	Command Action	Keystrokes
	Strategic Finance Setup (integration)	If available, opens the Strategic Finance Setup wizard for setting up a workbook that allows Crystal Ball to run with Strategic Finance data	Alt+c, t, e
	Compare Run Modes	Compares simulation run time in Normal and Extreme speed (if available)	Alt+c, t, r

Table 27 Help Commands

Button	Command	Command Action	Keystrokes
	Help	Displays online help for Crystal Ball	Alt+c, h
	Resources	Displays a Crystal Ball technical support, Oracle OTN for downloads, Crystal Ball and EPM documentation, examples, the Welcome screen, the licensing dialog, and the Crystal Ball About box	Alt+c, n
n/a	Technical Support	Opens the Crystal Ball Web page with a link to technical support	Alt+c, n, t
n/a	Oracle Technology Network	Opens the OTN download index for software and documentation	Alt+c, n, o
n/a	Crystal Ball Documentation	Displays a list of available online documentation for Crystal Ball	Alt+c, n, c
n/a	Oracle EPM Documentation	Displays the OTN index for Oracle Enterprise Performance Management documentation, including Crystal Ball	Alt+c, n, d
n/a	Examples Guide	Displays a list of available example models so you can load your choice into Crystal Ball	Alt+c, n, e
n/a	Welcome Screen	Displays a Welcome Screen that lets you automatically activate the process capability features for quality programs such as Six Sigma or set percentile preferences frequently used in the Oil and Gas industry.	Alt+c, n, w
n/a	Licensing	Displays the Activate a License dialog for entering a Crystal Ball serial number and activating a license	Alt+c, n, l

Button	Command	Command Action	Keystrokes
	About [Crystal Ball]	Offers version and other information about the current Crystal Ball release including the username	Alt+c, b

The following information concerns menus and commands in the Distribution Gallery and chart windows. This information is the same for all supported versions of Windows:

- [Table 15, “General chart menu commands ,” on page 295](#)
- [Table 16, “Assumption-specific chart menu commands ,” on page 296](#)
- [Table 17, “Forecast-specific chart menu commands ,” on page 296](#)
- [Table 18, “Overlay-specific chart menu commands ,” on page 297](#)
- [Table 19, “Sensitivity-specific chart menu commands ,” on page 297](#)
- [Table 20, “Trend-specific chart menu commands ,” on page 298](#)
- [Table 21, “Scatter-specific chart menu commands ,” on page 298](#)

Distribution Gallery Shortcut Keys

These are described in [“Distribution Gallery Shortcut Keys” on page 299](#).

Chart Preference Shortcut Keys

These are described in [“Chart Preference Shortcut Keys” on page 300](#).

Compatibility and File Conversion Issues

Excel 2007 workbooks can be saved in several file formats that are significantly different from those for previous versions of 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 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 Excel 2007.
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 Excel 2007 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.



Using the Extreme Speed Feature

In This Appendix

Overview	311
Compatibility Issues	312
Numerical Differences and the Compare Run Modes Tool	318
Other Important Differences	319
Maximizing the Benefits of Extreme Speed	321

Overview

Extreme speed, available in Crystal Ball Decision Optimizer, runs simulations up to 100 times faster than Normal speed. With Extreme speed, you won't need to wait for simulation results or compromise on the number of trials you run. Extreme speed makes it more practical to use Crystal Ball tools that run multi-simulations or to seek optimal solutions with OptQuest in a reasonable length of time.

The Extreme Speed feature uses PSI Technology, a high-speed, Excel-compatible Polymorphic Spreadsheet Interpreter for running simulations on workbooks. This technology was developed by Frontline Systems, the maker of Excel's Solver add-in. PSI Technology supports nearly all of the 320 standard Excel functions, including the financial, statistical, and engineering functions that are part of the Analysis Toolpak.

By default, 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 312](#) below, 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 (see [“Setting Speed Preferences” on page 78](#) for details).

This section contains the following main topics:

- [“Compatibility Issues” on page 312](#)
- [“Numerical Differences and the Compare Run Modes Tool” on page 318](#)
- [“Other Important Differences” on page 319](#)
- [“Maximizing the Benefits of Extreme Speed” on page 321](#)

Note: Because the Extreme Speed feature uses the Polymorphic Spreadsheet Interpreter, certain Extreme Speed functions may return slightly different results than the corresponding Excel function for extreme values of any input arguments. For example, this can occur with statistical and inverse distribution functions.

Compatibility Issues

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 your 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 Excel, or you can change your spreadsheet model to correct the incompatibility.

This section lists functions and formula constructs that are not compatible with Extreme speed and suggests workarounds. Besides the issues listed below, some differences may also exist due to undocumented Excel behaviors, changes in the newest versions of Excel, and so on. Also, small differences in the last few decimal places of certain built-in function values should be expected, due to minor algorithmic differences in the way formulas might be computed.

It is important to note that incompatibilities in functions and formula constructs only concern the cells involved in the calculation of a forecast cell. If there are incompatibilities in cells that are not part of that calculation path, these are not detected and the simulation is allowed to run.

This section discusses the following compatibility issues:

- [“Multiple-Workbook Models” on page 312](#)
- [“Circular References” on page 313](#)
- [“Crystal Ball Excel Functions” on page 313](#)
- [“User-Defined Functions” on page 314](#)
- [“Running User-Defined Macros” on page 316](#)
- [“Special Functions” on page 316](#)
- [“Undocumented Behavior of Standard Functions” on page 316](#)
- [“Incompatible Range Constructs” on page 316](#)
- [“Data Tables” on page 318](#)

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 multi-workbook model containing Crystal Ball data into a single workbook.

Circular References

Circular references within a model are supported as long as Iteration is checked on the Tools, then Options, then Calculation tab in Excel.

(In Excel 2007, click the Office button and choose Excel Options, then Formulas, and then check Enable Iterative Calculation in the Calculation Options group.)

If Crystal Ball detects a circular reference and Iteration is not checked, this error is displayed:

- Example message: "Circular reference detected at cell [Book1.xls]Sheet1!A1. (Code #5523)"
- Workaround: Stop the simulation and check Iteration on the Tools, then Options, then Calculation tab.

In Extreme speed, circular references with short Iteration setting may not match 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. Check 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 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 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

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 Excel.

This section includes the following topics:

- [“Pure Functions” on page 314](#)
- [“Range Arguments” on page 314](#)
- [“Volatile Functions and Array Arguments” on page 315](#)

Pure Functions

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. A function that is not "pure" might reference global data not passed as an argument. For example, it might get the value of a worksheet cell or a defined name and use this as an input to compute the function value. If the global data depends on the assumptions — if, for example, it is a worksheet cell with a formula computed from the assumptions — it will have a distribution of values in Normal Speed, but it will appear deterministic (have a single value) in Extreme Speed. This is because the worksheet cells change on every trial in Normal Speed, but they do not change in Extreme Speed.

Range Arguments

Range arguments in user-defined functions are only compatible with Extreme Speed when they are handled as Variant types. For example, for a function called on the worksheet as =MyFunc(A1:E4, 5, 4):

```

Function MyFunc (MyData As Variant, Rows As Long, Cols As Long) As Double
    For I = 1 to Rows
        For J = 1 to Cols
            MsgBox MyData(I, J) 'or otherwise work with the cell range as
an array
        Next J
    Next I
End Function

```

Volatile Functions and Array Arguments

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.

When a user-defined function is encountered in Extreme Speed, Crystal Ball first checks to see if the function is Volatile. If Crystal Ball is denied access to the VBA project and the user-defined function is not passing array or cell range arguments, Crystal Ball treats the function as Volatile.

If access to the project is denied and the call is passing array or cell range arguments, the following message is displayed:

Cannot interpret a user-defined function with array arguments. You must first check the 'Trust Access to Visual Basic Project' checkbox in Excel's macro security settings dialog. See Appendix C in the User's Guide for more information about this error.

Cause: The Excel Volatile property has not been set.

- ▶ In that case, in order for Extreme Speed to determine the state of the Volatile property in Excel 2002 (XP) and later, you must first make the following setting in Excel:

- 1 Go to the Tools, then Options panel.
- 2 Click the Security tab.
- 3 Click the Macro Security button.
- 4 Click the Trusted Publishers tab.
- 5 Check Trust Access To Visual Basic Project.

In Excel 2007, you should not encounter this specific problem with array arguments or any others involving the Analysis ToolPak, since the ToolPak is embedded directly into Excel 2007.

- ▶ However, to set the "Trust access..." property in Excel 2007 to ensure that the Volatile property is set correctly, follow these steps:

- 1 Click the Office button.
- 2 Click the following sequence of buttons and links: Excel Options, then Trust Center, then Trust Center Settings, then Macro Settings.
- 3 On the Macro Settings page, under Developer Macro Settings, check "Trust access to the VBA project object model."

Note that all user-defined functions are treated as Volatile in Excel 2000.

Running User-Defined Macros

In Extreme speed, it is not possible to run user-defined macros — such as CBBeforeTrial, CBAfterTrial, and CBAfterRecalc — during a simulation. Before- and after-simulation macros are allowed, such as CBBeforeSimulation and CBAfterSimulation. If the former group of simulation macros are present, they will be flagged as incompatible:

- Example message: "One or more user-defined simulation macros were detected (e.g., CBBeforeTrial, CBAfterTrial, etc.). (Code #5701)"
- Workaround: Use Normal speed to run these user-defined macros during a simulation.

Special Functions

A small group of Excel functions are not supported in Extreme speed: CALL, CELL, GETPIVOTDATA, INFO, HYPERLINK, REGISTER.ID, and the CUBE functions added in Excel 2007 (CUBEMEMBER, CUBEVALUE, CUBESET, CUBESETCOUNT, CUBERANKEDMEMBER, CUBEMEMBERPROPERTY, CUBEKPIMEMBER). OFFSET has also been reported as incompatible. Any forecast formulas that contain one or more of these functions will be flagged as incompatible:

- Example message: "Unsupported 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

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 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 Excel range constructs that are not supported in Extreme speed:

- [“Dynamic Ranges” on page 317](#)
- [“Labels in Formulas That Are Not Defined Names” on page 317](#)
- [“Multiple Area References” on page 317](#)
- [“3-D References” on page 317](#)

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 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.

Data Tables

While previous versions of Crystal Ball did not support the Excel TABLE function, this data table feature is now supported in Extreme speed. You can use one- and two-variable data tables in models that will run in Extreme speed.

Numerical Differences and the Compare Run Modes Tool

Ordinarily, there may be slight numerical differences in simulation results between Extreme and Normal speed modes. These differences are primarily due to roundoff errors and are usually in the relative range of $1e-12$ to $1e-15$. In certain circumstances, as for extremely large models containing thousands of formulas, these slight differences can compound and grow in magnitude.

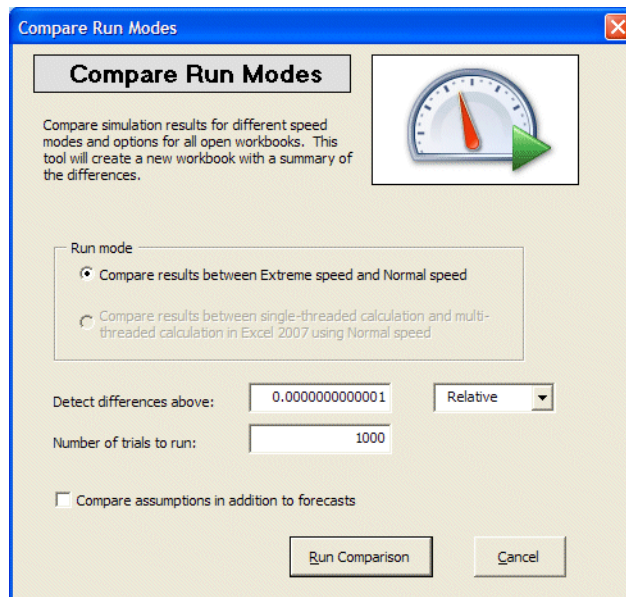
If you are concerned about possible differences in your own model, Crystal Ball provides a special Compare Run Modes tool that you can use to compare the results between the two run modes.

► To use this tool:

- 1 Open and click the model to test.
- 2 Choose **Run**, then **More Tools**, and then **Compare Run Modes**.

The Compare Run Modes dialog opens.

Figure 135 Compare Run Modes dialog



- 3 If you are using Crystal Ball with Excel 2007, choose whether to compare results between Extreme and Normal speed or between single-threaded calculation and multi-threaded calculation.
- 4 Indicate the amount of difference to detect, whether that difference is absolute or relative, and the number of trials to run. Check the box To compare assumptions as well as forecasts.

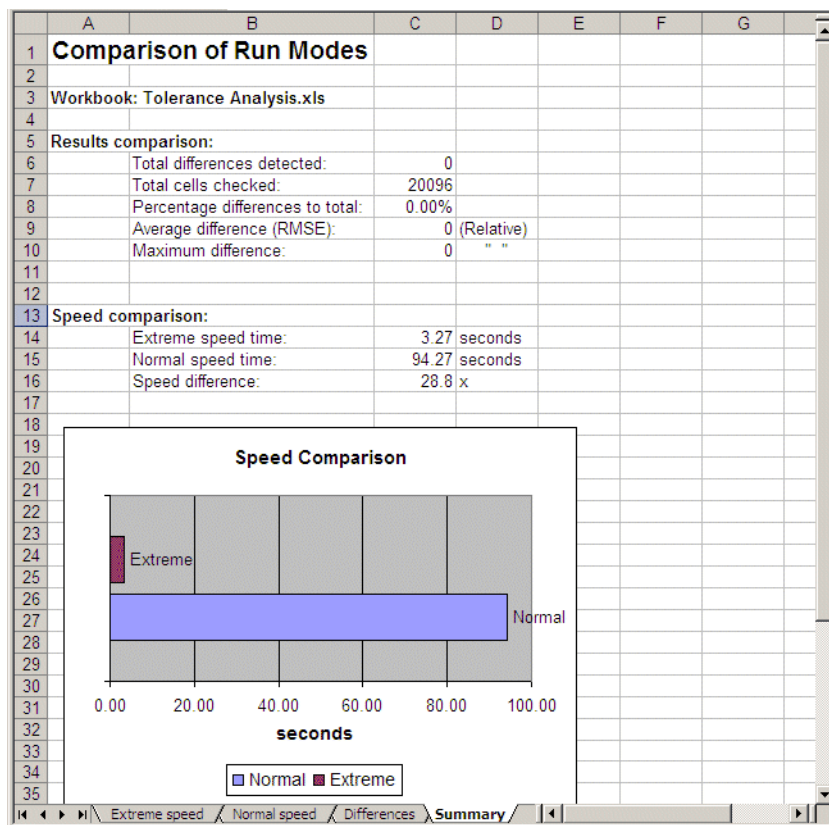
Depending on the size of your model, differences might not become obvious until after a fairly large number of trials have run. You might want to run 5,000 or more trials for your test.

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 multi-threaded calculations. Results are displayed in a new workbook. The comparison Summary tab is displayed when the comparison is complete.

Figure 136 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 136 Comparison results for Tolerance Analysis.xls, 5,000 trials



Because of variations in the random number seeds, you might see differences in comparison results if you use Excel’s RAND or Crystal Ball’s probability functions (such as CB.Uniform) in your model.

Other Important Differences

This section discusses several other differences between Extreme speed and Normal speed:

- “OptQuest and other Crystal Ball Tools” on page 320

- [“Precision Control and Cell Error Checking” on page 320](#)
- [“Spreadsheet Updating” on page 320](#)
- [“Very Large Models” on page 320](#)
- [“Memory Usage” on page 321](#)
- [“Spreadsheets with No Crystal Ball Data” on page 321](#)

OptQuest and other Crystal Ball Tools

OptQuest and certain other Crystal Ball tools run multiple simulations of your spreadsheet model back-to-back. Since Extreme speed enhances the performance of each simulation, you will see an overall speed improvement when using one of these tools. All of the compatibility and other differences apply to these tools as well.

Precision Control and Cell Error Checking

Extreme speed uses a bursting feature to optimize the balance between speed and system responsiveness. Since bursts are usually several hundreds or thousands of trials at a time, this feature affects a number of features like precision control, confidence testing, and checking for cell errors.

Crystal Ball tests for precision control (and performs confidence testing in OptQuest) after each burst of several hundred or thousands of trials. In Normal speed, these checks are performed every 50 trials by default. As a result, you may see your simulations run more trials than usual when these features are turned on. Generally speaking, these features are not as critical to simulation performance in Extreme speed as they are in Normal speed.

Because of bursting, Crystal Ball cannot check cell errors after every trial as it does in Normal speed, only at the end of a burst. If cell errors occur in forecast cells (such as "Divide by zero" or "#VALUE") and the Run Preferences, then Stop On Calculation Errors option is selected, the simulation stops at the end of the next burst.

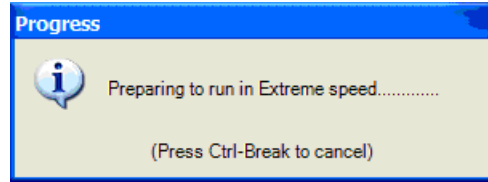
Spreadsheet Updating

While running simulations in Extreme speed, cells in your spreadsheet model appear to update every second or so after each burst. This is normal and does not affect simulation results. Single-stepping mode still updates cell values for every step.

Very Large Models

Very large models (with greater than 10,000 formulas, for example), might take Crystal Ball many seconds or minutes in Extreme speed to analyze the model and convert it into a form for high-speed simulation. When this happens, the following progress dialog opens.

Figure 137 Extreme Speed Progress Dialog Box



If you choose, you can cancel the simulation by pressing the Ctrl+Break keys or wait for the process to finish.

Memory Usage

Running simulations in Extreme speed is extremely memory-intensive. Depending on your machine, you may encounter issues with memory usage when running long simulations or working with large models.

During a long simulation (greater than 100,000 trials), you might also see that your machine's virtual memory is being used. For example, you might notice that your hard drive is being accessed continually and the simulation starts to slow down. No message is given when this condition occurs. If such a slow-down occurs and it is absolutely necessary that additional trials be run, you can try to disable the saving of assumption values (see the Run Preferences, then Options tab) and then restart the simulation.

If you run an Extreme Speed simulation multiple times on a large or complex model, you might find that you receive the "Sufficient memory may not..." warning dialog. This dialog lets you disable the Store Assumption Values run preference and change the number of trials to run. Notice that these changes in the warning dialog reset those preferences in the Run Preferences dialog on the Trials and Options tabs. They are then applied to other models unless you reset them after the large model has run.

Spreadsheets with No Crystal Ball Data

Spreadsheets without Crystal Ball data always run in Normal speed even if Extreme speed is selected in the Run Preferences dialog.

This could happen if you have Crystal Ball spreadsheet functions entered in the model but have not defined assumptions, forecasts, or decision variables.

Maximizing the Benefits of Extreme Speed

To get maximum benefit from running Crystal Ball in Extreme speed, you should be aware of several issues in your models that could potentially cause simulations to run more slowly than expected.

When you first start a simulation in Extreme speed, the model is analyzed and converted into a special form for high-speed processing. This form involves the use of a technique called *vectorization* to process batches of formula results together for maximum efficiency. Certain

functions and formula constructs in your model can interfere with this vectorization process. Some of the more common cases are discussed in the following sections:

- [“String Intermediate Results in Formulas” on page 322](#)
- [“Calls to User-Defined Functions” on page 322](#)
- [“Dynamic Assumptions” on page 322](#)
- [“Excel Functions” on page 323](#)

If one or more cases are detected, Crystal Ball Decision Optimizer displays the message "non-vectorized" on the Excel status bar while the simulation is running. Also, additional information is usually written to the Crystal Ball log file, which can be found with the suffix CB Log and extension .txt in:

```
C:\Documents and Settings\username\Application Data\Oracle\ Crystal Ball\11.0\Logs\CB  
Log_x.txt
```

Note: If you have a very large number of trials, the virtual memory feature of Microsoft Windows is activated. This can slow down processing. Too, if you have large numbers of forecasts and assumptions, managing these large arrays of values can take extra time. If you think array management could be an issue, try unchecking Store Assumption Values For Sensitivity Analysis on the Options tab of the Run Preferences dialog.

String Intermediate Results in Formulas

In Excel, it is possible to construct formulas that produce an intermediate character string result, which is used in later formulas to produce a numeric result. For maximum speed gains, you should avoid the use of strings in your formulas. Strings in formulas will not be flagged as incompatible, but will cause simulations to run much slower depending on the number of string formulas in your model.

- Workaround: Some simple strings like "Yes" and "No" can be replaced with 1 and 0 values, or True and False Boolean values.

Calls to User-Defined Functions

Calls to user-defined or third-party functions cannot be vectorized and will cause simulations to run slower.

- Workaround: There is no workaround for this case other than minimizing the use of these functions.

Dynamic Assumptions

Assumptions that contain cell references to parameter values that can change during a simulation are called dynamic assumptions. Crystal Ball needs to perform additional validation checks on the parameters for these assumption types during a simulation, causing simulations to run more slowly.

- Workaround: If the dynamic assumption feature is not needed, make sure that parameter cell references do not point to other assumption cells in your model.

Cell references in custom distributions are treated as static instead of dynamic when a model is run at Extreme speed.

Excel Functions

Crystal Ball supports LOOKUP and OFFSET functions in both Normal and Extreme speed. However, if you use more than a thousand in a model, this can slow down the initial parsing time and cause the simulation to run slowly.



Crystal Ball Tutorials

In This Appendix

Introduction.....	325
Tutorial 1 – Futura Apartments.....	325
Tutorial 2 – Vision Research.....	333
Improving Process Quality – Tutorial 3	352
Packaging Pump Design – Tutorial 4	366

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 325 is ready to run so you can quickly see how Crystal Ball works. If you work regularly with statistics and forecasting techniques, this might be all the introduction you need before running your own spreadsheets with Crystal Ball.
- “[Tutorial 2 — Vision Research](#)” on page 333 teaches more about defining and running simulations and interpreting their results.
- “[Improving Process Quality — Tutorial 3](#)” on page 352 shows how Crystal Ball supports process improvement initiatives similar to Six Sigma.
- “[Packaging Pump Design — Tutorial 4](#)” on page 366 shows how Crystal Ball supports quality initiatives for product and system design, such as Design for Six Sigma (DFSS).

Tutorial 1 – Futura Apartments

This tutorial contains the following sections::

- “[Starting Crystal Ball](#)” on page 326
- “[Opening the Example Model](#)” on page 327
- “[Running Simulations](#)” on page 328
- “[Results Analysis — Determining Profit](#)” on page 329
- “[Take a Look Behind the Scenes](#)” on page 330
- “[Resetting and Single-Stepping](#)” on page 331

- [“Tutorial Review” on page 332](#)

Starting Crystal Ball

- ▶ With Excel closed or open, choose Start, then All Programs, then Oracle Crystal Ball, then Oracle Crystal Ball.

If the Crystal BallWelcome screen opens, click Use Crystal Ball.

Crystal Ball opens and launches Excel. If Excel is already open, Crystal Ball opens in a new Excel window.

The following sections describe the Crystal Ball menus and toolbar:

- [“Crystal Ball Menus” on page 326](#)
- [“Crystal Ball Toolbar” on page 326](#)

Crystal Ball Menus

When you load Crystal Ball with Microsoft Excel, some new menus are displayed in the Excel menubar: Define, Run, and Analyze.

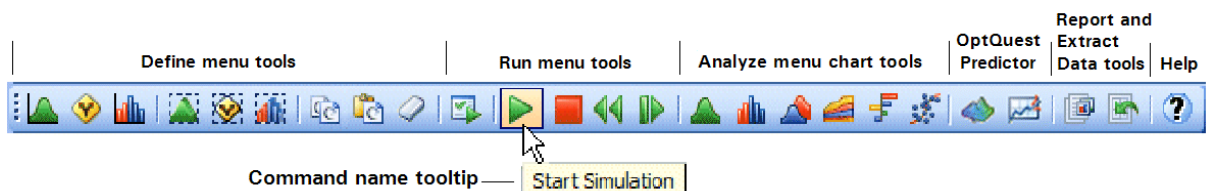
You can use these menus to define, run, and analyze simulations in Crystal Ball. You can also use commands on Excel’s Help menu to display online help, documentation, and example models for Crystal Ball.

Crystal Ball Toolbar

The Crystal Ball toolbar provides instant access to the most commonly used menu commands. Each section of the toolbar corresponds to a menu. When you move the cursor over a toolbar button, the command name is displayed.

Note: If you are using Crystal Ball in Excel 2007, you will see a single Crystal Ball tab and then a ribbon instead of a toolbar. For more information, see Appendix B, [“Crystal Ball Ribbon in Excel 2007” on page 301](#).

Figure 138 Crystal Ball Toolbar



- To turn the Crystal Ball toolbar off for the current session, choose View, then Toolbars, then Oracle Crystal Ball.

For more information about the menus and toolbar, see [Appendix B, “Accessibility”](#).

(If you are using Excel 2007, see “Using Crystal Ball in Excel 2007” on page 301.)

Opening the Example Model

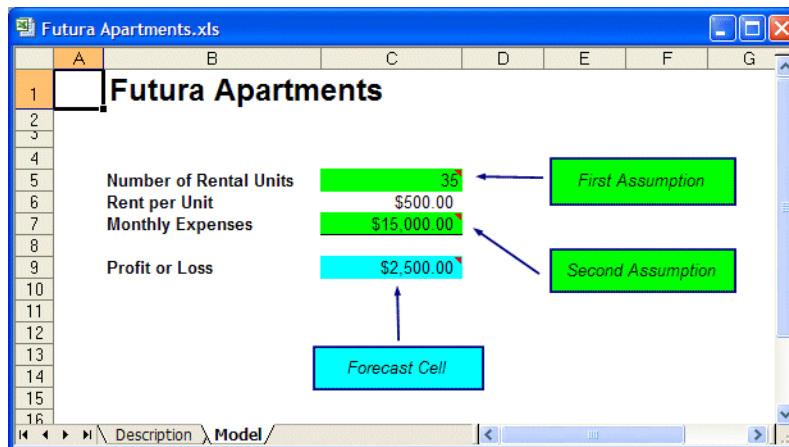
- Open the Futura Apartments workbook (Futura Apartments.xls) from the Crystal Ball Examples folder.

You can find this folder by choosing Help, then Crystal Ball, then Examples Guide. You can also choose Start, then All Programs, then Oracle Crystal Ball, then Examples in the Windows taskbar.

(In Excel 2007, choose Resources, then Examples Guide in the Help group.)

The workbook opens as shown in [Figure 139](#).

Figure 139 Futura Apartments workbook



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, choose Help, then Crystal Ball, then Examples Guide in the Excel menubar or choose Start, then All Programs, then Oracle Crystal Ball, then Examples and open the Examples Guide. (In Excel 2007, choose Resources, then Examples Guide.)

The 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 these 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 might 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, choose Run, 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 choose Run, then Stop [Simulation] if it is necessary to stop the simulation before all trials have run.

When the simulation stops, the forecast window opens, as in [Figure 140](#). The numbers will vary slightly each time the simulation is run, but the forecast window should look similar to this illustration.

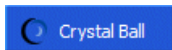
The forecast chart shows the total range of profit or loss outcomes predicted for the Futura Apartments scenario. Each bar on the chart represents the likelihood, or probability, of earning a given income. The cluster of columns near the center indicates that the most likely income level is between \$2000 and \$4000 per month. Note that there is also a small chance of losing almost \$2000 per month (the left end of the display range) and a small chance of making about a \$7,000 gain.

Figure 140 Futura Apartments profit/loss forecast



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 upper left corner of the chart shows 1000 trials but the upper right corner of the chart shows 998 displayed. The excluded values, if any, are called outliers. They are included in calculations but are not included in the forecast chart.

Note: If the forecast window disappears behind 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,



In Excel 2007, you can choose 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:

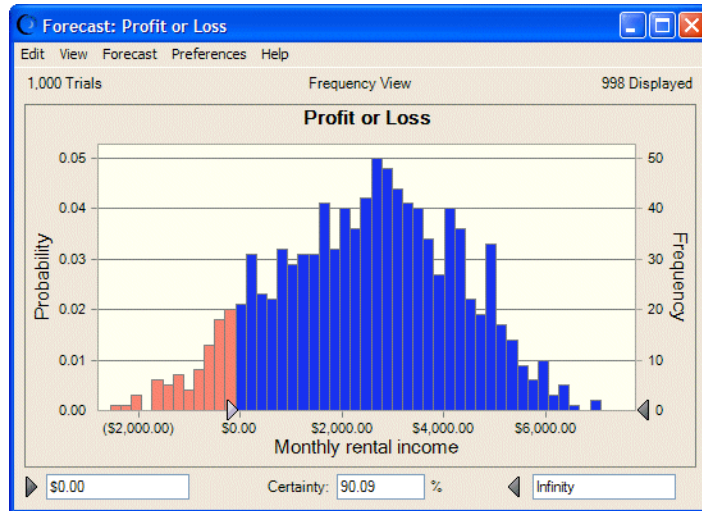
- 1 Select the left certainty field in the forecast window.
- 2 Type **0** in the field.



- 3 Press **Enter**.

The value in the Certainty field 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 141 shows the chance of making a profit is about 90%.

Figure 141 Chance of profit



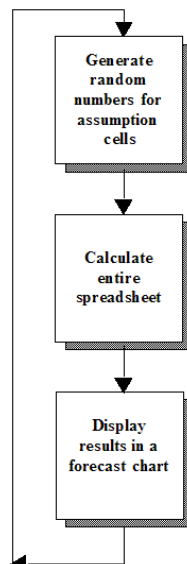
Take a Look Behind the Scenes

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 your own spreadsheet models, you need to carefully examine the nature of the problem and continually refine the models until they approximate your situation as closely as possible. See [“Crystal Ball Cells in the Example Model” on page 331](#) 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 might 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.

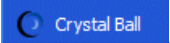
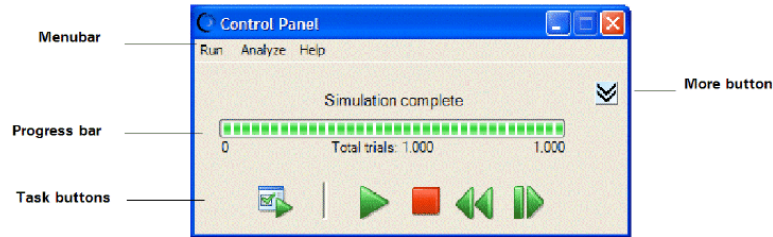


Note: If the Control Panel or any other Crystal Ball windows disappear behind Excel, click the Crystal Ball icon in the Windows task bar to display them again, .

Figure 142 Crystal Ball Control Panel



For information about the Crystal Ball Control Panel menus, see “The Crystal Ball Control Panel menubar” in Chapter 4 of the *Oracle Crystal Ball User's Guide*.

➤ To reset the simulation and clear all previous calculations, click the Reset button, .

➤ To single-step through the simulation one trial at a time, click the Single-step button, .

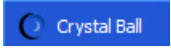
Notice that the values in the assumption and forecast cells change each time you click the Single-step button.

Closing Crystal Ball

This completes Tutorial 1. You can save and close Crystal Ball models the same as any other Excel workbook.

If you want, you can click the Reset button or choose Run, then Reset [Simulation] to reset your model before you close Crystal Ball.

➤ To close Crystal Ball, either:

- Right-click the Crystal Ball icon in the Windows taskbar and choose Close, ,
- or
- Close 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 333, 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”](#) on page 333
- [“Opening the Example Model”](#) on page 333
- [“Reviewing the Vision Research Scenario”](#) on page 334
- [“Defining Assumptions”](#) on page 334
- [“Defining Forecasts”](#) on page 344
- [“Running Simulations”](#) on page 346
- [“Interpreting the Results”](#) on page 347
- [“Closing Crystal Ball”](#) on page 352

Starting Crystal Ball

If Crystal Ball is not already started, follow the instructions in [“Starting Crystal Ball”](#) on page 326.

Opening the Example Model

- Open the Vision Research workbook (Vision Research.xls) from the Crystal Ball Examples folder.

You can find this folder by choosing Help, then Crystal Ball, then Examples Guide. You can also choose Start, then All Programs, then Oracle Crystal Ball, then Examples in the Windows taskbar.

(In Excel 2007, choose Resources, then Examples Guide.)

The Vision Research workbook for the ClearView project opens, as in [Figure 143](#).

Figure 143 Vision Research's ClearView Project Workbook

	A	B	C	D	E	F
1		Pharmaceutical Research - ClearView Project				
2					Suggested	
3					Assumptions:	
4		Costs (in millions)				
5		Development Cost of ClearView to Date	\$10.0			
6		Testing Costs	\$4.0		Uniform	
7		Marketing Costs	\$16.0		Triangular	
8		Total Costs	\$30.0			
9		Drug Test (sample of 100 patients)				
10		Patients Cured	100		Binomial	
11		FDA Approved if 20 or More Patients Cured	TRUE			
12		Market Study (in millions)				
13		Persons in U.S. with Nearsightedness Today	40.0			
14		Growth Rate of Nearsightedness	2.00%		Custom	
15		Persons with Nearsightedness After One Year	40.8			
16		Gross Profit on Dosages Sold				
17		Market Penetration	8.00%		Normal	
18		Profit Per Customer in Dollars	\$12.00			
19		Gross Profit if Approved (MM)	\$39.2			
20						
21		Net Profit (MM)	\$9.2			
22						
23						
24						

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 your 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 accomplish this, you choose among the distribution types in the Distribution Gallery (see [Figure 144](#)).

This part of the tutorial will help you understand how to choose 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 335](#)

- “Marketing Costs Assumption: Triangular Distribution” on page 337
- “Patients Cured Assumption: Binomial Distribution” on page 338
- “Growth Rate Assumption: Custom Distribution” on page 339
- “Market Penetration Assumption: Normal Distribution” on page 342

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:

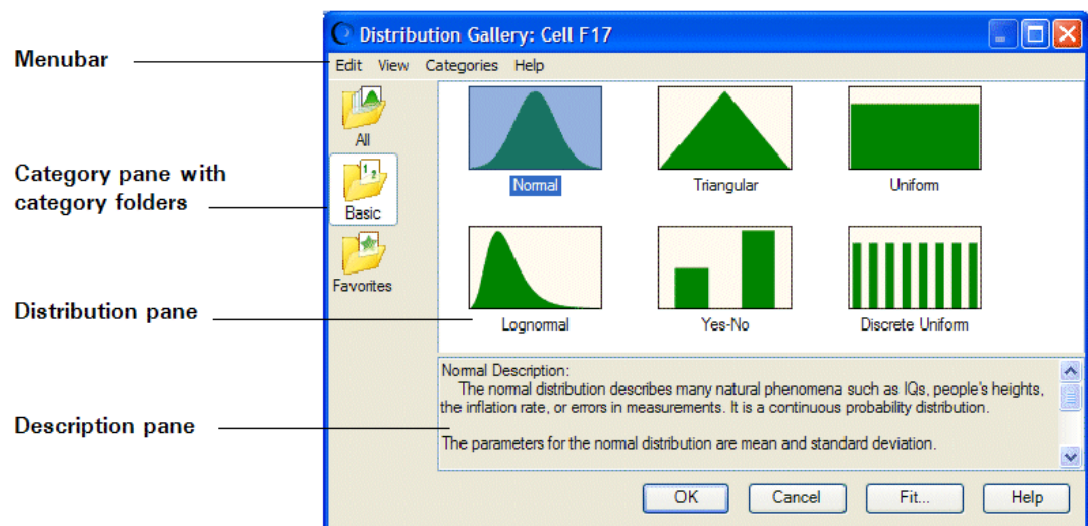
1 Click cell C5.

2 Choose Define, then Define Assumption. 

Because an assumption has not yet been defined in cell C5, the Distribution Gallery dialog opens as shown in [Figure 144](#).

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 choose it, information about that distribution is displayed at the bottom of the Distribution Gallery.

Figure 144 Distribution Gallery Dialog



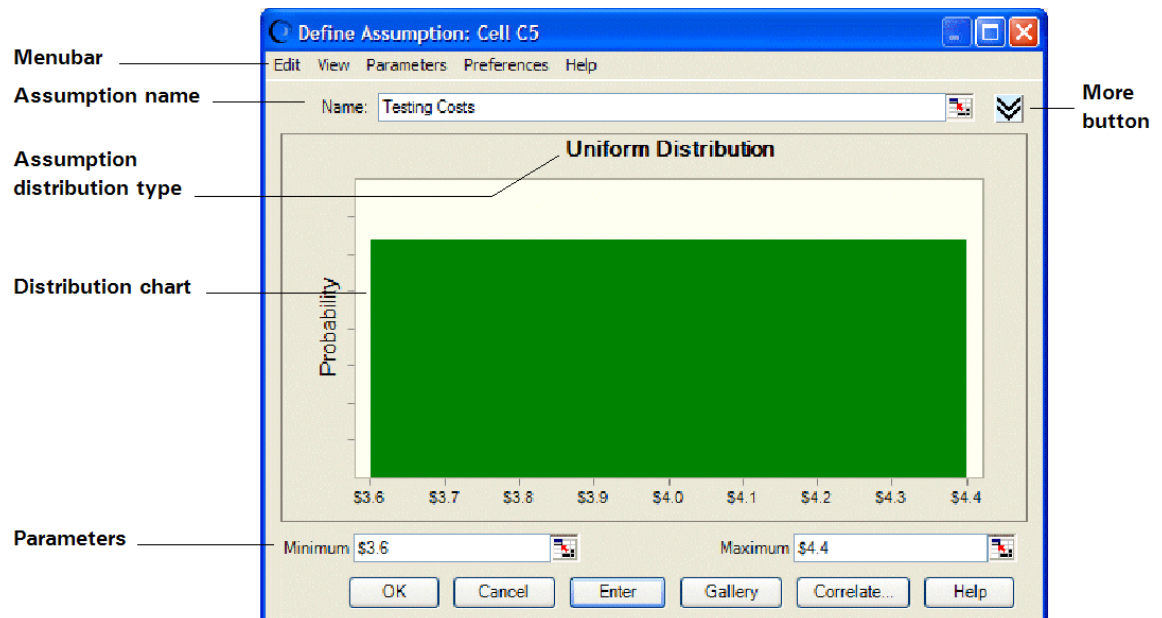
Note: In Excel 2007, if you click the upper half of the Define Assumption icon or if the assumption has already been defined, the Distribution Gallery opens. If you click the lower half of the Define Assumption icon, a list of All, Basic, or Favorite distributions opens, depending on the active category in the Distribution Gallery.

- 3 Click the Uniform distribution.
- 4 Click OK.

The Uniform Distribution dialog opens (Figure 145).

Since cell C5 already has text to the left of it on the worksheet, that text is displayed in the Assumption Name field. Use this name, rather than typing a new one. Also, notice that Crystal Ball assigns default values to the distribution parameters, Minimum and Maximum.

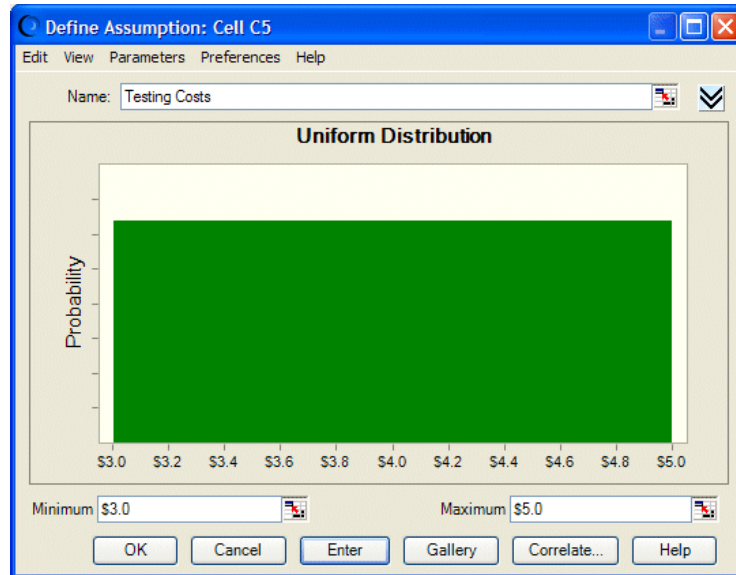
Figure 145 Uniform Distribution for C5



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 field (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 field.
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 146.

Figure 146 Changed distribution values



With the values from [step 1](#) and [step 3](#) entered correctly, your distribution looks like [Figure 146](#). 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.

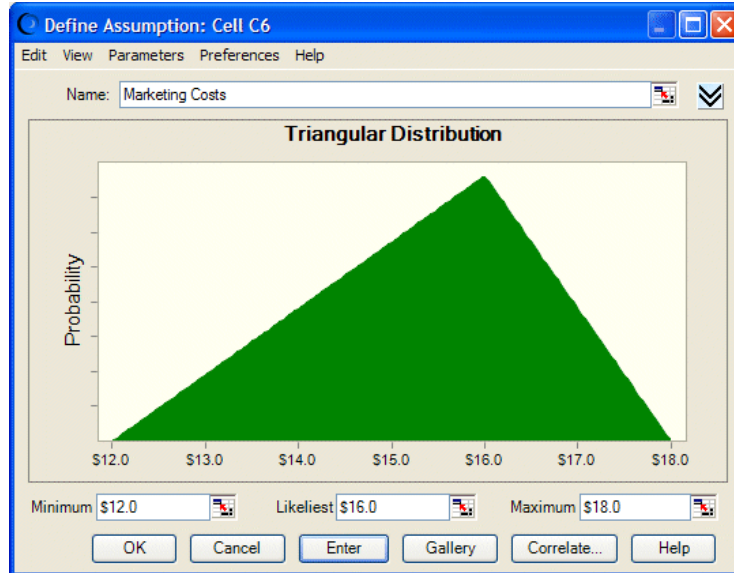
Vision Research chooses the triangular distribution to describe marketing costs because the triangular distribution describes a situation where you can estimate the minimum, maximum, and most likely values to occur. This assumption is already defined for you.

- To examine the assumption cell for marketing costs:

- 1 Click cell C6.
- 2 Choose **Define**, then **Define Assumption**. 

The Triangular Distribution dialog ([Figure 147](#)) opens for cell C6.

Figure 147 Triangular Distribution 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 chooses 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.

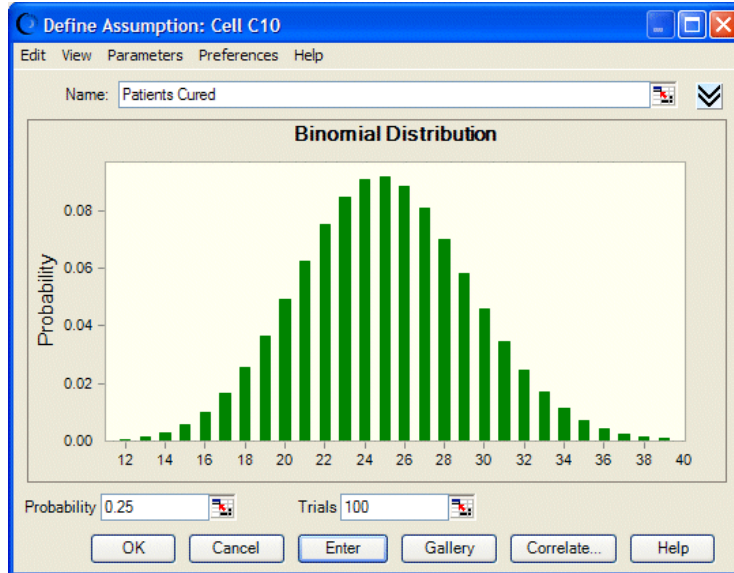
- To examine the assumption cell for patients cured, use the following steps:

- 1 Click cell C10.

- 2 Choose Define, then Define Assumption. 

The Binomial Distribution dialog opens as shown in [Figure 148](#).

Figure 148 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 chooses 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 Click cell C15.

2 Choose Define, then Define Assumption. 

(In Excel 2007, click the upper half of the Define Assumption icon.)

The Distribution Gallery dialog opens.

3 Click All at the left of the Distribution Gallery to show all distributions shipped with Crystal Ball.

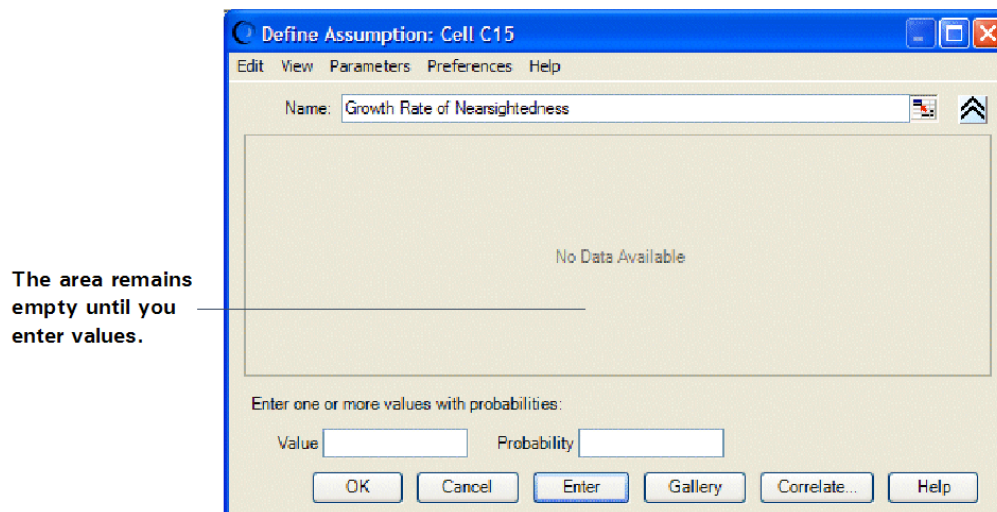
4 Scroll down to the end of the Distribution Gallery and click the Custom distribution.

5 Click OK.

The Custom Distribution dialog opens.

Notice in [Figure 149](#) that the chart area remains empty until you specify the Parameters type and enter the values for the distribution.

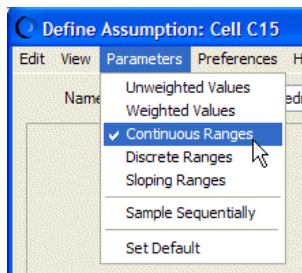
Figure 149 Custom Distribution Dialog



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.

6 Open the Parameters menu ([Figure 150](#)).

Figure 150 Custom Distribution Parameters Menu



7 Choose Continuous Ranges in the Parameters menu.

The Custom Distribution dialog now has three parameters: Minimum, Maximum, and Probability.

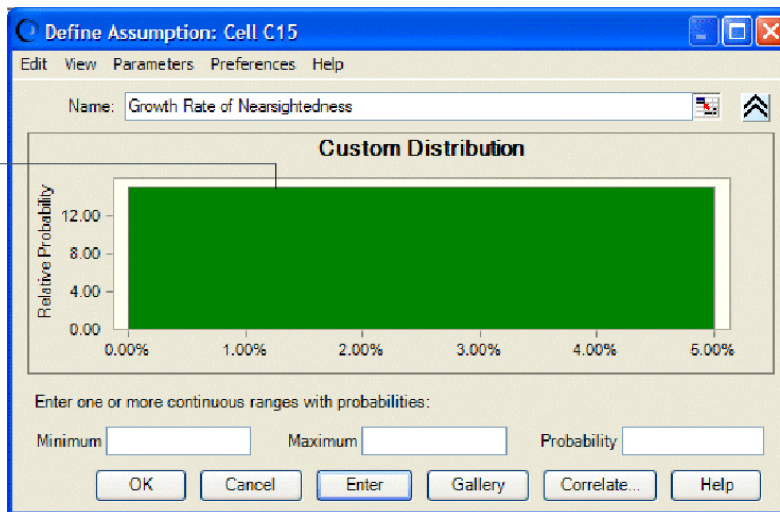
8 Enter the first range of values to show the growth of nearsightedness with low probability of competitive effects:

- a. Type 0% in the Minimum field.
This represents a 0% increase in the potential market.
- b. Type 5% in the Maximum field.
This represents a 5% increase in the potential market.
- c. Type 75% or .75 in the Probability field.
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 151).

Figure 151 Uniform Distribution Range

Uniform distribution for the first range of values.



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 field.

This represents a 15% decrease in the potential market.

- b. Type -5% in the Maximum field.

This represents a 5% decrease in the potential market.

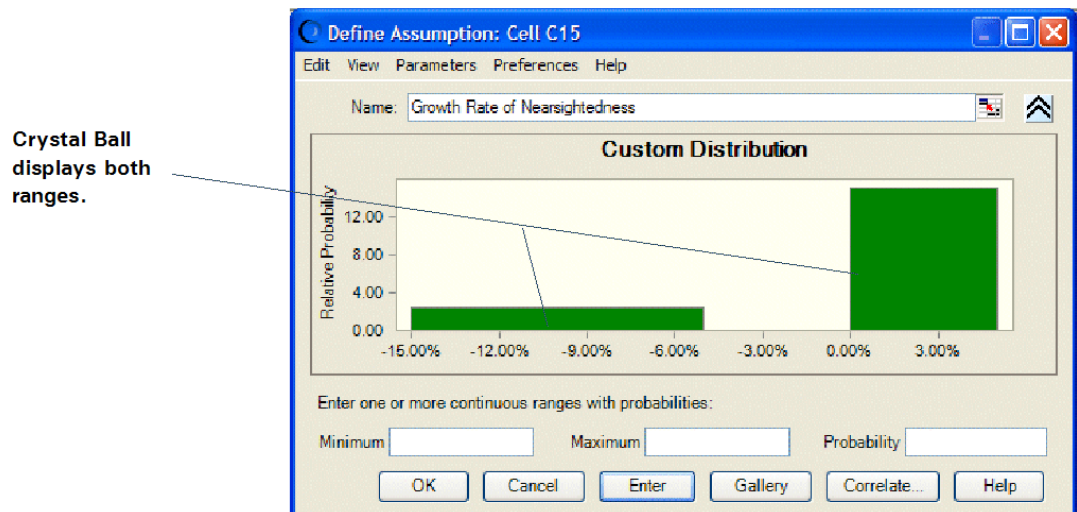
- c. Type 25% in the Probability field.

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 152).

Figure 152 Customized Uniform Distribution



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 chooses the normal distribution to describe the variable “market penetration.”

► To define the assumption cell for market penetration:

1 Click cell C19.

2 Choose Define, then Define Assumption. 

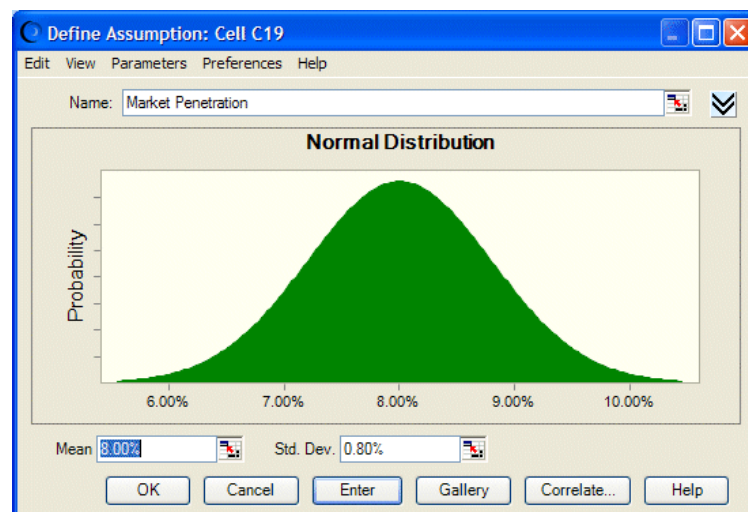
3 In the Distribution Gallery, click the normal distribution.

(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 153).

Figure 153 Normal Distribution for Cell C19



5 Specify the parameters for the normal distribution: the mean and the standard deviation.

a. If the Mean field doesn't contain 8.00%, type 8% in the Mean field.

This represents an estimated average for market penetration of 8%.

b. Type 2% in the Std. Dev. field.

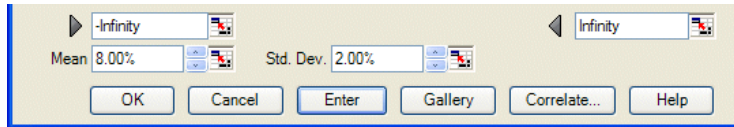
This represents an estimated 2% standard deviation from the mean.

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 fields above the parameters (Figure 154).

Figure 154 Assumption Truncation Fields



These fields, 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 fields are then called the truncation minimum and maximum.

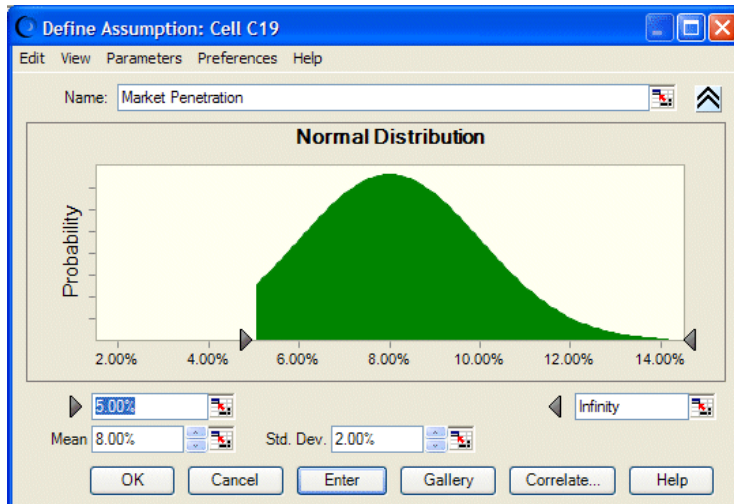
- 8 Type 5% in the left, minimum truncation field.

This represents 5%, the minimum market for the product.

- 9 Click Enter.

The distribution changes to reflect the values you entered (Figure 155).

Figure 155 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 your 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 345
- “Net Profit Forecast” on page 345

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 your 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).

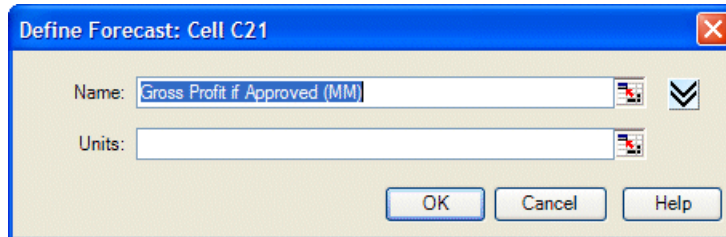
Now that you understand the gross profit formula, you are ready to define the forecast cell for gross profit.

To define this forecast cell:

2 Choose Define, then Define Forecast. 

The Define Forecast dialog opens as shown in [Figure 156](#). You can enter a name for the forecast. By default, the forecast cell label is displayed as the forecast name.

Figure 156 Define Forecast dialog—Gross Profit If Approved



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 field.**
- 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 formula bar above the worksheet. 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:

- 2 **Choose Define, then Define Forecast.** 

The Define Forecast dialog opens.

Again, use the forecast name that is displayed in the Forecast Name field and specify millions in the Units field.

- 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 your charts will look like this tutorial):


- 1 **Choose Run, then Run Preferences, then Trials.** 

The Run Preferences Trials dialog opens. For this example, we will run more trials to get more accurate forecast results.

- 2 **In the Number Of Trials To Run field, type 5000.**
- 3 **Click Sampling.**
- 4 **Choose Use Same Sequence Of Random Numbers.**
- 5 **In the Initial Seed Value field, type 999.**
- 6 **Notice there are two choices in the Sampling Methods group: Monte Carlo and Latin Hypercube. Latin Hypercube is less random and produces a smoother, more even results chart. For now, though, choose 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.

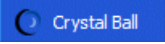
- To run the simulation, click Run, .

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 347](#)
- [“Determining the Net Profit Certainty Level” on page 348](#)
- [“Customizing Forecast Charts” on page 350](#)

Note: Crystal Ball windows are separate from Excel windows. If Crystal Ball’s windows or charts disappear from your screen, they are usually simply behind the main Excel window. To bring them to the front, click the Crystal Ball icon in the Windows taskbar or press Alt +Tab and choose Crystal Ball, .

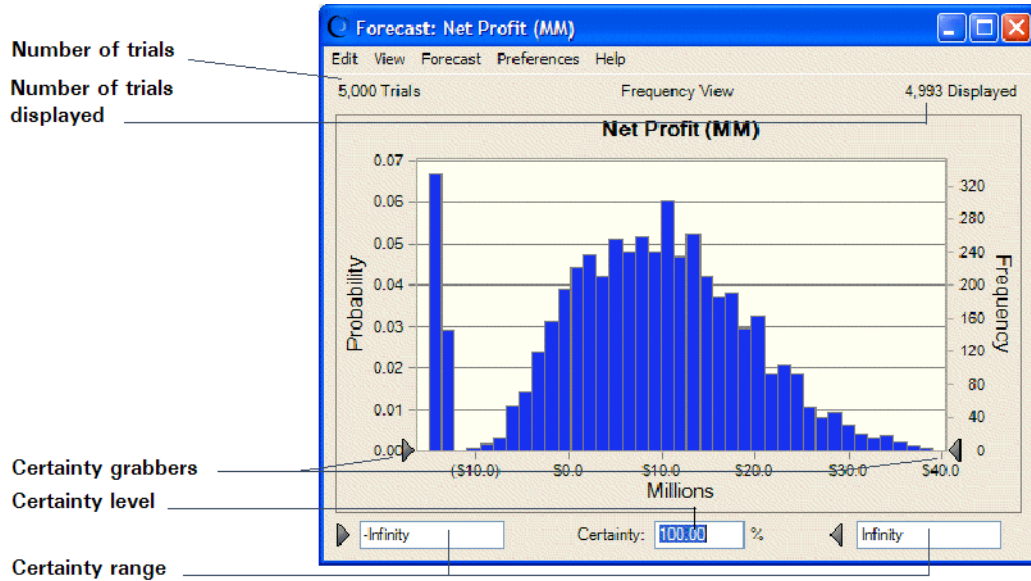
Note: To display forecast charts in Excel 2007, choose Analyze, then View Charts, then Forecast Charts.

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 157](#), 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 don’t display the most extreme values (outliers). Here, the display range includes values from approximately –\$15 million to \$38 million.

Figure 157 The 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 example above 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

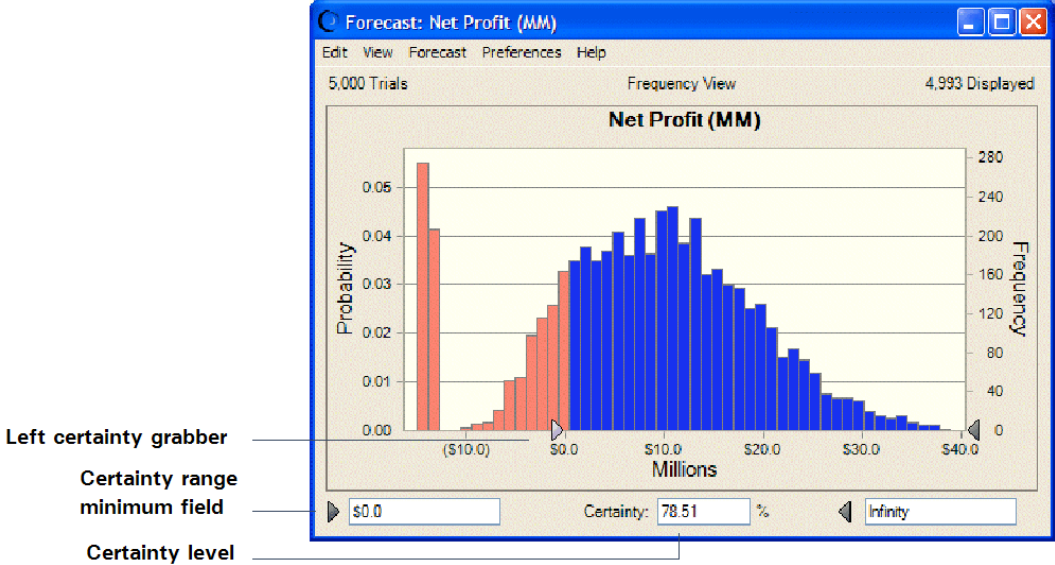
The Vision Research president wants to know how certain Vision Research can be of achieving a profit and what are the chances of a loss.

- To determine the certainty level of a specific value range:
 - 1 In the Net Profit forecast chart, type 0 in the certainty range minimum field.
 - 2 Press Enter.

Crystal Ball moves the left certainty grabber to the break-even value of \$0.0 and recalculates the certainty level.

Analyzing the Net Profit forecast chart again (Figure 158), 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 158 Net Profit Forecast—\$0 Minimum

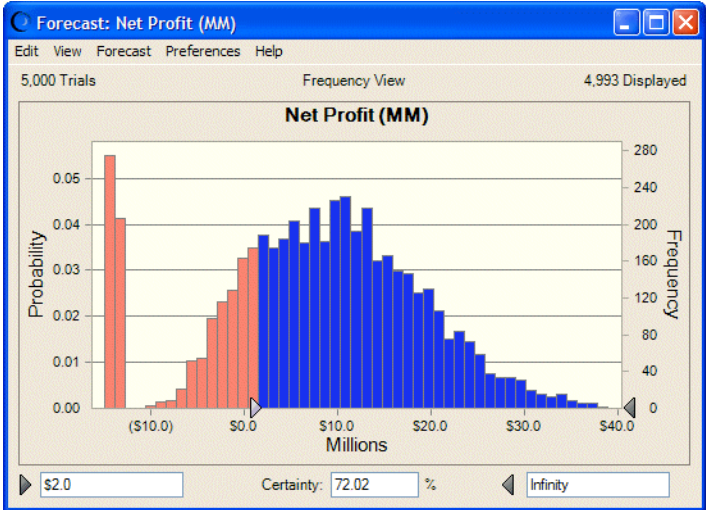


Now, the president of Vision Research would like to know the certainty of achieving a minimum profit of \$2,000,000. With Crystal Ball, you can easily answer this question.

- To do so:
 - 1 Type 2 in the certainty range minimum field.
 - 2 Press Enter.

As Figure 159 shows, Crystal Ball moves the left certainty grabber to \$2.0 and recalculates the certainty level. Vision Research can be about 72% certain of achieving a minimum net profit of \$2,000,000.

Figure 159 Recalculated Certainty Level



Vision Research is encouraged by the forecast result. The president now wants to know how certain Vision Research can be of achieving a minimum net 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.

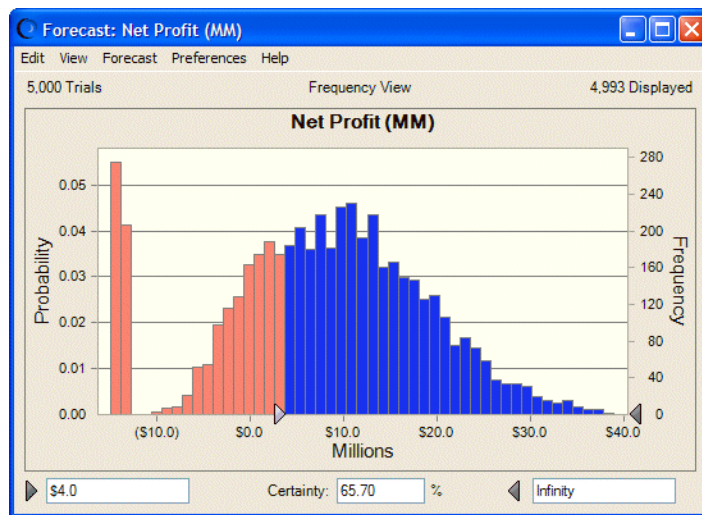
➤ Again, Crystal Ball can easily answer this question:

- 1 Type 4 in the range minimum field.
- 2 Press Enter.

Crystal Ball moves the left certainty grabber to \$4.0 and recalculates the certainty level.

The Net Profit forecast chart in [Figure 160](#) 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 160 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, choose Preferences, then Chart in the forecast chart window. You can click the Help button to learn more about the preferences on each tab.

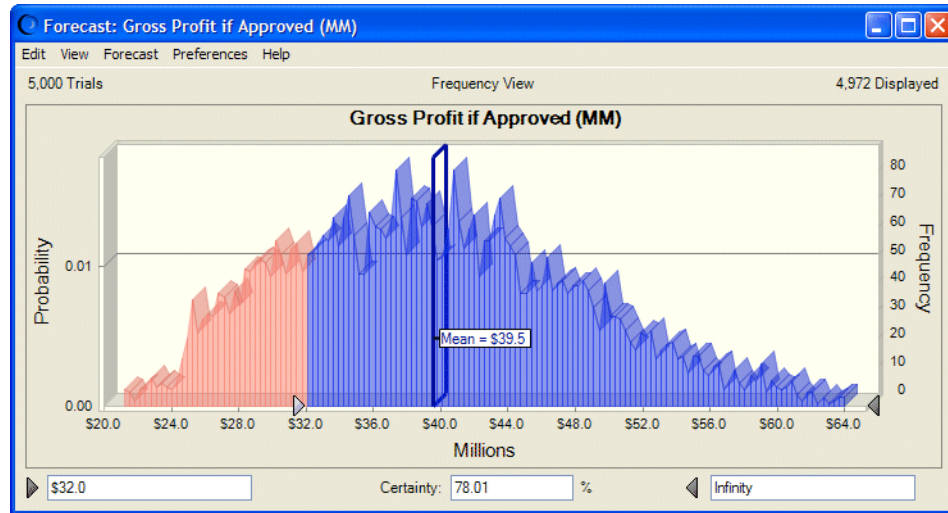
You can also use keyboard shortcuts to customize the appearance of charts without using the Chart Preferences dialog.

- 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+3 to display the chart in 3D.
- Drag the edges of the chart window until the proportions and size suit your presentation plans.

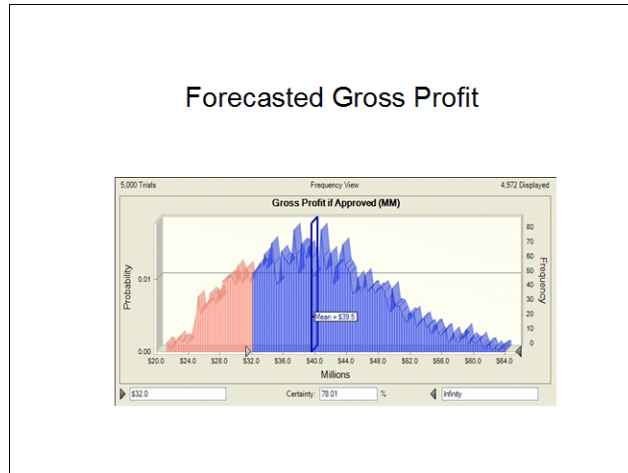
For example, [Figure 165](#) shows the ClearView gross profit forecast presented as a 3-D area chart with a mean marker, stretched to show more detail in the *x*-axis. The chart is also set for 50% transparency. The certainty fields have been set to show that the certainty of a gross profit greater than \$32 million is about 78%.

Figure 161 Customized Gross Profit Chart



You can choose Edit, then Copy Chart in the chart menubar to copy a chart to the clipboard for pasting into Excel or another application. [Figure 162](#) shows the ClearView gross profit chart pasted into a presentation slide.

Figure 162 Gross Profit Chart Pasted into a Presentation Slide



Closing Crystal Ball

- To close Crystal Ball, exit 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 might ask as they analyzed the results of the simulation.

As you read through the *Oracle Crystal Ball User's Guide*, you will learn more about customizing forecast charts, creating other kinds of charts, interpreting the descriptive statistics, and printing comprehensive reports for any simulation. Crystal Ball provides these features so that you can quantify the risk inherent in your assumptions.

Crystal Ball keeps your assumption and forecast definitions (but not the forecast values) with the spreadsheet. When you save your spreadsheet, the definitions are saved with it. To learn about saving and restoring forecast results, see [“Saving and Restoring Simulation Results” on page 86](#).

The following section, [“Improving Process Quality — Tutorial 3” on page 352](#), shows how to use Crystal Ball in the Analyze and Improve phases of Six Sigma and other process quality improvement methodologies.

Improving Process Quality – Tutorial 3

Six Sigma and other process improvement methodologies strive to save costs and time by minimizing process variation and reducing rework. Six Sigma has five phases for gathering information, analyzing it, and implementing suggested improvements: Define, Measure, Analyze, Improve, Control. The following sections in this tutorial show how Crystal Ball can be

used in the Analyze and Improve phases to discover inconsistencies and reduce variation in a bank's loan processing system:

- [“Overall Approach” on page 353](#)
- [“Using the Loan Processing Model” on page 355](#)

[“Packaging Pump Design — Tutorial 4” on page 366](#), shows how to use Crystal Ball in design quality programs such as Design for Six Sigma (DFSS).

Overall Approach

Suppose you are assigned the task of improving loan processing quality at a bank. You want to minimize average processing time, keeping below the bank's target. At the same time, you want to evaluate and improve processing time consistency using the following techniques:

- **Define** — You plan to talk with stakeholders in various departments to learn how they are currently working, how they view of the problem, and what outcome they hope to see.
- **Measure** — You will determine current processing times and the amount of variation within them.
- **Analyze** — You plan to use Crystal Ball to help you discover process capability, or how closely the processing times map to process requirements.
- **Improve** — You will use information gathered in the previous phases to design and implement improvements in processing time and consistency.
- **Control** — You need to ensure permanent improvements by setting up a system of feedback loops to continuously measure process results and change the output if measures exceed desired control targets and control limits.

In the Define and Measure phases, you obtain and use information to build a Crystal Ball model. Then, you use Crystal Ball to simulate real-world variations that occur in processing loans. Finally, you can use sensitivity analysis and further optimization to arrive at the best balance between time and consistency.

The following sections give details of each phase:

- [“Define Phase” on page 353](#)
- [“Measure Phase” on page 354](#)
- [“Analyze Phase” on page 354](#)
- [“Improve Phase” on page 354](#)
- [“Control Phase” on page 355](#)

Define Phase

The bank's loan processing procedures involve six steps. You interview staff involved with each step and learn that marketing and management groups are hoping for completion of all six steps within 96 working hours. Based on these interviews, you establish both the target and upper

specification limit (USL) at 96 hours. There is no lower specification limit (LSL), although consistency (the sigma level) seems to be an issue. You decide to obtain more concrete data.

Measure Phase

You document time and time variation data for each processing step, as follows:

- **Customer Inquiry** involves the creation of an initial rate quote following the first customer contact by phone, in-person visit, or the Internet. Historical data indicates this cycle time is lognormally distributed with a mean of one hour and a standard deviation of 0.25 hours.
- **Loan Application** involves the completion of forms by customers, with or without staff assistance. This step takes from one to five eight-hour days, but usually takes three days.
- **Document Verification** and processing occurs in the bank, where a loan specialist reviews credit data, presents loan alternatives to customers, and independently verifies information. This step usually takes between two and four eight-hour days. However, about two out of ten times, the loan is suspended and takes between four and six days for additional reviews and documentation.
- **Underwriting**, or loan approval, usually takes from one hour to 8 hours. All lengths of time have the same likelihood of occurrence.
- **Loan Closing** includes the preparation of the final documentation, locking in an interest rate, and arranging where to deposit funds. Historical data show that this step has a mean of two days, but you don't yet know how the data are distributed.
- **Loan Disbursement**, moving the funds to the customer's bank, usually takes 16 hours, with some variation. Two-thirds of disbursement times fall within 12 and 20 hours.

After gathering this information, you decide to load it into Excel and use Crystal Ball to analyze it.

Analyze Phase

During the Analyze phase, you create an Excel workbook that includes historical data on loan closing times. Then, you can capture the time and variation information for each step as a Crystal Ball assumption. Finally, you can define overall processing time as a Crystal Ball forecast. When the simulation runs, you can view capability metrics to gain insight into the degree of process variation, or inconsistency. You can also generate a sensitivity chart to learn more about the main sources of inconsistency.

[“Using the Loan Processing Model” on page 355](#), shows how to use a Crystal Ball model in the Analyze and Improve phases to accomplish your quality goals.

Improve Phase

You can experiment with the effects of changing the main sources of inconsistency. If you have OptQuest, you can also define decision variables and optimize for the shortest processing time and least time variation.

Control Phase

You set up a system of measuring cycle times for each step and analyzing them on a regular basis. You run a Crystal Ball simulation on real data once a month with a program of corrective actions to take whenever results exceed desired limits by a specified amount.

Using the Loan Processing Model

This section shows how to construct a model that effectively simulates each step of the loan process with dual goals of minimizing processing time and maximizing time consistency. Then, you run the model and analyze the output using Crystal Ball's process capability features.

The following sections describe how to work with the loan processing model and analyze data from it:


- [“Introduction” on page 325](#)
- [“Activating the Process Capability Features” on page 355](#)
- [“Setting the Sampling Seed Value” on page 356](#)
- [“Opening the Example Model” on page 333](#)
- [“Reviewing the Vision Research Scenario” on page 334](#)
- [“Reviewing the Assumptions” on page 357](#)
- [“Reviewing the Forecast” on page 359](#)
- [“Running Simulations” on page 360](#)
- [“Analyzing Simulations” on page 360](#)
- [“Investigating Improvement Possibilities” on page 362](#)

Starting Crystal Ball

If Crystal Ball is not already started, start it as usual ([“Starting Crystal Ball” on page 326](#)). If the Crystal Ball Welcome screen opens, check Quality in the upper left, and then click Use Crystal Ball at the right.

Activating the Process Capability Features

- To confirm that the process capability features have been activated and activate them, if necessary:

- 1 Choose Run, then Run Preferences. 
- 2 Click the Statistics tab in the Run Preferences dialog.
- 3 Check Calculate Capability Metrics.
- 4 Click the Options button to confirm the settings.

In the Capability Options panel, set the options to use short-term metrics with a Z-score shift value of 1.5 (the default Short Vs. Long Term settings) and use the default Calculation Method settings.

- 5 Click OK in both dialogs to accept the current settings and close them.

Setting the Sampling Seed Value

To more closely reproduce the results in this tutorial, you might want to set the sampling seed value on the Sampling tab of the Run Preferences dialog (“Setting Run Preferences” on page 346).

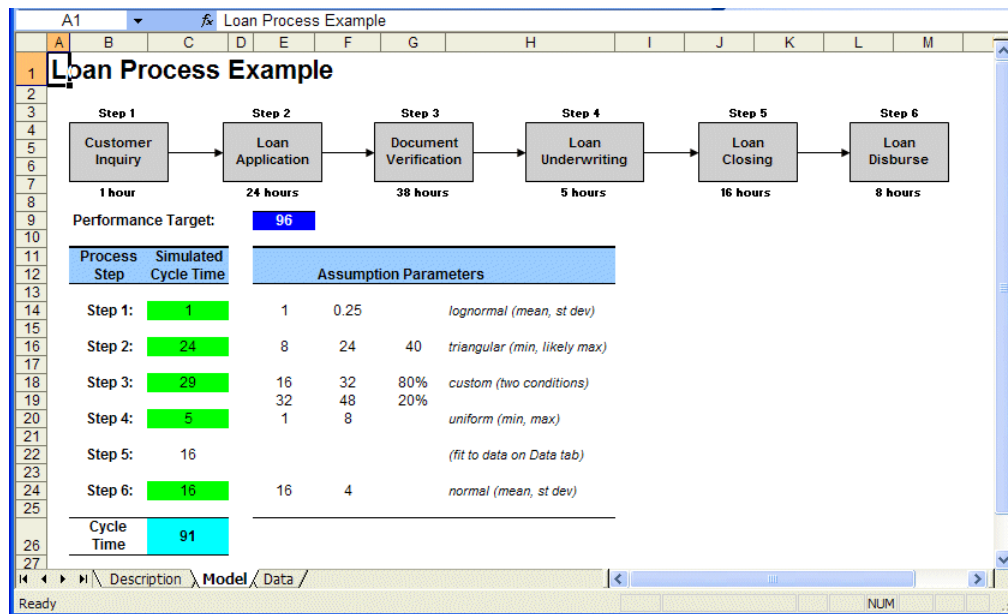
Opening the Example Model

Open Loan Process.xls from the Crystal Ball Examples folder. To choose this example from a list, choose Help, then Crystal Ball, then Examples Guide or choose Start, then All Programs, then Oracle Crystal Ball, then Examples in the Windows taskbar.

(In Excel 2007, choose Resources, then Examples Guide in the Help group.)

The workbook opens, as shown in [Figure 163](#).

Figure 163 Loan Processing Example Model



Reviewing the Parts of the Model

The loan processing spreadsheet models a process improvement effort with two basic goals: meeting the cycle time target as closely as possible and maximizing the sigma level. The model has these parts:

- The flowchart at the top of the model illustrates the process with approximate measured mean times for each step.
- The blue box beneath the flowchart highlights the cycle time target.
- The green boxes in the Simulated Cycle Time column are Crystal Ball assumptions that represent each step of the loan processing effort.
- The assumption parameters to the right of each assumption show the distribution and the parameters entered for each assumption. They are entered in each assumption as cell references relative to cells in column C.
- The blue box at the bottom of the Simulated Cycle Time column is a Crystal Ball forecast that represents the total cycle time.

Reviewing the Assumptions

The assumption definitions are based on the measurements obtained in the second Six Sigma phase, described in “[Measure Phase](#)” on page 354. For example, Step 1, Customer Inquiry, has a mean of 1 hour and a standard deviation of 0.25 hour as discussed in “[Measure Phase](#)” on page 354. You can compare the other assumptions with the descriptions in “[Measure Phase](#)” on page 354 to see how they match.

Notice that Step 3 is defined with a custom distribution. We will examine it in more detail shortly and then define the distribution in Step 5.

Examining the Custom Distribution

Because the measurement for Step 3 involves two separate sets of values, it is defined as a custom distribution.

► To explore this:

- 1 Select cell C18, the assumption for Step 3.
- 2 Choose Define, then Define Assumption to display the Define Assumption dialog for that assumption.



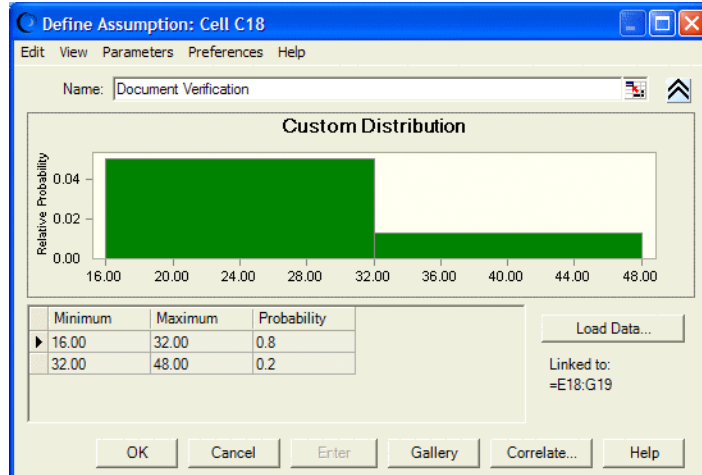
[Figure 164](#) shows the expanded Define Assumption dialog for Step 3, Document Verification.

The dialog has been expanded by clicking the More button.



This dialog reflects the information from “[Measure Phase](#)” on page 354 that 80% of the time, cycle time for this step ranges from two to four days (16 to 32 hours) but 20% of the time, cycle time ranges from four to six days (32 to 48 hours).

Figure 164 Custom Assumption for Step 3, Document Verification



- 3 Click OK or Cancel to close the dialog.

Fitting a Distribution for Step 5

When you first open Loan Process.xls, no assumption has been defined for Step 5, Loan Closing. The description in “Measure Phase” on page 354 states that it takes an average of two days (16 hours) to close loans but the distribution is not known.


- To create an assumption for Step 5 and fit a distribution to it:

- 1 Select cell C22.

- 2 Choose Define, then Define Assumption to display the Distribution Gallery dialog for that cell. 

- 3 Click the Fit button.

The Fit Distribution dialog opens.

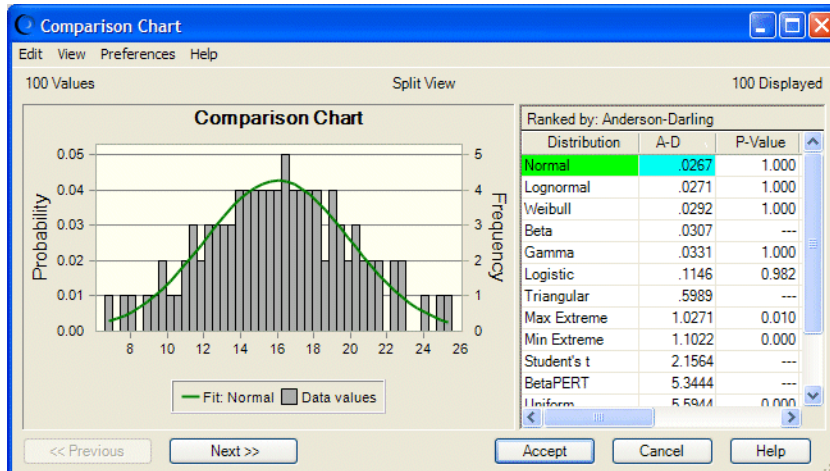
- 4 Click the cell selector for the Range edit box. Then, click the Data tab of the workbook and select cells A2 through A101. 

When you accept the selection, the Fit Distribution dialog opens with the range entered.

- 5 Leave the other default settings as shown and click OK.

The Comparison Chart dialog opens (Figure 165). The normal distribution appears to be the best fit.

Figure 165 Comparison Chart Dialog, Cell C22

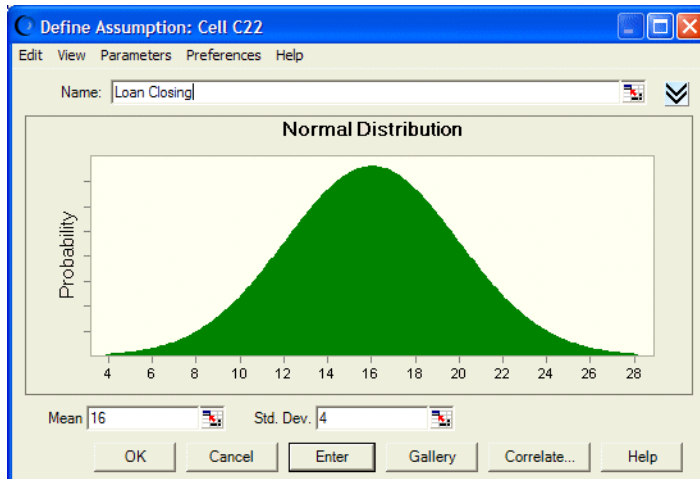


6 Click Accept to accept the normal distribution.

The Define Assumption dialog opens.

Figure 166 shows that the new assumption for Step 5 is a normal distribution with a mean of 16 and a standard deviation of 4.

Figure 166 Define Assumption Dialog, Step 5, Cell C22



7 Rename the assumption to "Loan Closing" and click OK.

Now, all assumptions for the Loan Process model are complete.

Reviewing the Forecast

The forecast in cell C26 represents total cycle time. To view its formula in the Excel formula bar, select cell C26. The formula is =SUM(C14:C24) — the sum of the assumptions for Steps 1 through 6.

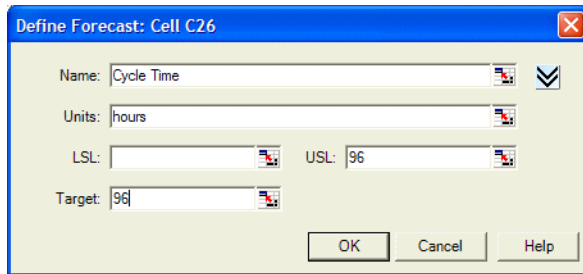
- To view and edit the forecast definition:

- 1 Choose Define, then Define Forecast or click the toolbar button. 

The Define Forecast dialog opens.

Figure 167, following, shows that the forecast has a name, a units entry, and a USL, the upper specification limit of 96 hours. These were entered when the example model was first defined.

Figure 167 Cycle Time Forecast with LSL and Target Entered




As established in the Define phase of this project, 96 hours is the loan processing target as well as the USL.

- 2 Enter 96 in the Target edit box and click OK.

Running Simulations

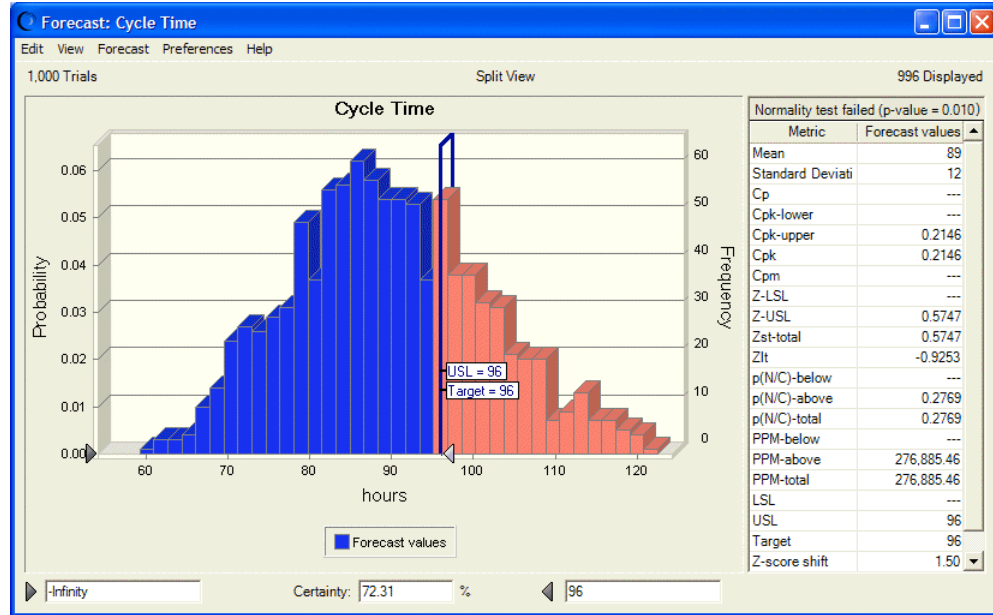
At this point, the model's assumptions and forecast are complete.

- To run the simulation and generate a forecast chart, click the Start [Simulation] button .

Analyzing Simulations

When you run the simulation for this model, the Cycle Time forecast chart opens (Figure 168, following). Because the forecast is defined with an upper specification limit and a target, the chart is displayed in Split View with the forecast chart on the left side and process capability metrics on the right. The message above the metrics indicates that the distribution is non-normal (the normality test failed), so capability metrics are calculated from the forecast values.

Figure 168 The Cycle Time Forecast with Process Capability Metrics



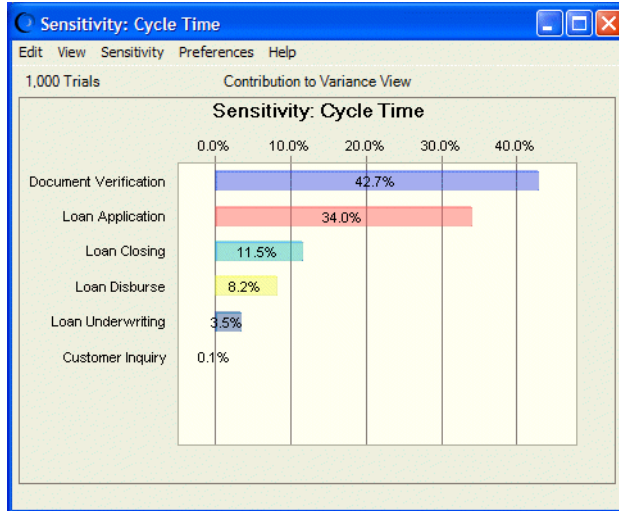
Notice that marker lines are displayed for the USL and target. Because the USL is defined, the maximum certainty grabber is automatically set to that value. Because no LSL is defined, the minimum certainty grabber is automatically set to $-\infty$. The Certainty field contains 72.31; about 72% of forecasted values fall below the USL.

Looking at the process capability metrics, the forecast distribution is not normal, so the Z scores are not generally appropriate to use. The p(N/C)-above (defects above the USL) is about .28, which confirms the certainty level shown in the forecast chart; more than one-quarter of the forecasted values fall above the USL. The Cpk-upper and Cpk are about 0.21, where you had hoped to see at least 1.00 (the 3-sigma level). The loan specialists you interviewed were correct — cycle time variation is large.

You generate a sensitivity chart (Figure 169) to determine which of the loan processing steps has the most influence on the Cycle Time forecast variance. To do this, select the forecast chart and choose Forecast, then Open Sensitivity Chart.

Figure 169 shows that the loan processing step with the greatest effect on cycle time variance is Document Verification (Step 3). Obviously, this is an ideal target for improvement.


Figure 169 Sensitivity Chart for the Cycle Time Forecast



Investigating Improvement Possibilities

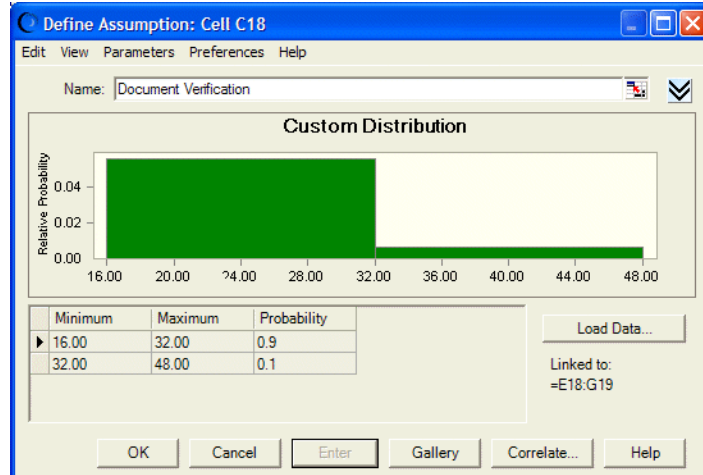
You wonder how much you would need to reduce variation in Document Verification time before overall quality would improve significantly. You decide to increase the probability of a cycle time of four days or less.

➤ To do this:

- 1 Click the Reset button to reset the simulation. 
- 2 Type a new probability in cell G18. Change it to 90%.
- 3 Adjust cell G19 downward to match. Change it to 10%.
- 4 Select cell C18 and open the Define Assumption dialog.

As shown in [Figure 170](#), the two parts of this assumption are both uniform in height over their range, although the one on the left is nine times taller.

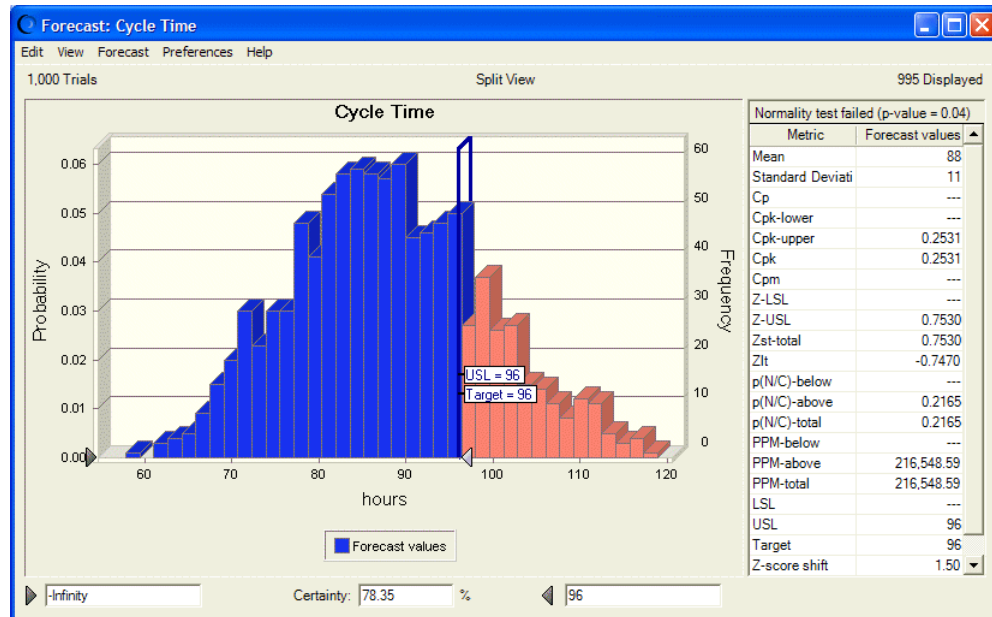
Figure 170 Document Verification Assumption, Adjusted



This assumption was previously displayed in Figure 164. Because the probabilities in the table are linked to workbook cells, when you adjusted the workbook, you also adjusted the assumption probabilities.

- 5 Close the Define assumption dialog and run the simulation.
- 6 Review the forecast chart in Figure 171.

Figure 171 The Cycle Time Forecast with Process Capability Metrics



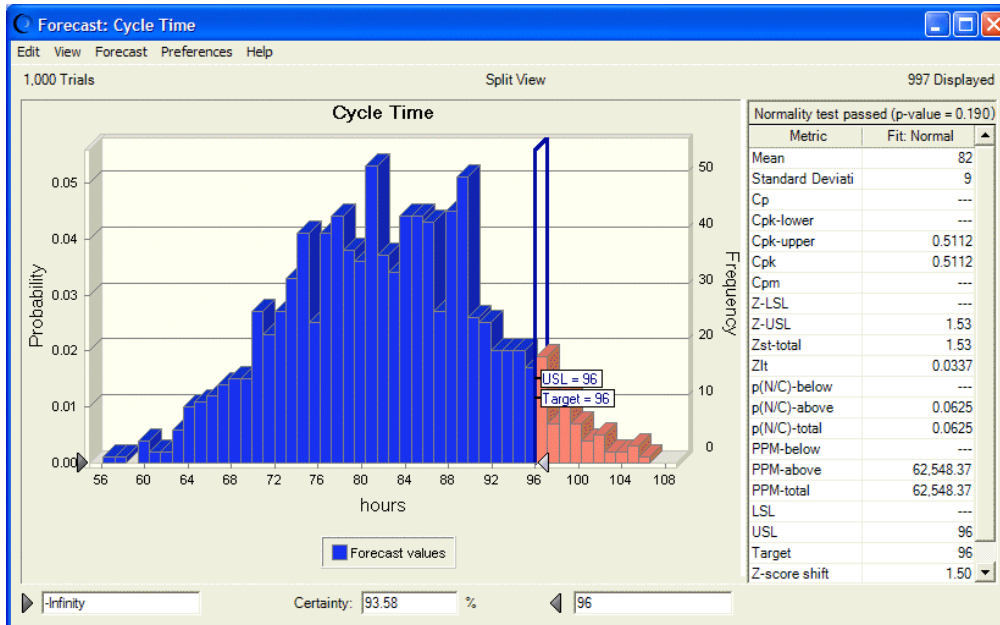
Crystal Ball sets the upper certainty level at the USL/Target value (96). If the lower certainty grabber is not located at -Infinity, click the lower grabber and drag it to the left end of the chart as shown in Figure 171. Now, the certainty of cycle time falling at or below the USL is about 78%. You decide to make a drastic change and edit the assumption parameters for Document Verification as follows (change 32 to 24 in the first row; change 90% to 100% and 10% to 0%):

Step 3: 29 16 24 100%
 32 48 0%

Now, there is 100% probability that all document verification times will fall between two and three days.

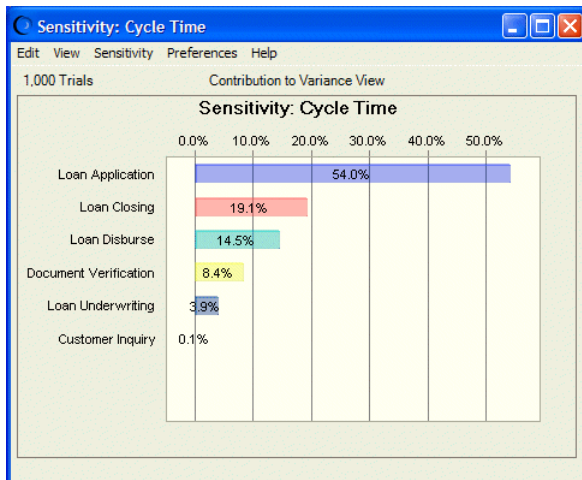
Figure 172 shows that when you run with this new assumption definition, the certainty of falling at or below the USL rises to about 93.5% and PPM-total drops to 62,548. Also, the distribution is now normal; it was not normal for the last simulation. Z-USL and Zst-total are 1.53, the sigma level for this simulation.

Figure 172 Cycle Time Forecast after Adjusting Document Verification



You check the sensitivity chart for this simulation (Figure 173) and find that the impact of Loan Application is now much greater than Document Verification.

Figure 173 Sensitivity Chart after Adjusting Document Verification

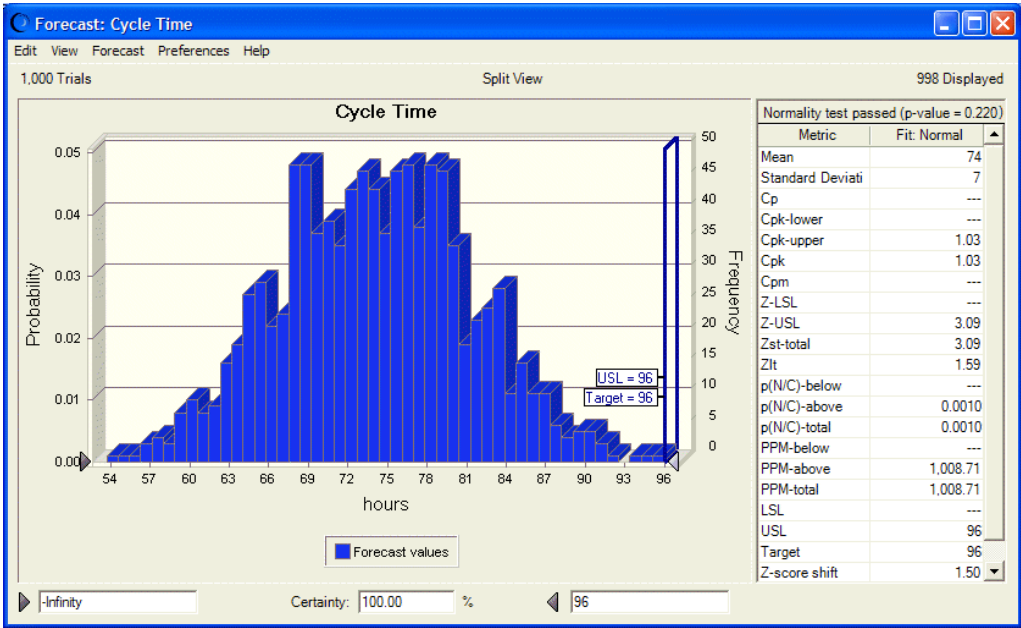


You believe that Document Verification has been pared down about as much as it can be, so you decide to experiment further with making the Loan Application cycle time shorter and more consistent.

- To do this:
 - 1 Reset the simulation and change the Step 2 parameters to 8, 16, and 24.
 - 2 Run the simulation.

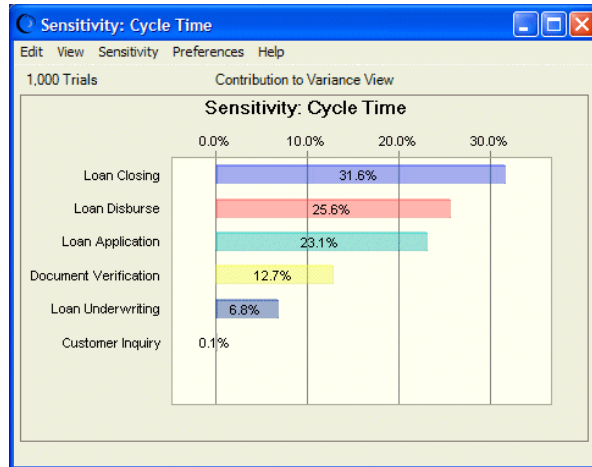
Results are much better. Figure 174 shows that the mean cycle time has dropped to 74 hours. The certainty of falling below the USL/Target value is 100% and the sigma level has risen to 3.09. Cpk-upper and Cpk have risen over 1 which, given the shape and location of the distribution, confirms that the sigma level is greater than 3.

Figure 174 Forecast Chart after Loan Application Adjustment



When you check the sensitivity chart (Figure 175), Loan Closing and Loan Disbursement are now the main contributors to cycle time variation. You learn that these processes might be difficult to improve further, so you decide to implement improvements to Document Verification and Loan Application cycle times and then move into the Control phase, discussed in “Control Phase” on page 355.

Figure 175 Sensitivity Chart after Loan Application Adjustment



Packaging Pump Design – Tutorial 4

Design for Six Sigma (DFSS) and other design improvement methodologies are intended to improve product quality at the start of product development.

DFSS has five phases: Define, Measure, Analyze, Design, Validate (or Verify). The ultimate mission of DFSS is to meet general Six Sigma goals of satisfying customer needs while minimizing variation and to accomplish this as early in the development cycle as possible.

The following sections show how DFSS techniques can be used with Crystal Ball to simulate various design options for a fluid pump in a food production setting:

- [“Overall Approach” on page 366](#)
- [“Using the DFSS Liquid Pump model” on page 369](#)
- [“Using OptQuest to Optimize Quality and Cost” on page 377](#)

Overall Approach

Suppose you are a pump manufacturer. You want to design a pump for a liquid packaging system that draws processed fluids from a vat into jars at a consistent rate. You want to meet the specified flow rate target and limits while maximizing performance and minimizing costs.

Using the phases of DFSS, you follow this overall design approach:

- Define — Obtain an appropriate flow rate target and limits from the customer and recommend a type of pump based on customer considerations
- Measure — Consider the elements of the Known Flow Rate equation to determine the pump design features that affect flow rate and obtain information about tolerances, costs, and so on
- Analyze — Use Monte Carlo analysis and sensitivity analysis to study how different design elements affect pump performance and affect production quality

- Design — Use optimization techniques with defined tradeoffs between flow rate performance and total cost to determine the design parameters that best meet a defined quality level while reducing cost
- Validate — Based on the optimized design parameters, create physical prototypes and test to confirm that this design configuration yields the best-performing, most cost-effective pump

In the Define and Measure phases, you obtain and use information to build a Crystal Ball model. Then, you use Crystal Ball to simulate real-world variations that occur in the actual manufacturing of the product. Finally, if you have Crystal Ball Decision Optimizer, you can use sensitivity analysis and further optimization to arrive at the best balance between quality and cost.

The following sections give details of each phase:

- [“Define Phase” on page 367](#)
- [“Measure Phase” on page 368](#)
- [“Analyze Phase” on page 368](#)
- [“Design Phase” on page 368](#)
- [“Validate Phase” on page 369](#)

The next main section, [“Using the DFSS Liquid Pump model” on page 369](#), works through these phases using a Crystal Ball example model.

Define Phase

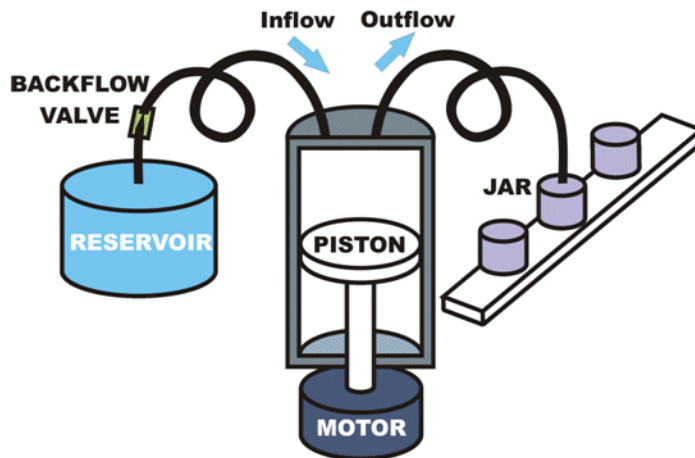
Marketing and production considerations determine the acceptable range of flow rates based on how many units should be produced daily to meet market demand, what is useful production time per day based on plant setup and productivity, and how many pumps are placed in each plant.

The food processing company translates marketing requirements into these engineering specifications and provides them to you:

- Lower specification limit (LSL) = 47.26 ml/sec
- Upper specification limit (USL) = 53.92 ml/sec
- Target = 50.595 ml/sec

Based on these requirements, you propose a displacement pump with a reciprocating piston. [Figure 176](#), following, shows a basic schematic of the system.

Figure 176 The jar-filling system with displacement pump



Measure Phase

You notice that the variables in the Known Flow Rate equation are piston radius, piston stroke length, backflow rate, and motor speed. You observe that your in-house machine shop controls the piston radius and stroke length while the backflow valve and motor are purchased components.

Your machine shop indicates it is capable of 3-sigma quality levels within a tolerance of ± 1 millimeter (mm) for the piston radius and stroke length. Your purchasing department asks you to use an inexpensive backflow valve and motor.

Analyze Phase

During the Analyze phase, you create an Excel workbook that captures the Known Flow Rate equation, characteristics of the pump components used in the equation (piston radius, piston stroke length, motor speed, and backflow rate), flow rate target and limits, machining cost coefficients, plus nine motor and backflow valve cost options.

Then, you define Crystal Ball assumption and forecast cells and simulate your design options.

Design Phase

If you have OptQuest, you can also define decision variables for:

- A range of possible piston radii and associated tolerances (related to standard deviation through capability)
- A range of possible piston stroke lengths and associated tolerances,
- The different possible backflow valve and motor options

After this is done, you can set up quality requirements for flow rate and optimize for the least-cost configuration that meets those quality requirements.

Validate Phase

This phase involves the physical creation of a prototype based on simulation forecasts followed by physical testing to validate the design. Because so much preliminary work was done with spreadsheet modeling instead of building additional prototypes, a final design can be developed quickly and at minimal cost.

Using the DFSS Liquid Pump model

Now, see how to construct a model that effectively simulates the design process with dual goals of maximizing quality and minimizing cost. Then, you run the model and analyze the output using Crystal Ball's process capability features.

This tutorial contains the following review and lesson sections::

- [“Starting Crystal Ball” on page 369](#)
- [“Activating the Process Capability Features” on page 369](#)
- [“Setting the Sampling Seed Value” on page 370](#)
- [“Opening the Example Model” on page 370](#)
- [“Reviewing the Parts of the Model” on page 371](#)
- [“Running Simulations” on page 373](#)
- [“Analyzing Simulations” on page 373](#)
- [“Adjusting Models” on page 375](#)


If you have Crystal Ball Decision Optimizer, see [“Using OptQuest to Optimize Quality and Cost” on page 377](#) for a useful optimization example.

Starting Crystal Ball

If Crystal Ball is not already started, start it as usual ([“Starting Crystal Ball” on page 326](#)).

Activating the Process Capability Features

► To confirm that the process capability features have been activated.

- 1 Choose Run, then Run Preferences. 
- 2 Click the Statistics tab in the Run Preferences dialog.
- 3 Check Calculate Capability Metrics.
- 4 Click the Options button to confirm the settings.

For this example, use the defaults: use short-term metrics, calculate metrics from the normal distribution with a significance level of 0.05, and, if the normality test fails, calculate metrics from the forecast values.

- 5 Click OK in both dialogs to accept the current settings and close them.

Setting the Sampling Seed Value

Set the sampling seed value to 999 in the Run Preferences dialog, Sampling tab, and use Monte Carlo simulation.

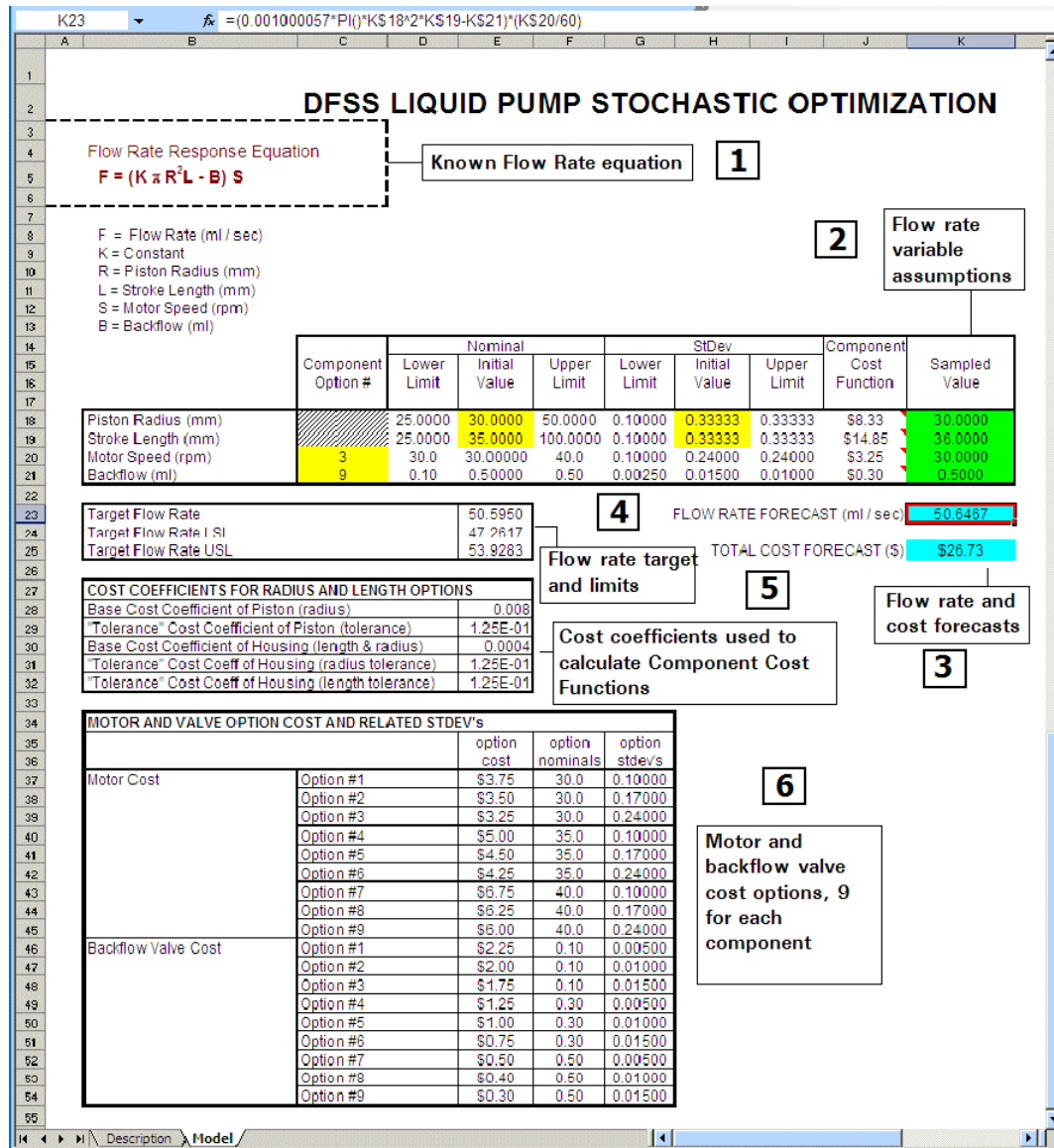
Opening the Example Model

Open DFSS Fluid Pump.xls from the Crystal Ball Examples folder. To choose this example from a list, choose Help, then Crystal Ball, then Examples Guide in Excel or choose Start, then All Programs, then Oracle Crystal Ball, then Examples in the Windows taskbar.

(In Excel 2007, choose Resources, then Examples Guide.)

The workbook opens, as shown in [Figure 177](#).

Figure 177 Fluid Pump Model



This spreadsheet models the fluid pump design problem to be solved.

Reviewing the Parts of the Model

The liquid pump spreadsheet models a design effort with two basic goals: meeting the flow rate target as closely and consistently as possible and minimizing cost. The following sections describe six main parts of the model, indicated by numbers in [Figure 177](#):

- “Known Flow Rate Formula” on page 371
- “Flow Rate Variable Assumptions” on page 371
- “Flow Rate and Cost Forecasts” on page 372
- “Flow Rate Target and Limits” on page 372
- “Cost Coefficients” on page 372
- “Motor and Backflow Valve Cost Options” on page 373

Known Flow Rate Formula

1


The Known Flow Rate formula specifies the relevant variables discussed earlier: piston radius, piston stroke length, backflow rate, and motor speed.

Flow Rate Variable Assumptions

2

The flow rate variable assumptions are Crystal Ball assumptions that allow each of the flow rate variables, listed under the Known Flow Rate formula (1), to be included in the Monte Carlo simulation.

► To see how these are defined:

- 1 Select cell K18 and click the Define Assumption button. 
- 2 **Optional:** Look at K19, K20, and K21.

Each assumption is defined as a normal distribution with a mean equal to the Nominal Initial Value in the column toward the left of the table and a standard deviation equal to the StDev Initial Value in the middle of the table. The Mean and Standard Deviation parameters are not entered directly. Instead, they are entered as cell references to the Initial Value cells in the table to their left.

Note: In this model, whenever you see the word "nominal," it means approximate, designed, or theoretical, as opposed to the actual measured value.

Flow Rate and Cost Forecasts

The flow rate and cost forecasts are Crystal Ball forecasts, the output of the Monte Carlo simulation.

3

The Flow Rate Forecast is based on the Known Flow Rate formula (1).

► To view it:

1 Select cell K23.

The formula in that cell is the Known Flow Rate formula (a function of the flow rate variables) expressed in Excel format.

2 Click the Define Forecast button.



3 Notice that the values in cells E24, E25, and E23 are displayed in the Define Forecast dialog as the process capability lower specification limit (LSL), upper specification limit (USL), and target value, respectively.

They are defined as cell references. To demonstrate this, click in one of the text boxes. The related cell reference is displayed. (Note: If you don't see these text boxes in the Define Forecast dialog, process capability features have not been activated in the Run Preferences dialog.)

The Total Cost Forecast is the sum of the Component Cost Function column values in the upper table. To view it:

4 Select cell K25.

Notice its formula is simply the sum of the component costs in cells J18 through J21. No target or limits have been established for this forecast.

Flow Rate Target and Limits

4

The flow rate target and upper and lower specification limits (4) are values defined by the food processing plant in the Define phase of the DFSS process. The previous section shows how they can be used to set the Target, LSL, and USL for the Flow Rate Forecast in cell K23.

Cost Coefficients

5

The cost coefficients table contains values used to calculate the component cost functions, summed to yield the Total Cost Forecast (3).

- To see how these are used to calculate the component cost functions:

- 1 **Select cell J18.**

This formula uses the Base Cost Coefficient of the piston, the initial value of the piston radius, the "Tolerance" Cost Coefficient of the piston, and the initial value of the standard deviation. The cost is directly proportional to the radius squared due to raw material usage and inversely proportional to the standard deviation squared (a common method to relate tolerance to cost).

- 2 **Optional: View the contents of cells J19, J20, and J21.**

These formulas are also similarly derived from cost coefficients or nominal costs relevant to each particular flow rate variable.


Motor and Backflow Valve Cost Options

6

The motor and backflow valve cost options are two sets of nine options each provided by the motor and backflow valve vendors. Different performance specifications have different costs associated with them.

Running Simulations

At this point you have created assumptions and forecasts.

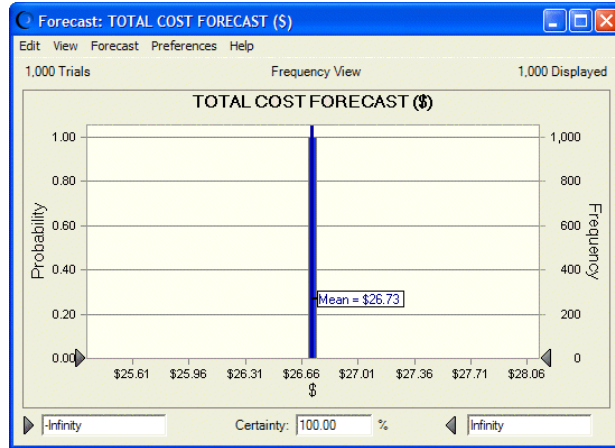
- To run the simulation and generate forecast charts, click the Start [Simulation] button .

Analyzing Simulations

When you run the simulation for this model, two forecast charts are displayed.

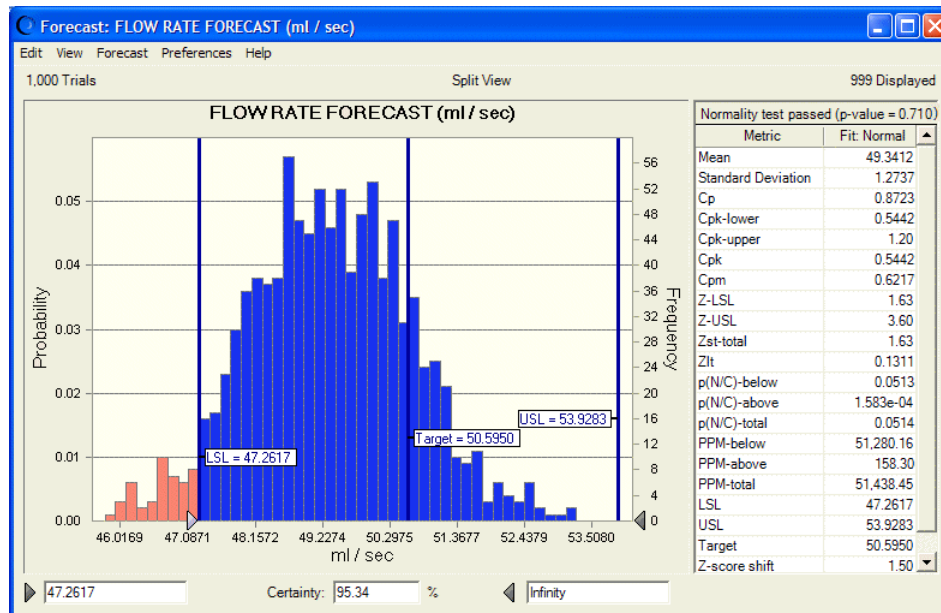
The Total Cost Forecast ([Figure 178](#), following) includes no assumption cells. It is displayed as a single value instead of a range of predicted values. The forecasted total cost is \$26.73 for the pump (shown here with the Mean marker line displayed).

Figure 178 The Total Cost Forecast Chart



Because you entered a target and specification limits, the Flow Rate Forecast chart opens in Split View with the forecast chart on the left side and process capability metrics on the right, shown in Figure 179.

Figure 179 The Flow Rate Forecast with Process Capability Metrics



Notice that marker lines are displayed for the LSL, Target, and USL values. (You might see different marker lines; the Mean and Standard Deviation marker lines have been removed to simplify the screenshot.) Because the LSL and USL are defined, the certainty grabbers are automatically set to those values. According to the value in the Certainty field for this simulation, 95.34% of forecasted values fall between 47.2617 and 53.9283, the specification limits. The mean is about one standard deviation lower than the target.

The distribution curve is normal. Looking at the process capability metrics, the Z-LSL shows the LSL is 1.63 sigmas below the mean. You were hoping to see a value of at least 3. The Cp capability index is lower than 1, so the short-term potential sigma level is less than 3.

You generate a sensitivity chart (Figure 180) to determine which of the flow rate variables has the most influence on the Flow Rate Forecast.

Figure 180 Sensitivity Chart for the Flow Rate Forecast

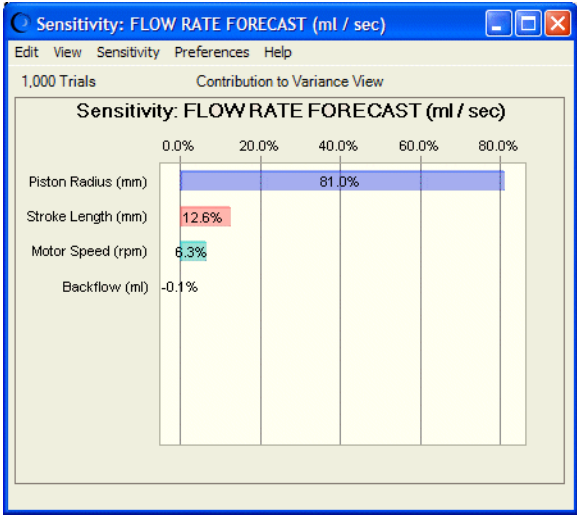


Figure 169 shows that the flow rate variable with the greatest effect on the Flow Rate Forecast is the piston radius. Reducing the standard deviation of the piston radius should affect the overall flow rate variance and improve the process capability metrics. You wonder how reducing the piston standard deviation by 50% would affect the flow rate forecast quality. You decide to adjust the model and find out.

Adjusting Models

- To see the effect of reducing the standard deviation of the piston radius:
 - 1 Select cell H18.
 - 2 Reduce the value by half, to 0.16667.
 - 3 Enter this same value in the Upper Limit cell, I18.

Now, the table of flow rate variables is displayed as shown in Figure 181.

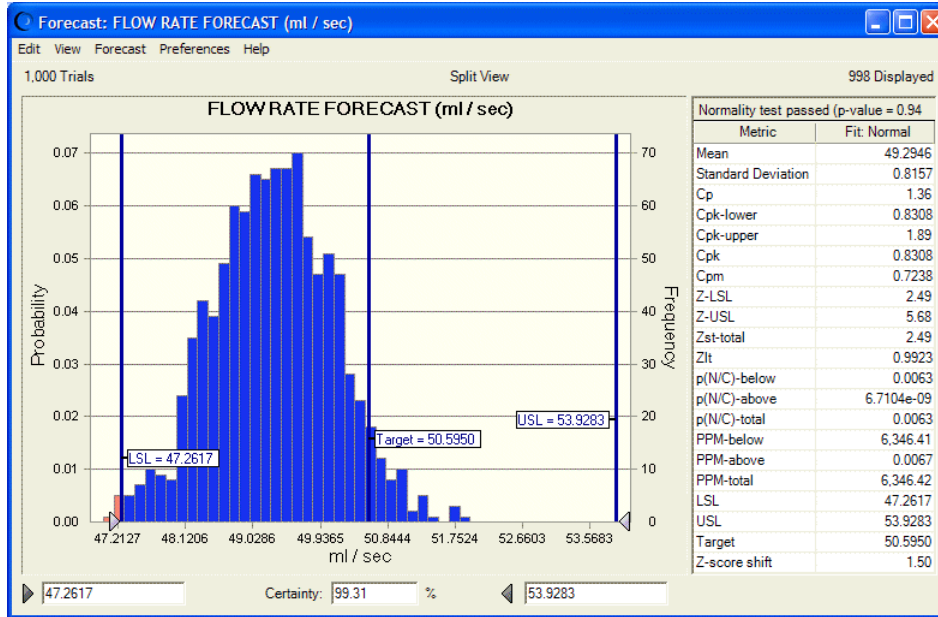
Figure 181 Flow Rate Variable Initial Values and Limits

	Component Option #	Nominal			StDev			Component Cost Function	Sampled Value
		Lower Limit	Initial Value	Upper Limit	Lower Limit	Initial Value	Upper Limit		
Piston Radius (mm)		25.0000	30.0000	50.0000	0.10000	0.16667	0.33333	\$11.70	30.0000
Stroke Length (mm)		25.0000	35.0000	100.0000	0.10000	0.33333	0.33333	\$18.22	36.0000
Motor Speed (rpm)	3	30.0	30.00000	40.0	0.10000	0.24000	0.24000	\$3.25	30.0000
Backflow (ml)	9	0.10	0.50000	0.50	0.00250	0.01500	0.01000	\$0.30	0.5000

- 4 Reset and run the simulation again.

The Flow Rate Forecast chart is displayed, similar to Figure 182.

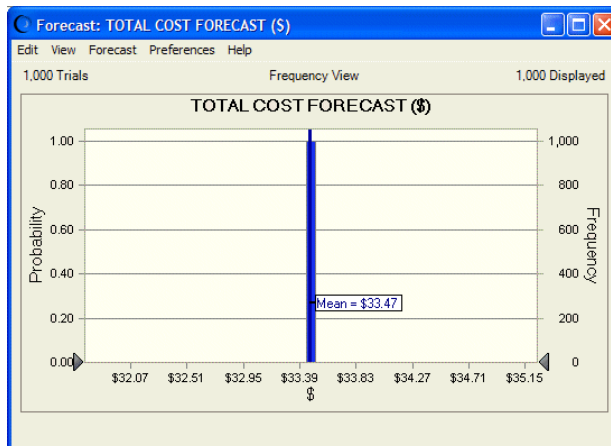
Figure 182 Flow Rate Forecast Chart After Model Adjustment



In Figure 182, quality appears much better than that shown in Figure 168. The mean is less than 1.5 standard deviations lower than the target, and the standard deviation is smaller. USL is almost 6 sigmas away from the mean ($Z\text{-USL} = 5.68$) and LSL is over 2 sigmas away ($Z\text{-LSL} = 2.49$). The certainty of the forecasted flow rate falling within LSL and USL is now over 99%.

The Total Cost Forecast chart has also changed, as shown in Figure 183. The quality improvements result in higher costs. Where the total cost per pump was \$26.73, now it is \$33.47, a 25% increase. You and your team must determine whether to sacrifice quality to lower the cost or whether to test modifications to the other three flow rate variable components as well.

Figure 183 The Total Cost Forecast Chart after Model Adjustment



Using OptQuest to Optimize Quality and Cost

If you have Oracle Crystal Ball Decision Optimizer, Fusion Edition with OptQuest, an optimization tool, you can use it to maximize quality and minimize cost. To do this, you must consider the relationship between design parameters and cost. And, you must consider the relationship between motor and backflow valve options and cost.

The Total Cost Forecast is defined as the sum of the four component costs, examined in “Flow Rate Variable Assumptions” on page 371. The formulas used to calculate these values are based on the mean and standard deviation of the piston radius, the mean and standard deviation of the piston stroke length, nine different motor options, and nine different backflow valve options.

To apply OptQuest to this model, follow the steps in these sections:

- “Defining Decision Variables” on page 377
- “Identifying Optimization Goals” on page 378
- “Running OptQuest” on page 378

Defining Decision Variables

To optimize these variables with OptQuest, a set of decision variables are defined in cells C20, C21, E18, E19, H18, and H19 (Figure 184).

Figure 184 Table of Flow Rate with Cells Defined as Decision Variables

	Component Option #	Nominal			StDev			Component Cost Function	Sampled Value
		Lower Limit	Initial Value	Upper Limit	Lower Limit	Initial Value	Upper Limit		
Piston Radius (mm)		25.0000	30.0000	50.0000	0.10000	0.33333	0.33333	\$8.33	30.0000
Stroke Length (mm)		25.0000	35.0000	100.0000	0.10000	0.33333	0.33333	\$14.85	35.0000
Motor Speed (rpm)	3	30.0	30.00000	40.0	0.10000	0.24000	0.24000	\$3.25	30.0000
Backflow (ml)	9	0.10	0.50000	0.50	0.00250	0.01500	0.01000	\$0.30	0.5000

Cells C20, C21
Cells E18, E19
Cells H18, H19

► To view the contents of each decision variable, reset Crystal Ball and:

1 Select a decision variable cell.

2 Choose Define, then Define Decision. 

3 In the Define Decision Variable dialog, there is a name, an upper and lower bound, a type setting, and a step size for discrete variables.

Note: If you changed the Piston Radius standard deviation Initial Value and Upper Limit for the last part of the DFSS Pump tutorial, be sure to change them both back to their original values as shown in Figure 184. Also, be sure that these values are included in the decision variable for the Piston Radius standard deviation (Cell H18). Check it as described in steps 1 and 2 above.

The upper and lower bound for piston machining variables are the same as those in the Lower Limit and Upper Limit tables of [Figure 184](#). For the motor speed and backflow valve variables, the upper and lower bounds are the lowest and highest options (1 and 9, respectively).

In choosing the piston machining values shown in [Figure 184](#), you could identify raw stock availability to define a range of piston radii and lengths for investigation. You could also identify a feasible range of tolerances for machining the radius and length.

Identifying Optimization Goals

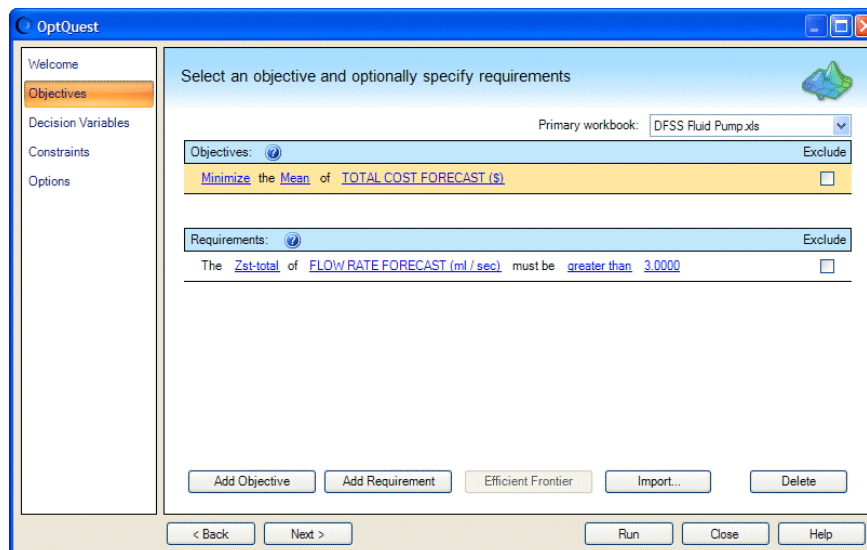
If you have OptQuest, you can actually perform the optimization. First, identify optimization goals. For this project, they are:

- Minimize cost.
- Reduce variation of flow rate to at least 3 sigma levels. That is, Z-st-total, expressed in this example as Zst, should be equal to or greater than 3.

Running OptQuest

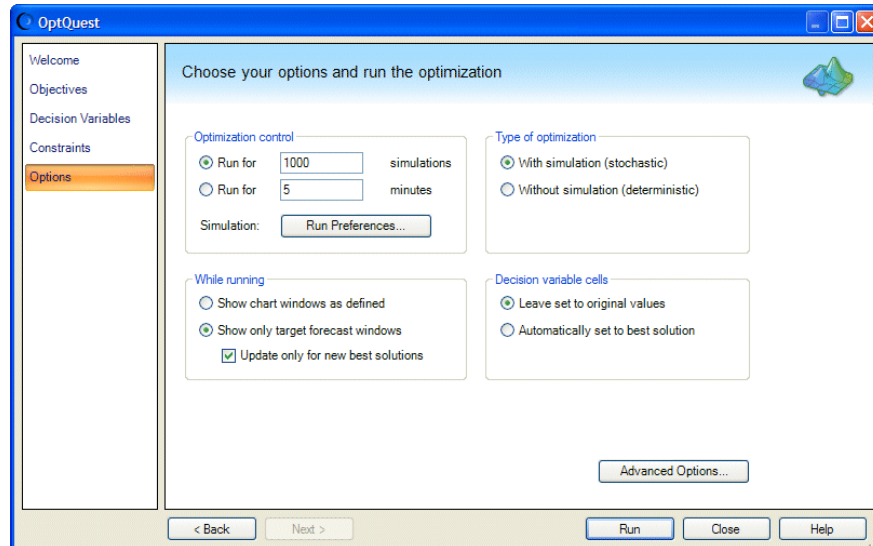
- To optimize these goals in OptQuest, reset the simulation in Crystal Ball and:
 - 1 Open the Crystal Ball Run Preferences dialog and set Number Of Trials To Run to 1000. For this example, Sampling was set to Latin Hypercube with an Initial Seed Value of 999 (set on the Sampling tab of the Run Preferences dialog).
 - 2 Choose Run, then OptQuest.
 - 3 When the OptQuest wizard opens, click Objectives in the navigation pane to display the Objectives panel if it is not already onscreen.
 - 4 Confirm that the Objectives panel opens, as shown in [Figure 185](#).

Figure 185 Forecast Optimization Defined in OptQuest



- Click Next until you reach the Options panel (Figure 186, following).

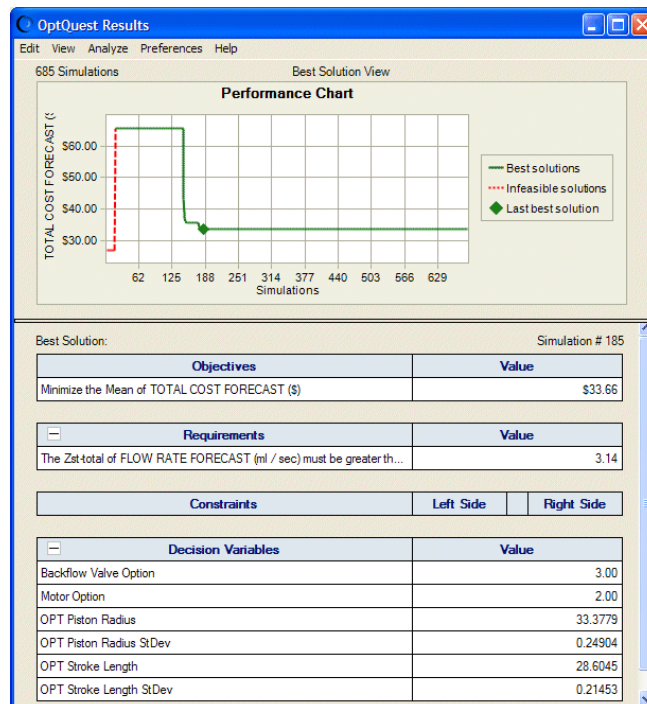
Figure 186 OptQuest Options panel



- Choose Run For 1000 Simulations, then click Run.

OptQuest starts looking for the best feasible solution. Ultimately a solution will be found that is similar to that shown in Figure 187.

Figure 187 OptQuest Solution for the Fluid Pump Problem



Your optimized values should be similar to these:

Option	Optimized Value
Total cost	\$33.66
Zst (sigma level)	3.14
Backflow valve option	3
Motor option	2
Piston radius (mm)	33.38
Piston radius standard deviation	0.249
Stroke length (cm)	28.60
Stroke length standard deviation	0.214



Using the Process Capability Features

In This Appendix

Introduction.....	381
About Crystal Ball's Process Capability Features	381
About Quality Improvement Methodologies	382
How Crystal Ball Supports Quality.....	384
Working Through Process Capability Tutorials.....	386
Preparing to Use Process Capability Features.....	386
Analyzing Process Capability Results	388
Capability Metrics List	393

Introduction

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.

The following sections introduce the process capability features and describe how to use them:

- “About Crystal Ball's Process Capability Features” on page 381
- “Preparing to Use Process Capability Features” on page 386
- “Analyzing Process Capability Results” on page 388
- “Capability Metrics List” on page 393

About Crystal Ball's Process Capability Features

Use the Statistics tab of the Run Preferences dialog to activate the process capability features. After they are activated, you can:

- Add upper and lower specification limits and target values to forecast definitions (“[Setting Specification Limits and Targets](#)” on page 387).
- Display the Capability Metrics view in the forecast window, in addition to the basic Frequency, Cumulative Frequency, Reverse Cumulative Frequency, Statistics, and Percentiles views (“[Viewing Capability Metrics](#)” on page 388).

- Use Crystal Ball's Split View feature to display the Capability Metrics view to the right of one of the forecast chart views ([“Viewing Forecast Charts and Capability Metrics Together” on page 389](#)). This is the default.
- View marker lines for specification limits and the target value on forecast charts ([“Viewing LSL, USL, and Target Marker Lines” on page 391](#)).
- Extract capability metrics to a worksheet using Analyze, then Extract Data or the Auto Extract forecast preferences ([“Extracting Capability Metrics” on page 391](#)).
- Include capability metrics in reports ([“Including Capability Metrics in Reports” on page 392](#)).
- Include several capability metrics in OptQuest, if you have a license for it, and specify them as objectives or requirements.
- Access capability metrics in the Crystal Ball Developer Kit using these calls: CB.SetFore, CB.GetFore, CB.DefineForeND, CB.SetView, CB.GetForeStat, CB.RunPrefsND, CB.GetRunPrefs, CB.CreateRptND, and CB.ExtractDataND (see the Crystal Ball Developer Kit User's Guide for more information)

Several of these calls have equivalent spreadsheet functions and can be used in worksheet cells instead of VBA macros.

The following sections summarize process capability initiatives for quality improvement and describe how Crystal Ball's process capability features support those initiatives:

- [“About Quality Improvement Methodologies” on page 382](#)
- [“How Crystal Ball Supports Quality” on page 384](#)
- [“Working Through Process Capability Tutorials” on page 386](#)

About Quality Improvement Methodologies

Starting about 1975, competitive pressures on manufacturers encouraged them to discover new quality methodologies. Leading companies developed a variety of techniques to save costs and time by improving processes, designing more effectively, and increasing the value of product modifications.

Some of the most successful methodologies have been Six Sigma, Design for Six Sigma (DFSS), Lean principles, and similar tools for quality improvement. The following sections summarize several of these:

- [“Methodologies for Improving Processes — Six Sigma” on page 382](#)
- [“Methodologies for Improving Design — DFSS” on page 383](#)
- [“Methodologies for Adding Value — Lean Principles” on page 383](#)

Methodologies for Improving Processes — Six Sigma

Broken processes reduce quality in a variety of organizations, from banking to manufacturing to healthcare, and more. In the United States, Six Sigma is probably the best known process

improvement methodology, although other techniques have similar goals and effectiveness in the field.

Six Sigma is a methodology for improving processes to achieve any or all of the following goals:

- Reducing the defect rate to 3.4 per million (outside the range of 6 standard deviations above and below the mean)
- Creating improvements of 70% or better
- Using the Define-Measure-Analyze-Improve-Control methodology of information gathering, analysis, and action
- Producing rapid improvement of an organization's financial "bottom-line."

Six Sigma methodology is data-driven and focuses on the relationship between system inputs and outputs, both of which can vary. The inputs, or independent variables, are symbolized by X ; the outputs, or dependent variables, are symbolized by Y . The goal of a Six Sigma program is to yield maximum quality and minimum variation in Y by controlling variation in all the X variables, the factors that influence it.

Six Sigma teams talk about the "hidden factory" of workers behind the scenes who rework defects and perform other extra tasks to make up for broken processes. Six Sigma programs achieve their goals by discovering the hidden factory in their organization and releasing its workers for more productive tasks.

Methodologies for Improving Design – DFSS

Design for Six Sigma (DFSS) developed following the success of Six Sigma and other process improvement methodologies. If a similar multi-phase improvement technique could be applied to design, costs and time could be saved by eliminating waste and unnecessary prototyping. Successful designs could move to production quicker, reducing costs and increasing an organization's competitive edge. DFSS proved to be a successful tool for improving design in a variety of settings. The five phases of DFSS are Define, Measure, Analyze, Design, and Verify (DMADV).

The ultimate mission of DFSS is to address general Six Sigma goals of meeting customer needs while minimizing variation and to accomplish this as early in the development cycle as possible.

Methodologies for Adding Value – Lean Principles

The Lean approach to quality focuses on eliminating waste, improving efficiency, and increasing value. Lean techniques seek to increase value by improving the flow of value stream activities and reducing waste. Other Lean principles include just-in-time delivery driven by customer pull — not push — and a constant, incremental search for perfection (sometimes called *kaizen*).

Lean practitioners use value stream mapping to identify process steps with the greatest impact on the overall product. Then, Lean projects are created to improve those processes. The "hidden factory" is a major target for Lean programs, as practitioners seek to eliminate rework and scrap. Lean principles are often used with statistical methodologies such as Six Sigma.

How Crystal Ball Supports Quality

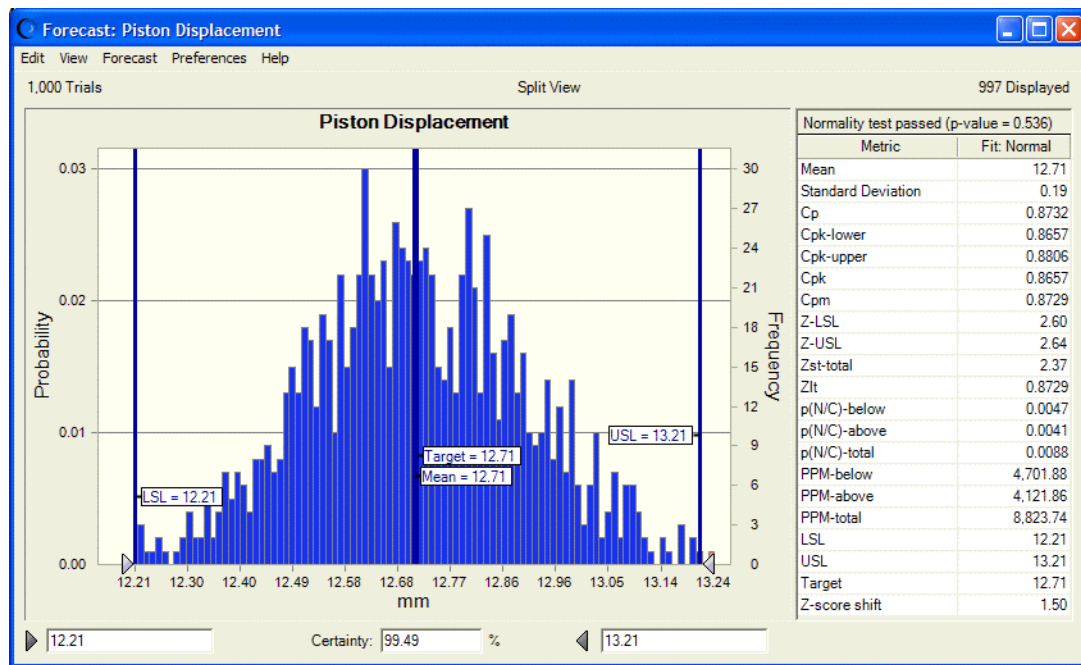
Crystal Ball is most helpful in phases of quality improvement programs where uncertainty and variation have the greatest impact. In the Define phase, for example, cost savings forecasting, project cost estimation, and resource scheduling are all subject to uncertainty. These types of analyses are ideal targets for simulation.

In the Analyze and Improve phases, the focus is variation. Simulation can help reduce the variation around tolerances or process steps.

In any phase, defining model inputs (X's) as a distribution of values yields a more realistic range of results. Then, the results (Y's), defined as Crystal Ball forecasts, can be analyzed as demonstrated in the following chapters of this guide.

By default, the forecast certainty range is automatically set to the upper and lower specification limits (USL and LSL), if at least one of them is entered for the forecast. Then, you can tell at a glance the probability of output falling within them, 99.49% in the example in [Figure 188](#). Split View shows capability metrics to the right of the forecast chart.

Figure 188 Piston Displacement Forecast Chart

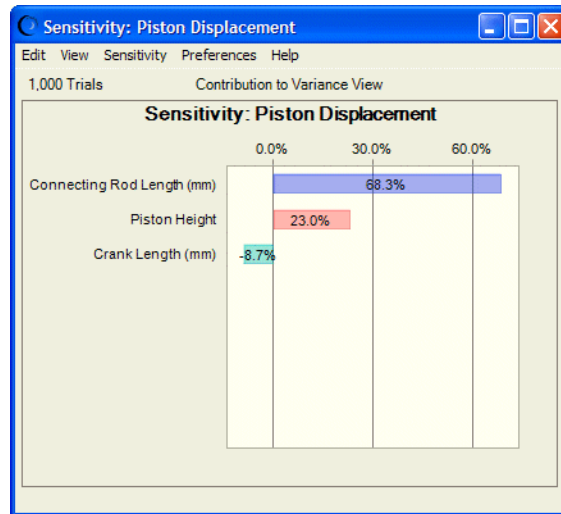


Capability Metrics view indicates whether the forecast distribution is normal, to guide your interpretation of the capability metrics. For example, Z metrics are always displayed, although they are generally used only for normal distributions. The Z-total metric indicates the sigma level of quality. In this example, the level is 2.37 sigmas. For this forecast, 8,824 units per million will be outside the specification limits. The Cp and Cpk values are less than one, which suggests that the quality level is lower than 3 sigmas. To cycle among other views, such as Statistics and Percentiles, press the Spacebar.

Note: By default, Crystal Ball applies a 1.5 sigma Z-score shift value when calculating capability metrics. If your organization uses a different value or does not use a Z-score shift value, be sure to adjust this setting in the Capability Options panel.

Crystal Ball’s sensitivity charts are also helpful to quality practitioners. They show which inputs, or assumptions, have the greatest impact on the selected forecast. For example, the following sensitivity chart (Figure 189) shows that Connecting Rod Length has the greatest effect on the Piston Displacement forecast shown in the previous figure.

Figure 189 Piston Displacement Sensitivity Chart



Crystal Ball’s data extraction and reporting capabilities are also helpful in quality analysis. For example, you can automatically extract capability metrics to a prominent location in your model for immediate access to current sigma levels and other important measures.

If you have OptQuest, it — along with the Crystal Ball Developer Kit and OptQuest Developer Kit — can add further power to your arsenal of quality improvement tools.

When you define certain cells as Crystal Ball decision variables, you can then optimize them with OptQuest and copy the new, optimal values back into your Crystal Ball model. For example, “Using OptQuest to Optimize Quality and Cost” on page 377, shows how you can use OptQuest to adjust several controllable inputs simultaneously to yield a set of optimal results.

Visual Basic for Applications (VBA) developers can use the Crystal Ball Developer Kit to support quality projects in a variety of creative ways. This model uses the Developer Kit to create a color-coded dashboard that highlights which process steps are lowest in quality and which are most important to the process output.

For other ways to apply Crystal Ball to your own quality improvement projects, review the examples in this guide and examine the other models supplied with Crystal Ball and posted online. For more information, see:

<http://www.oracle.com/crystalball>

Working Through Process Capability Tutorials

As you learn about the Crystal Ball process capability features, consider working through the following tutorials:

- [“Improving Process Quality — Tutorial 3” on page 352](#)
- [“Packaging Pump Design — Tutorial 4” on page 366](#)

They show how the process capability features can be used within quality improvement methodologies to simplify quality initiatives in a variety of settings.

Preparing to Use Process Capability Features

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. The following sections describe these procedures:

- [“Activating the Process Capability Features” on page 386](#)
- [“Setting Capability Calculation Options” on page 386](#)
- [“Setting Specification Limits and Targets” on page 387](#)

Activating the Process Capability Features

- To activate Crystal Ball’s process capability features:
 - 1 Choose **Run**, then **Run Preferences** to display the **Run Preferences** dialog.
 - 2 Click the **Statistics** tab.
 - 3 Check **Calculate Capability Metrics**.
 - 4 Click the **Options** button to set the capability calculation options, described in the next section.
 - 5 Click **OK** when setting changes are complete.

Setting Capability Calculation Options

After you activate the process capability features, you can set a variety of options to further customize these features for your situation.

- To set the process capability options:
 - 1 Display the **Statistics** tab of the **Run Preferences** dialog.
 - 2 Click the **Options** button as described in step 5 of the previous section.

The **Capability Options** panel opens.
 - 3 Indicate whether metrics should use short-term or long-term formulas, depending on the time-span of your model.
 - 4 Optionally, 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 387).
- 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 might 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 choose 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 choose Define, then Define Forecast.

The Define Forecast dialog opens. With process capability features activated, it includes Name, Units, LSL, USL, and Target fields..

- 2 Enter specification limits and target values for this forecast into the appropriate fields.

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 fields 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, , to the right of the Name field.
- 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 391](#)

Analyzing Process Capability Results

When capability metrics have been activated and appropriate information entered, run a Crystal Ball simulation as usual. Then, you can perform the following capability analyses:

- [“Viewing Capability Metrics” on page 388](#)
- [“Extracting Capability Metrics” on page 391](#)
- [“Including Capability Metrics in Reports” on page 392](#)

Viewing Capability Metrics

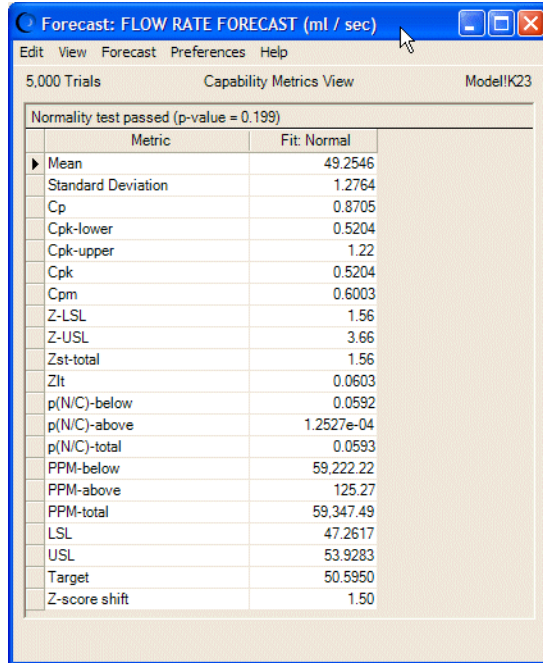
After you have defined a forecast with at least one specification limit (and, optionally, a target), you can run a simulation and display capability metrics for the forecast.

► To display capability metrics:

- 1 Define a forecast with LSL, USL, and Target values as described in [“Setting Specification Limits and Targets” on page 387](#).
- 2 Run the simulation and display the chart for that forecast.
- 3 In the forecast window, choose View, then Capability Metrics.

A table of metrics opens, similar to [Figure 190](#).

Figure 190 Capability Metrics View



Metric	Fit: Normal
Mean	49.2546
Standard Deviation	1.2764
Cp	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 “[Capability Metrics List](#)” on page 393.

The following sections describe other ways you can analyze capability metrics visually:

- “[Viewing Forecast Charts and Capability Metrics Together](#)” on page 389
- “[Viewing LSL, USL, and Target Marker Lines](#)” on page 391

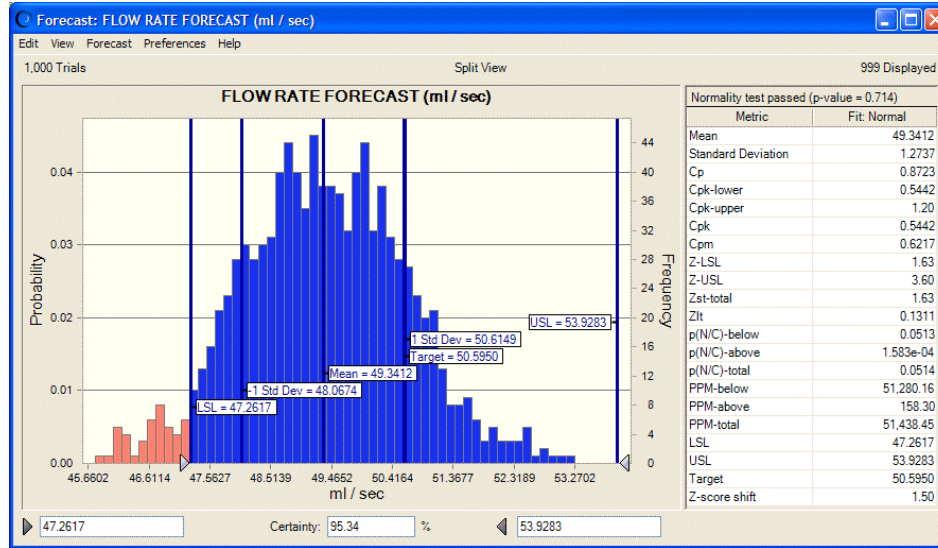
Viewing Forecast Charts and Capability Metrics Together

It can be helpful to view a forecast chart and its capability metrics side by side. This is now the default view when capability metrics are activated.

- To do this manually:
- 1 Follow the instructions in the previous section to display capability metrics.
 - 2 In the forecast window, choose **View** to open the **View** menu.
 - 3 Choose **Split View** at the bottom of the menu.
 - 4 Open the **View** menu again and choose **Frequency**.

The Frequency chart and capability metrics both appear, similar to [Figure 191](#).

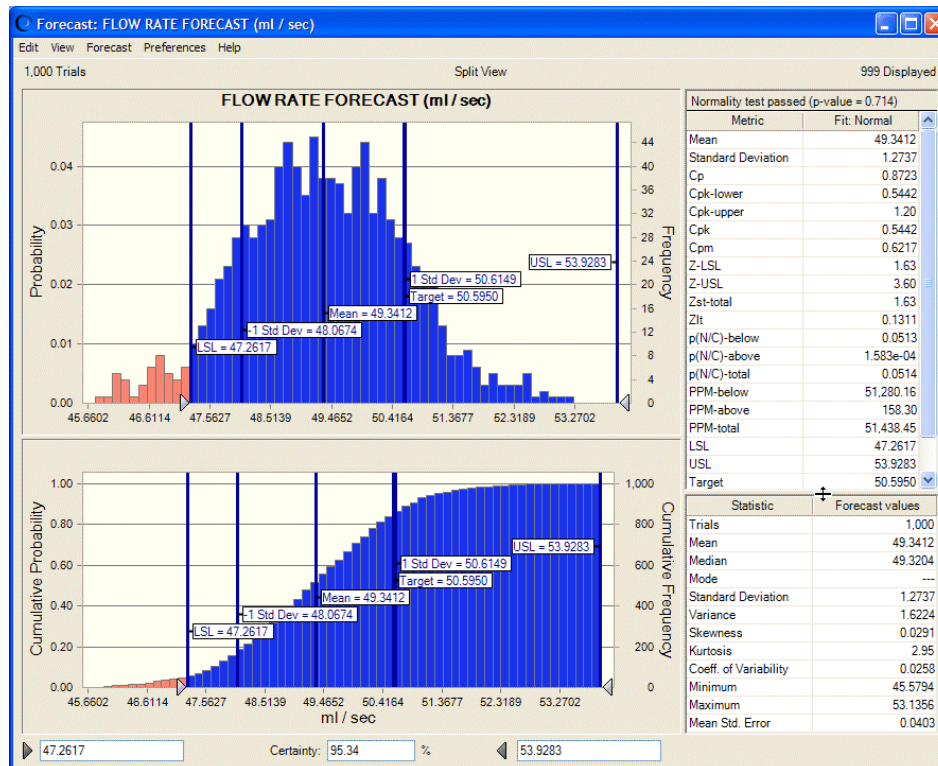
Figure 191 Frequency Chart and Capability Metrics in Split View



5 Optionally, continue opening the View menu and choosing charts or data.

Figure 192 shows a Frequency chart, a Cumulative Frequency chart, plus Statistics and Capability Metrics tables.

Figure 192 Frequency and Cumulative Frequency Charts with Capability Metrics and Statistics 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 22, "Shortcut Keys for Chart Preferences," on page 300.

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

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. For an example, see [Figure 192](#).

Notice that 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 fields 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 Choose **Preferences**, 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 checked to display the specification limit and target marker lines on that forecast chart.

To hide the markers, uncheck **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

You can extract capability metrics automatically or manually, as described in the following sections:

- [“Extracting Capability Metrics Automatically” on page 391](#)
- [“Extracting Capability Metrics Manually” on page 392](#)

Extracting Capability Metrics Automatically

- You can automatically extract capability metrics whenever a simulation runs. To extract metrics automatically:
 - 1 In a forecast window, choose **Preferences**, then **Forecast** and display the **Auto Extract** tab of the **Forecast Preferences** dialog.
 - 2 Check **Extract Forecast Statistics Automatically...** and scroll down to the bottom of the data selection list.
 - 3 Check **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 your worksheet, along with any other data you have requested.

Note: For more information about the Auto Extract feature, see “Auto Extract Tab” on page 67. IMPORTANT! Be sure to choose an open area of your worksheet as the Starting Cell to avoid overwriting your model.

Extracting Capability Metrics Manually

- To extract capability metrics manually after a simulation runs:
 - 1 Choose Analyze, then Extract Data to display the Extract Data Preferences dialog.
 - 2 Check Capability Metrics at the bottom of the Select Data To Extract list.
 - 3 Choose appropriate Forecasts and Assumptions settings and specify locations and other preferences on the Options tab. For more information, see “Extracting Data” on page 161 or click the Help button in the Extract Data Preferences dialog.
 - 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 193 for an example.

Figure 193 Manually Extracted Capability Metrics

	A	B	C
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	Cp	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	---

Including Capability Metrics in Reports

- To include capability metrics in full, forecast, or custom reports:
 - 1 Choose Analyze, then Create Report to display the Create Report dialog.
 - 2 Click a report type: Full, Forecast, or Custom.

If you choose 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 choose Custom, the Custom Report dialog opens.

3 If it is not already highlighted, highlight Forecasts in the Report Sections list.

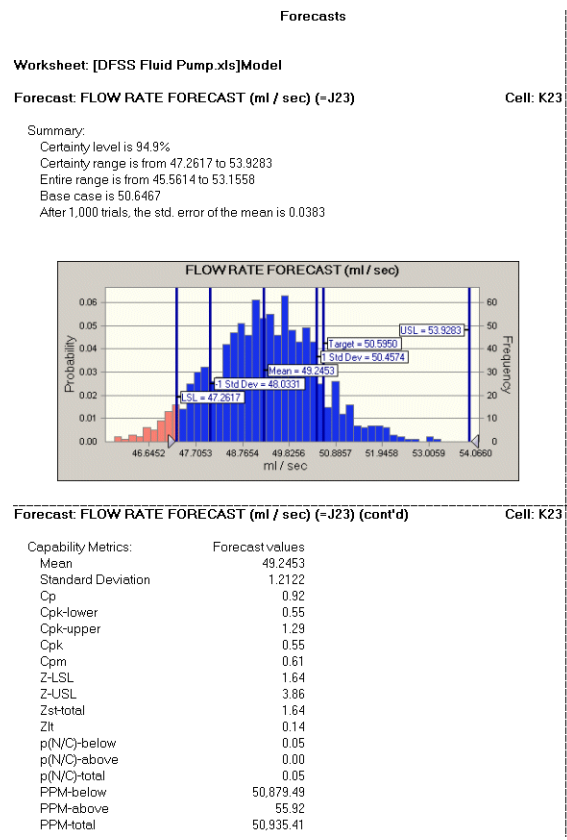
The Forecasts Details list is displayed. With the process capability features activated, Capability Metrics is checked by default.

4 If you don't want to include the capability metrics for some reason, uncheck that setting in the Forecasts Details list. Otherwise, leave it checked and follow the instructions in online help or ["Defining Custom Reports"](#) on page 160 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 194](#).

Figure 194 Frequency Report with Capability Metrics



Capability Metrics List

The following table lists and defines the statistics shown in Capability Metrics view and indicates whether each statistic is displayed for long-term or short-term data. There is a "y" if it is displayed and an "n" if it does not display. For a discussion of the equations used to calculate each of these statistics, see the online *Oracle Crystal Ball Statistical Guide*.

Z scores are typically reported only for normal data. Crystal Ball always displays Z scores. It is up to the user to determine if the values are appropriate.

Table 28 Capability Statistics Calculated by Crystal Ball

Metric	Long-term	Short-term	Description
Mean	y	y	Mean of the forecast values
Standard deviation	y	y	Standard deviation of the forecast values
Cp	n	y	Short-term capability index indicating what quality level the forecast output is potentially capable of producing. It is defined as the ratio of the specification width to the forecast width. If a Cp is equal to or greater than 1, then a short-term 3-sigma quality level is possible.
Pp	y	n	Long-term capability index indicating what quality level the forecast output is potentially capable of producing. It is defined as the ratio of the specification width to the forecast width. If a Cp is equal to or greater than 1, then a long-term 3-sigma quality level is possible.
Cpk-lower	n	y	One-sided short-term capability index; for normally distributed forecasts, the ratio of the difference between the forecast mean and lower specification limit over three times the forecast short-term standard deviation; often used to calculate process capability indices with only a lower specification limit.
Ppk-lower	y	n	One-sided long-term capability index; for normally distributed forecasts, the ratio of the difference between the forecast mean and lower specification limit over three times the forecast long-term standard deviation; often used to calculate process capability indices with only a lower specification limit.
Cpk-upper	n	y	One-sided short-term capability index; for normally distributed forecasts, the ratio of the difference between the forecast mean and upper specification

Metric	Long-term	Short-term	Description
			limit over three times the forecast short-term standard deviation; often used to calculate process capability indices with only an upper specification limit.
Ppk-upper	y	n	One-sided long-term capability index; for normally distributed forecasts, the ratio of the difference between the forecast mean and upper specification limit over three times the forecast long-term standard deviation; often used to calculate process capability indices with only an upper specification limit.
Cpk	n	y	Short-term capability index (minimum of calculated Cpk-lower and Cpk-upper) that takes into account the centering of the forecast with respect to the midpoint of the specified limits; a Cpk equal to or greater than 1 indicates a quality level of 3 sigmas or better.
Ppk	y	n	Long-term capability index (minimum of calculated Ppk-lower and Ppk-upper) that takes into account the centering of the forecast with respect to the midpoint of the specified limits; a Ppk equal to or greater than 1 indicates a quality level of 3 sigmas or better.
Cpm	n	y	Short-term Taguchi capability index; similar to Cpk but considers a target value, which may not necessarily be centered between the upper and lower specification limits.
Ppm	y	n	Long-term Taguchi capability index; similar to Ppk but considers a target value, which may not necessarily be centered between the upper and lower specification limits.
Z-LSL	y	y	The number of standard deviations between the forecast mean and the lower specification limit.

Metric	Long-term	Short-term	Description
Z-USL	y	y	The number of standard deviations between the forecast mean and the upper specification limit.
Zst	y	n	For short-term metrics when only one specification limit is defined, equal to Z-LSL if there is only a lower specification limit or Z-USL if there is only an upper specification limit.
Zst-total	n	y	For short-term metrics when both specification limits are defined, the number of standard deviations between the short-term forecast mean and the lower boundary of combining all defects onto the upper tail of the normal curve. Also equal to Zlt-total plus the Z-score shift value if a long-term index is available.
Zlt	n	y	For long-term metrics when only one specification limit is defined, equal to Z-LSL if there is only a lower specification limit or Z-USL if there is only an upper specification limit.
Zlt-total	y	n	For long-term metrics when both specification limits are defined, the number of standard deviations between the long-term forecast mean and the lower boundary of combining all defects onto the upper tail of the normal curve. Also equal to Zst-total minus the Z-score shift value if a short-term index is available.
p(N/C)-below	y	y	Probability of a defect below the lower specification limit; DPUBELow
p(N/C)-above	y	y	Probability of a defect above the upper specification limit; DPUABOVE
p(N/C)-total	y	y	Probability of a defect outside the lower and upper specification limits; DPUTOTAL
PPM-below	y	y	Defects below the lower specification limit, per million units

Metric	Long-term	Short-term	Description
PPM-above	y	y	Defects above the upper specification limit, per million units
PPM-total	y	y	Defects outside both specification limits, per million units
LSL	y	y	Lower specification limit, the lowest acceptable value of a forecast involved in process capability, or quality, analysis.
USL	y	y	Upper specification limit, the highest acceptable value of a forecast involved in process capability analysis.
Target	y	y	The ideal target value of a forecast involved in process capability analysis.
Z-score shift	y	y	An optional shift value to use when calculating long-term capability metrics. The default, set in the Capability Options panel, is 1.5.



Bibliography

In This Appendix

Bootstrap	399
Monte Carlo Simulation	399
Probability Theory and Statistics.....	400
Random Variate Generation Methods.....	400
Specific Distributions	401
Tornado Charts and Sensitivity Analysis	401
Two-Dimensional Simulation.....	402
Uncertainty Analysis	402
Sequential Sampling with SIPs	402

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Sequential Sampling with SIPs

The SIPs format described in "[Sequential Sampling with Custom Distributions](#)" on page 285 conforms to the Stochastic Library approach set forth in the following articles:

Savage, Sam, Stefan Scholtes, and Daniel Zweidler. "Probability Management, Part 1," *OR/MS Today* 33(1): 21-28 (February 2006).

Savage, Sam, Stefan Scholtes, and Daniel Zweidler. "Probability Management, Part 2," *OR/MS Today* 33(2): 60-66 (April 2006).

These articles are available for download at:

<http://www.probabilitymanagement.org>

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 variability also coefficient of variance or coefficient of variation 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 your model that you can control.

decision variable cell Cells that contain the values or variables that are within your 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.

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 sub-dividing 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 77.](#))

mean The familiar arithmetic average of a set of numerical 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.

outliers also outlying values Values generated during a simulation on the extreme end of a distribution and 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 "Standard deviation" in the "Statistical Definitions" chapter of the online *Oracle Crystal Ball Statistical 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, Fusion Edition 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 "Variance" in the "Statistical Definitions" chapter of the online *Oracle Crystal Ball Statistical Guide*.)

virtual memory Memory which uses your hard drive space to store information after you run out of random access memory. Virtual memory supplements your random access memory.

workbook An Excel file composed of at least one worksheet.

worksheet An Excel file in which you work and store your data. A worksheet is part of a workbook.

Index

Numbers

2D Simulation tool, [30](#)
2D simulation tool, [210](#)

A

absolute cell references, [42](#), [43](#)
activating process capability features, [355](#), [369](#)
alternate parameters, [43](#), [231](#)
analysis, simulation, [360](#), [373](#)
Analyze menu, [290](#)
Analyze phase
 liquid pump example, [368](#)
 loan processing example, [354](#)
analyzing simulation results, [93](#)
analyzing time-series data, [31](#)
Anderson-Darling test, [45](#), [109](#)
Apply To, [120](#)
applying settings, [120](#)
assumption
 preferences, [50](#)
assumption cells
 defined, [37](#)
 liquid pump example, [371](#)
 loan processing example, [357](#)
assumption charts, [26](#)
assumption parameters
 alternate, [43](#)
assumptions
 correlated, [47](#)
 correlating, [47](#)
 defining, [38](#), [334](#)
 entering, [38](#)
 freezing, [80](#)
 selecting and reviewing, [70](#)
assumptions, fitting to distributions, [358](#)
Auto Extract preferences, [67](#)

B

Batch Fit
 example, [172](#)
 tool, [169](#)
Batch Fit tool, [29](#)
bibliography, [401](#)
Bootstrap
 example, [195](#)
 tool, [191](#)
Bootstrap tool, [29](#)

C

capability metrics, [87](#), [381](#)
 liquid pump example, [373](#), [375](#)
 loan processing example, [362](#)
categories
 creating distribution, [57](#)
 deleting distribution, [58](#)
 rearranging distribution, [58](#)
 sharing distribution, [59](#), [60](#), [61](#)
 viewing and editing distribution properties, [58](#)
categories of distributions, [57](#)
Category pane of the Distribution Gallery, [52](#)
caveats for tornado and spider charts, [191](#)
Cell menu, [290](#)
cell preferences, [72](#)
cell references, [42](#)
 absolute, [43](#)
 dynamic and static, [42](#)
 relative, [42](#)
cells
 freezing, [80](#)
certainty level, [329](#), [348](#)
certainty levels
 forecast chart, [96](#)
 trend charts, [137](#)
chart preferences, [112](#)

- shortcut keys, 300
- chart preferences shortcut keys, 112
- charts, 27
 - assumptionr, 26
 - closing, 123
 - copying, 122
 - customizing, 112, 350
 - deleting, 124
 - displaying, 121
 - forecast, 22
 - interpreting, 347
 - managing, 121
 - OptQuest, 27
 - overlay, 23
 - overlay with 2D Simulation, 216
 - pasting, 122
 - preferences, 112
 - printing, 123
 - scatter, 25, 149
 - sensitivity, 24, 138
 - spider, 185
 - tornado, 183
 - trend, 24
 - trend with 2D Simulation, 216
- chi-square distribution, 242
- chi-square test, 45, 110
- closing charts, 123
- Compare Run Modes tool, 31, 318
- comparing distributions, 281
- compatibility, file, 308
- consulting, 16
- contact information, 16
- continuing a simulation, 81
- continuous
 - distributions, 228
- Control Panel
 - Crystal Ball, 83
 - showing after reset, 83
- Control Panel, Crystal Ball, 331
- Control Panel, hiding, 83
- Control phase
 - loan processing example, 355
- conversion, file, 308
- copying charts, 122
- copying distributions, 54
- correlating assumptions, 47
- Correlation chart, 49

- Correlation Matrix
 - example, 180
 - tool, 177
- Correlation Matrix tool, 29
- correlations
 - defined, 177
 - specifying, 47
- creating distribution categories, 57
- creating distributions, 54
- Crystal Ball
 - Monte Carlo simulation, 21
 - quality support, 384
 - starting, 355, 369
 - system requirements, 14
- Crystal Ball Control Panel, 83, 331
- Crystal Ball menus, 290
- Crystal Ball toolbar buttons, 290, 301
- Crystal Ball tools, 29
- custom distribution, 265
 - important notes, 279
 - sequential sampling, 285
- custom distributions, 339
- customizing
 - charts, 350
- customizing charts, 112

D

- data
 - editing, 68
 - entering custom, 274
 - extracting, 28
 - grouped, 271
- Data Analysis
 - example, 221
- Data Analysis tool, 30
- Decision Table
 - example, 202
 - tool, 199
- Decision Table tool, 30
- decision variable cells, 377
 - defined, 37
- decision variables
 - defining, 63
 - optimizing, 31
- default settings, 120
- Define Forecast dialog, 65
- Define phase

- liquid pump example, [367](#)
 - loan processing example, [353](#)
 - defining
 - assumption cells, [38](#)
 - assumptions, [334](#)
 - forecasts, [344](#)
 - defining assumptions, [38](#)
 - deleting charts, [124](#)
 - deleting distribution categories, [58](#)
 - deleting distributions, [56](#)
 - Description pane, Distribution Gallery, [53](#)
 - Design for Six Sigma, [383](#)
 - defined, [366](#)
 - phases, [366](#)
 - tutorial, [366](#)
 - Design phase
 - liquid pump example, [368](#)
 - DFSS, [383](#)
 - defined, [366](#)
 - DMADV, [366](#)
 - phases, [366](#)
 - tutorial, [366](#)
 - DFSS example
 - liquid pump example, [366](#)
 - DFSS Fluid Pump.xls, [370](#)
 - DFSS liquid pump model, using, [369](#)
 - dialogs
 - Select, [72](#)
 - discrete
 - distributions, [228](#), [229](#)
 - ranges, [271](#)
 - display range preferences, [100](#)
 - displaying charts, [121](#)
 - distribution
 - preferences, [50](#)
 - distribution categories, [57](#)
 - creating, [57](#)
 - deleting, [58](#)
 - rearranging, [58](#)
 - sharing, [59](#), [60](#), [61](#)
 - distribution category properties
 - editing and viewing, [58](#)
 - distribution fitting, [44](#)
 - overlay charts, [130](#), [131](#)
 - overview, [44](#)
 - Distribution Gallery
 - Category pane, [52](#)
 - Description pane, [53](#)
 - displaying, [51](#)
 - Distribution pane, [52](#)
 - managing categories, [57](#)
 - managing distributions, [53](#)
 - menubar and buttons, [52](#)
 - using, [51](#)
 - window, [51](#)
 - Distribution Gallery menus, [291](#)
 - Distribution Gallery, Basic, [335](#)
 - Distribution pane, Distribution Gallery, [52](#)
 - distributions, [231](#)
 - binomial, [338](#)
 - continuous, [228](#)
 - copying, [54](#)
 - creating, [54](#)
 - custom, [339](#)
 - deleting, [56](#)
 - discrete, [229](#)
 - discrete or continuous, [228](#)
 - managing, [53](#)
 - modifying, [55](#)
 - normal, [342](#)
 - parameters, [231](#), [282](#)
 - pasting, [54](#)
 - triangular, [337](#)
 - truncating, [280](#), [342](#)
 - uniform, [335](#)
 - distributions as Excel functions, [284](#)
 - DMADV, [366](#)
 - DMAIC, [353](#)
 - dynamic cell referencing, [42](#)
- ## E
- editing distribution category properties, [58](#)
 - emailing distribution categories, [60](#)
 - entering custom data, [274](#)
 - Enterprise Performance Management, [30](#)
 - Enterprise Performance Management integration tool, [168](#)
 - Enterprise Performance Management tool, [30](#)
 - erlang distribution, [242](#)
 - examples
 - Batch Fit, [172](#)
 - Bootstrap, [195](#)
 - Correlation Matrix, [180](#)
 - Data Analysis, [221](#)

Decision Table, [202](#)
 Scenario Analysis, [207](#)
 Tornado Chart, [188](#)
 Two-dimensional Simulation, [213](#)

Excel charts
 pasting to, [122](#)

Excel functions and distributions, [284](#)
 expanded Define Forecast dialog, [65](#)
 extract data, [161](#)
 extracting data, [28](#)

F

file compatibility and conversion, [308](#)
 Filter preferences, [67](#)
 fitting distributions
 locking parameters, [47](#)
 overview, [44](#)
 fitting distributions to assumptions, [358](#)
 fitting distributions to data, [44](#)
 forecast cells, [359](#)
 defined, [37](#)
 liquid pump model, [372](#)
 forecast charts, [22](#)
 analyzing, [93](#)
 distribution types, [102](#)
 format, [101](#)
 groups, [111](#)
 Forecast Preference dialog, [65](#)
 forecast preferences, [65](#)
 Forecast Preferences dialog
 Auto Extract tab, [67](#)
 Filter tab, [67](#)
 Forecast Window tab, [66](#)
 Precision tab, [66](#)
 Forecast Window preferences, [66](#)
 forecasts
 defining, [64](#)
 fitting distributions, [44](#)
 percentiles view, [105](#)
 selecting and reviewing, [70](#)
 statistics view, [105](#)
 understanding, [95](#)
 forecasts, defining, [344](#)
 formulas in parameters, [43](#)
 freezing assumptions, [80](#)
 freezing cells, [80](#)
 functions in Crystal Ball spreadsheets, [88](#)

Futura Apartments model, [327](#)

G

global macros, [91](#)
 grouped data, [271](#)
 groups, [111](#)
 guidelines
 analyzing simulation results, [93](#)

H

help, [16](#)
 Help menu, [290](#)
 hidden factory, [383](#)
 how this manual is organized, [14](#)

I

Improve phase
 loan processing, [362](#)
 loan processing example, [354](#)
 insufficient memory warning, [79](#)
 integration, [30](#), [168](#)
 integration tools, [30](#), [168](#)
 interpreting charts, [347](#)

K

Kolmogorov-Smirnov test, [45](#), [110](#)

L

Lean principles, [383](#)
 liquid pump example
 adjusting, [375](#)
 Analyze, [368](#)
 capability metrics, [375](#)
 Define, [367](#)
 Design, [368](#)
 illustrated, [370](#)
 limits and target, [372](#)
 Measure, [368](#)
 parts, [371](#)
 Validate, [369](#)
 viewing, [370](#)
 Loan Process.xls, [356](#)
 loan processing example, [353](#)
 Analyze phase, [354](#)
 Control phase, [355](#)

- Define phase, [353](#)
 - Improve phase, [354](#), [362](#)
 - Measure phase, [354](#)
 - metrics, [362](#)
 - using, [355](#)
 - loan processing model, [356](#)
 - locking parameters, [47](#)
 - lognormal distribution
 - parameter sets, [249](#)
 - LSL, [372](#)
- M**
- macros
 - global, [91](#)
 - user-defined, [88](#)
 - managing categories
 - Distribution Gallery, [57](#)
 - managing charts, [121](#)
 - managing distributions
 - Distribution Gallery, [53](#)
 - marker lines, limits and target, [360](#), [373](#)
 - Measure phase
 - liquid pump example, [368](#)
 - loan processing example, [354](#)
 - memory
 - warning of insufficient, [79](#)
 - menus
 - Analyze, [290](#)
 - Cell, [290](#)
 - Crystal Ball, [290](#)
 - Distribution Gallery, [291](#)
 - Help, [290](#)
 - Run, [290](#)
 - model sensitivity, [138](#)
 - modifying distributions, [55](#)
 - monotonic relationships, [184](#)
 - Monte Carlo simulation, [330](#)
 - benefits, [21](#)
 - defined, [20](#)
 - in Crystal Ball, [21](#)
 - optimization goals, [378](#)
 - optimizing decision variables, [31](#)
 - Options preferences, [79](#)
 - OptQuest, [31](#)
 - running, [378](#)
 - using, [375](#)
 - OptQuest charts, [27](#)
 - outliers, [95](#)
 - outlying values, [95](#)
 - overlay chart
 - 2D Simulation, [216](#)
 - overlay charts, [23](#)
 - customizing, [130](#)
 - distribution fitting, [130](#), [131](#)
 - overview, [126](#)
 - Overlay Example, [128](#)
- P**
- p(N/C)-above, [360](#)
 - parameters
 - alternate, [43](#), [231](#)
 - formulas, [43](#)
 - locking, [47](#)
 - range names, [43](#)
 - Parameters menu, [231](#), [341](#)
 - parameters, distribution, [282](#)
 - pasting charts, [122](#)
 - pasting distributions, [54](#)
 - percentiles
 - view, [105](#)
 - PPM-above, [360](#)
 - PPM-total, [360](#)
 - precision control
 - defining with forecast, [64](#)
 - displayed percentiles, [105](#)
 - displayed statistics, [105](#)
 - Precision preferences, [66](#)
 - predicting trends, [31](#)
 - Predictor, [27](#), [31](#)
 - Predictor charts, [27](#)
 - preferences for charts, [112](#)
 - Preferences menu
 - distributions, [50](#)
 - printing charts, [123](#)
 - probability, [226](#)
 - probability distributions, [231](#)
 - chi-square, [242](#)

- comparing, [281](#)
- custom, [265](#)
- erlang, [242](#)
- selecting, [229](#)
- process capability features, [31](#), [381](#)
 - activating, [355](#), [369](#)
- profit, determining, [329](#)
- properties
 - distribution category, [58](#)
- publishing distribution categories, [59](#)
- pump example, [366](#)

Q

- quality features, [31](#), [381](#)
- quality improvement, loan processing example, [362](#)
- quality methodologies
 - and Crystal Ball, [384](#)

R

- range names in parameters, [43](#)
- rearranging distribution categories, [58](#)
- references, [401](#)
 - absolute cell, [43](#)
 - cell, [42](#)
 - dynamic and static, [42](#)
 - relative cell, [42](#)
- relative cell references, [42](#)
- relative cell referencing, [42](#)
- relative probability, [266](#)
- reports, [27](#)
 - overview, [157](#)
- requirements, [14](#)
- resetting a simulation, [81](#)
- restoring results, [86](#)
- restoring simulation results, [87](#)
- results, saving and restoring, [86](#)
- Run menu, [290](#)
- run preferences, [76](#)
- running a simulation, [81](#), [360](#), [373](#)
- running OptQuest, [378](#)
- running simulations, [328](#), [346](#)

S

- Sampling preferences, [77](#)
- saving and restoring simulation results, [86](#)
- saving results, [86](#)

- saving simulation results, [86](#)
- scatter charts, [25](#)
 - creating, [150](#)
 - customizing, [152](#)
 - overview, [149](#)
- Scenario Analysis
 - example, [207](#)
 - tool, [205](#)
- Scenario Analysis tool, [30](#)
- screen capture notes, [16](#)
- second-order variables, [218](#)
- Select dialog, [72](#)
- selecting assumptions, forecasts, and other data types, [126](#)
- selecting some data, [72](#)
- sending distribution categories, [60](#)
- sensitivity analysis
 - calculation, [141](#)
- sensitivity chart, [360](#), [375](#)
- sensitivity charts, [24](#)
 - creating, [139](#)
 - customizing, [143](#)
 - overview, [138](#)
- sequential sampling, [285](#)
- setting defaults, [120](#)
- setting forecast preferences, [65](#)
- setting preferences
 - Options, [79](#)
 - Sampling, [77](#)
 - Statistics, [80](#)
 - Trials, [77](#)
- sharing distribution categories, [59](#), [60](#), [61](#)
- shortcut keys for charts, [112](#), [300](#)
- simulation
 - analyzing, [360](#), [373](#)
 - running, [360](#), [373](#)
- simulation results
 - restoring, [87](#)
 - saving, [86](#)
 - using, [87](#)
- simulation results, saving and restoring, [86](#)
- simulations
 - running, [328](#), [346](#)
 - starting, [81](#)
- Single Step, [82](#)
- SIPs, [285](#)
- Six Sigma, [382](#)

DMAIC, 353
 Six Sigma features, 31, 381
 specification limits
 liquid pump example, 372
 spider chart, 185
 spreadsheet functions in Crystal Ball, 88
 starting Crystal Ball, 355, 369
 starting simulations, 81
 static cell referencing, 42
 Statistics preferences, 80
 statistics view, 105
 stopping a simulation, 81
 Strategic Finance integration tool, 168
 Strategic Finance tool, 30
 subscribing to distribution categories, 59
 support resources, 16
 system requirements, 14

T

tables of 2D Simulation results, 215
 target, 372
 t
 t, 360
 technical support, 16
 time-series analysis, 31
 tool for comparing run modes, 318
 toolbar buttons, 290, 301
 tools, 30, 168
 2D Simulation, 30, 210
 Batch Fit, 29, 169
 Bootstrap, 29, 191
 Compare Run Modes, 31
 Correlation Matrix, 29, 177
 Data Analysis, 30
 Decision Table, 30, 199
 Scenario Analysis, 30, 205
 Strategic Finance, 30
 Tornado Chart, 30, 183
 Tornado Chart
 description, 183
 example, 188
 tool, 183
 uses, 183
 Tornado Chart tool, 30
 training, 16
 trend analysis, 31
 trend chart with 2D Simulation, 216

trend charts, 24
 certainty levels, 137
 creating, 133
 customizing, 133
 overview, 131
 value axis, 137
 Trials preferences, 77
 triangular distributions, 337
 truncating distributions, 280, 342
 Tutorial 1, loan processing example, 353
 Tutorial 2, pump design with DFSS, 366
 Two-dimensional Simulation
 example, 213

U

uncertainty, 210
 uniform distributions, 335
 unpublishing distribution categories, 61
 user-defined macros, 88
 using OptQuest, 375
 using simulation results, 87
 USL, 372

L

L, 360

V

Validate phase
 liquid pump example, 369
 value axis settings, 137
 variability
 vs. uncertainty, 210
 variables
 defining decision, 63
 second-order, 218
 viewing distribution category properties, 58
 Vision Research model, 334

W

Welcome screen, 33
 who should use this program, 14

Z

Z scores, 360

A B C D E F G H I K L M N O P Q R S T U V W Z