

# **Tutorial**

Release 4.3



Lumina Decision Systems, Inc. 26010 Highland Way Los Gatos, CA 95033 Phone: 650-212-1212

Fax: 650-240-2230 Web Site: www.lumina.com



### **Copyright notice**

Information in this document is subject to change without notice and does not represent a commitment on the part of Lumina Decision Systems, Inc. The software program described in this document is provided under a license agreement. The software may be used or copied, and registration numbers transferred, only in accordance with the terms of the agreement. It is against the law to copy the software on any medium except as specifically allowed in the license agreement. No part of this document may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or information storage and retrieval systems, for any purpose other than the licensee's personal use, without the express written consent of Lumina Decision Systems, Inc.

This document is © 1993-2011 Lumina Decision Systems, Inc. All rights reserved.

The Analytica® software program described in this document is copyrighted:

© 1982-1991 Carnegie Mellon University.

© 1992-2011 Lumina Decision Systems, Inc. All rights reserved.

Analytica was written using MacApp®: © 1985-1996 Apple Computer, Inc. Analytica incorporates Mac2Win technology, © 1997 Altura Software, Inc. Analytica incorporates the Reprise License Manager libraries licensed from Reprise Software, Inc. Analytica incorporates he Premium Solver SDK licensed from Frontline Systems, Inc. Analytica incorporates the PCRE library, ©1997-2008, University of Cambridge.

The Analytica software contains software technology licensed from Carnegie Mellon University exclusively to Lumina Decision Systems, Inc., and includes software proprietary to Lumina Decision Systems, Inc. The MacApp software is proprietary to Apple Computer, Inc. The Mac2Win technology is technology to Altura, Inc. Both MacApp and Mac2Win are licensed to Lumina Decision Systems only for use in combination with the Analytica program. Neither Lumina nor its Licensors, Carnegie Mellon University, Apple Computer, Inc., and Altura Software, Inc., make any warranties whatsoever, either express or implied, regarding the Analytica product, including warranties with respect to its merchantability or its fitness for any particular purpose.

Analytica is a registered trademark of Lumina Decision Systems, Inc.

### **Credits**

The Analytica Tutorial was written by Brian Arnold and Lynda Korsan with Max Henrion and Randa Mulford (Expert Support, Inc.). New releases have been edited by Lonnie Chrisman, Richard Morgan, Paul Sanford and Fred Brunton.

About Analytica	1
Tutorial overview	3
Installing Analytica	4
Conventions used in this tutorial	5
Assumed background	5
Observed a Using the Develope Deve Martial	-
	/
Opening the Rent vs. Buy model	8
Accessing Halp Descurees	
Accessing help Resources	
Computing output values	
Examining and changing uncertain input	
Displaying alternative uncertain views	
Using the Rent vs. Buy model: summary	
Saving the richt va. Buy model, summary	
Ouitting Analytica	
	····· £ 1
Chapter 2: Exploring the Rent vs. Buy Model	25
Recognizing influence diagrams	26
Opening Object windows	29
Moving between Object windows	30
Using the Attribute panel	32
Inspecting definitions in the Attribute panel	33
Opening modules	35
Inspecting values in the Attribute panel	38
Displaying results	40
Exploring the Rent vs. Buy model: summary	43
Chanter 3: Analyzing the Rent vs. Buy Analysis Model	45
Examining the difference between renting and buying	46
Importance analysis	47
Performing parametric (sensitivity) analysis	50
Evaluating alternative decisions.	
Analyzing the Rent vs. Buy Analysis model: summary	60
Chapter 4: Creating Models	61
Creating a new model	62
Editing a diagram	63
Creating variable nodes	63
Saving your model	66
Deleting a variable	67
Moving nodes	
Editing variable titles	
Drawing arrows between nodes	
Deleting an arrow	
Connecting multiple arrows	
Entering attributes into the Object window	
Defining a variable as a function of other veriables	/ / /// /// ///
Entering a variable as a runction of other variables	
Defining a variable as a list	יוס גא
Viewing results in the Result window	
Defining a variable using a built-in function	
<b>0 0 - - - - - - - - - -</b>	

Saving your model	88
Summary: Creating Models	89
Chapter 5: Working with Arrays (Tables)	01
Summarizing variables using Expression syntax	<b>3</b>
Creating on index veriable	
	94 96
Adding a new dimension to an array	90
Lising conditional expressions	98
Viewing the results of a multi-dimensional array	100
Adding a new value to an index	
Using local variables and indexes in an expression	103
Reducing an array using subscripts	105
Completing cash flows	
Combining dissimilar arrays	
Array Reducing Functions.	
Performing Net Present Value (NPV) analysis	
Summary: Working with arrays	
Chapter 6: Creating the Party Problem Model	111
Documenting the model	112
Creating the Party Location, Weather, and Utility variables	113
Drawing arrows between variables	114
Defining Party Location as a list of labels	115
Defining Weather as a probability table	117
Defining Utility as a deterministic table	120
Computing Utility	123
Creating the Party Problem model: summary	124
Chapter 7: Creating the Eaves and Harss Model	407
	12/
Setting up the Hare sub-model	
Using the Dynamic() function	
Completing the Hare sub-model	
Using the color palette	
Duplicating a module	134
Completing the Fey sub model	
Creating aliases	סכו 127
Drawing influence arrows across modules	
Viewing multiple results simultaneously	140 140
Foxes and Hares Act III	
Summary: Creating the Foxes and Hares Model	
Chapter 8: Sharing Models with Others	143
Analytica Player	144
Analytica Web Player (AWP)	144
Summary: Sharing Models	154
Chapter 9: On Your Own	165
	133
Dusiness Examples	
Data Ahaiysis	

Analytica Windows and Dialogs	177
Glossary	173
Summary	171
Libraries	169
User Guide Examples	
Risk Analysis	167
Optimizer Examples	166
Function Examples	
Engineering Examples	
Dynamic Models	
Decision Analysis	159

## Introduction

## About Analytica

This section introduces Analytica and its uses, explains what is included in this tutorial, and tells you how to use this manual.



#### Welcome to Analytica

You are about to discover a powerful tool for real-world modeling and analysis. Analytica embodies the idea of using a white board for problem solving. Using a visual, point-and-click approach, you draw nodes and arrows to depict the relationships between model components. This approach allows you to describe the essential *qualitative* nature of the problem without getting lost in the details. As the model develops and your understanding of the problem becomes clear, you can define the exact *quantitative* details of the model.

A key feature of Analytica is its ability to create hierarchies of models. By grouping related components of a problem into separate submodels, you can impose a multi-level organization to your model. This helps you to manage complex relationships and allows other users to more easily grasp important concepts.



Another key feature of Analytica is the use of *Intelligent Arrays*<sup>™</sup>. These enable you to add or remove dimensions such as time periods, geographic regions, alternative decisions, etc., with minimal changes to the model structure. Unlike spreadsheets, which require you to repeat formulas with each new dimension, Analytica separates the dimensions from the relationships so that models remain simple. As the dimensions change, Analytica automatically updates, reports, and graphs the results.

Each node, or object, in an Analytica model has a window that displays the node's inputs and outputs, and allows you to enter definitions, descriptions, units of measure, and other documentary information. This self-documenting capability, combined with hierarchical models and Intelligent Arrays, makes it easier to understand and communicate how models work.

Analytica features fully integrated risk and sensitivity analysis for analyzing models with uncertain inputs; powerful facilities for time-dependent, dynamic simulations; powerful graphing capabilities; and over 200 financial, statistical, and scientific functions for calculating just about any type of mathematical expression.

#### Who can use Analytica

Analytica is for the modeler and problem solver — from the financial analyst modeling business opportunities to the engineer designing new products to the scientist investigating the behavior of physical phenomena.

It is particularly suited to users in the fields where you have to reason with uncertainties, or arrays of data, or both, i.e., management consulting, health and environmental sciences, aerospace, oil and gas, construction, manufacturing, financial services, and investing.

#### **Tutorial overview**

This tutorial is a hands-on introduction to using Analytica. Step-by-step instructions show you how to explore and analyze an existing Analytica model and how to create a new Analytica model. Because later tutorial sections build on the material in earlier chapters, you should work through the chapters in order.

We recommend that everyone new to Analytica complete Chapters 1 through 5, which takes two to three hours. If you want to work more quickly, skip the text and only follow the instructions in the boxed steps. Then, if you are unsure about any terms or concepts, look them up in the Glossary or review the text. And before you start your own modeling, you should review Chapter 9, which describes the sample models included with Analytica. This way, you can benefit from examples similar to what you might be modeling.

This tutorial is designed to introduce you to some of Analytica's basic features. When you are familiar with the basics, refer to the *Analytica User Guide* for more detailed information on Analytica's features.

#### · Chapter 1: Using the Rent vs. Buy Model

This chapter shows how to open and run an Analytica model. Using a simple interface to an example model that analyzes the total costs of buying or renting a house, you will calculate results and change input values to see the effects on the results. You will display uncertain results in a variety of ways.

Chapter 2: Exploring the Rent vs. Buy Model

This chapter shows you how to browse a model's structure and assumptions by examining its influence diagrams, variables, and definitions.

Chapter 3: Analyzing the Rent vs. Buy Analysis Model

This chapter shows you how to perform importance analysis and sensitivity analysis to see which uncertain variables most heavily influence the outcome.

#### Chapter 4: Creating Models

This chapter shows you how to create a new Analytica model. In the process of building a model that analyzes the costs of owning and operating an automobile, you will create variables, define relationships between variables, add documentary text, and compute results. In addition, you will create modules and add dependencies between modules.

#### Chapter 5: Working with Arrays (Tables)

This chapter shows you how to add *index variables* and *edit tables* (these will be defined later) to a model, and demonstrates how tables work in Analytica, including an introduction to table functions.

#### Chapter 6: Creating the Party Problem Model

This chapter walks you through a familiar problem: where to have your next party. This model introduces probability tables and conditional deterministic tables. You should complete this chapter if your models will use discrete or conditional uncertainties.

#### Chapter 7: Creating the Foxes and Hares Model

In this chapter you create a dynamic model of population sizes that depend on each other and that change with time. You should complete this chapter if your models will use dynamic simulation or variables that change over time.

#### · Chapter 8: Sharing Models with Others

In this chapter, you'll learn how to make the models you create available for use by others,

either via Analytica Player or on the web.

Chapter 9: On Your Own

This chapter briefly describes all the example models provided with Analytica. You should investigate these as you begin to build your own models.

#### **Installing Analytica**

Before you start this tutorial, follow these steps to install the Analytica application and associated model files on your computer.

- 1. Go to the Lumina web site: www.lumina.com.
- 2. Click the **Downloads** option under the **Support** heading.
- Read the instructions on the web page that comes up. Click the AnaSetup.exe link next to the Analytica (32-bit) heading.
- 4. A file download dialog box appears. Click **Run** to download the installation program and start running it to install Analytica. Or you can click **Save** to download the installation program to run later.
- 5. If you clicked **Run**, the Windows Installer should automatically start up and begin installing Analytica.
- 6. Follow the instructions:
  - a. Confirm that you accept the terms of the End-User License Agreement (EULA).
  - b. Express vs. Custom install: This option appears when upgrading, when the installer already has all information it needs to proceed. Select Express to complete the installation. Select Custom to review or change license information, install location, or other installation options.
  - c. Option to automatically uninstall earlier releases of Analytica for you when upgrading.
  - d. License information. Options:
  - **Previously activated individual license**: Applicable if you are re-installing and already have a valid Analytica license file located in the previous install directory.
  - New individual license: (most common selection) Select when you have an *activation key*, either from an Analytica purchase or from 30-day free Trial evaluation. If you are a system administrator installing Analytica for a user account other than the one you are running the installer from, you should select this option but leave the activation key field blank -- the activation key must be entered from the account that Analytica will be used from. When the activation key is left blank, you will have another opportunity to enter it when Analytica is first launched.
  - Centrally managed license (RLM License Server): Used when your organization
    provides floating licenses or named-user licenses, hosted from an RLM License Server.
    With this type of license, your organization's system administrators manage the
    licenses, and you don't need an activation key.
  - Free Player: The free player license is always available, allows you to view, change inputs, and evaluate existing models, but not to change or save the model itself.
  - e. End-User Identification. All fields here are optional. Your name and email is used to configure an account for you on the Analytica Wiki, which provides a tremendous asset when learn and using Analytica, and thus is highly recommended. If you already have an Analytica Wiki account, you can enter your login and password here so that Analytica can automatically log you in when a hyperlink within Analytica links to the Wiki, conveniently avoiding the login page.
  - f. Install location. The default installation location for Analytica is C:\Program Files\Lumina\Analytica 4.3. However, if your account is not an administrator account, you may not have the access permission rights to write to that directory, in which case you should change the Destination Folder to C:\Users\«userName»\AppData\Lumina\Analytica 4.3

If you've installed any edition of Analytica, including Player, Trial, and then later obtain a license for a different edition, you do not need to re-run the installer. You can enter the new license or activation key by selecting **Update License...** on the Analytica **Help** menu.

#### Conventions used in this tutorial

The conventions used in this tutorial are as follows:

Boxed, numbered instructions along the left side of the page give you the steps to take.
 Explanatory text often follows a step, accompanied by pictures of the Analytica screens similar to the ones you see on your computer.

For example:



 Special Analytica terms are displayed in *bold italic type*; they are defined when they are first introduced.

For your reference, a glossary at the end of the tutorial defines the terms used in this tutorial.

Tips alert you to useful or important information. They look like this:

**Tip** These alert you to useful or important information.

#### Assumed background

This tutorial assumes that you already have the basic skills needed to run Windows programs, including the following:

Term	Meaning
click	Press and release the mouse button one time.
double-click	Quickly press and release the mouse button two times.
drag	Press and hold down the mouse button while moving the cursor to a new location on the screen, then release the mouse button.
press	Press and hold down the mouse button.
select	Click an interface object, such as a menu command or a cell in a table; selected objects usually appear highlighted.

You also need to know how to use pull-down and popup menus, scroll bars, and windows.

If you are not familiar with these basic operations, look at the reference material that came with your computer.

This tutorial also assumes that you have basic skills of financial or quantitative modeling — for example, from previously using a spreadsheet program.

It assumes that you are acquainted with elementary statistics and are comfortable with the concepts of mean, median, and standard deviation. It also assumes that you have some understanding of probability distributions, such as the normal and uniform, and are familiar with the concepts of probability density function and cumulative distribution function. These terms are reviewed briefly in the Glossary at the end of the tutorial.

# **Chapter 1**

## Using the Rent vs. Buy Model

This chapter shows you how to:

- Open an existing model
- · Calculate results
- · Change input values to calculate different results



In this chapter, you use the *Rent vs. Buy* model, an Analytica model that compares the cost of renting a house to the cost of buying one. After working through the chapter, you will know how to open an existing model, use it to calculate results, and change input values to calculate different results.

### **Opening the Rent vs. Buy model**

3.

To begin, follow these steps.

- 1. Launch Analytica:
  - Click the Start button on the Windows taskbar. Click All Programs  $\rightarrow$  Analytica 4.3  $\rightarrow$  Analytica 4.3



2. After Analytica starts, select File  $\rightarrow$  Open from the menu.



4. Open the Rent vs. Buy model.



Analytica reads in the Rent vs. Buy model.

### Becoming familiar with the Diagram window

When you open a model, Analytica first displays a top-level **Diagram** window. The *Rent vs. Buy* model diagram shows several input variables that affect the trade-offs between renting and buying, **Normal** buttons, a **Calc** button, and a node labeled *Model*.

	🗊 Diagram - Ren	ıt vs. Buy				<
	Time horizon	(years) 10	Buying price	(\$)	140K	1
	Discount rate	(%/year) 6	Percent down payment	(%)	20	
Normal buttons	Rate of inflation	(%/year) Normal	Mortgage interest rate	(%/year)	9.5	
	Monthly rent	(\$) 1200	Appreciation rate	(%/year)	Normal	
			lodel			
		Costs of buying and re	enting (\$) Calc	6		
Calc button-	ð 1				▶	-

This top-level diagram is an end-user interface to the model itself, which is contained in the *Model* node. In this chapter, you use only the interface in this top level diagram; in the following chapters you will explore the model in more depth.

Across the top of the screen is a horizontal palette of buttons. This is called the tools palette.



When you first open the *Rent vs. Buy* model, the **browse tool** is highlighted on the palette. With the browse tool selected, the cursor looks like a hand  $\sqrt[n]{}$  when it is over the diagram. The browse

tool allows you to calculate the model, change input values, and examine — but not change — the structure of the model. In this chapter, you only use the browse tool.

#### **Accessing Help Resources**

At any time, you can press the *F1* key on the keyboard or use the **Help** pull-down menu to access Analytica's help resources. These include User Guide and Tutorial documents as well as Analytica's online Wiki pages.

#### **Computing output values**

In the Rent vs. Buy model, the output value of interest is at the bottom, Costs of buying and renting.



The output value displays in a **Result** window. This **Result** window shows a graph of two *probability density* curves, one for buying and one for renting. In a probability density graph, the units of the vertical scale are chosen so that the total area under each curve is 1 (100%).  $25\mu$  corresponds to  $25 \times 10^{-6}$  or 0.000025.

**Tip** Numerical suffixes like  $\mu$  and K are used extensively throughout Analytica. A quick reference for these suffixes is given on the back page of this tutorial.



Since the graph is of probability densities, both buying and renting have probabilistic, or uncertain, inputs. The probability density graph for each appear to be bell-shaped curves (*normal* distribution), although they appear a bit "noisy."

This probability density graph appears jagged because Analytica is using a sample size of 100. A larger sample size would produce a smoother curve, but the curve would take longer to compute. You can also make this graph appear smoother by increasing the number of samples per plot point. See "Uncertainty View Options" in the *Analytica User Guide* for more information.

The graphs show that the cost of renting, given the model's inputs, are between about \$105,000 and \$155,000 (the negative numbers mean cost — cash flowing out), while the cost of buying is between \$115,000 and a gain of \$75,000.



**Note:** Your results can vary slightly, since the model is generating random inputs based on a normal distribution for the uncertainty of the rate of inflation and for the appreciation rate.

Click the model **Diagram** window to bring it to the front. Notice that the button next to *Costs of buying and renting* has changed to **Result**. The **Result** button indicates that the value has been computed; clicking the **Result** button re-displays the computed values.



## Changing input values and recomputing

Now you will change some input values to the model and recompute the rent vs. buy comparison. You will change the values of *Time horizon, Monthly rent*, and *Buying price*.

	🗊 Diagram - Rent	: vs. Buy			
1. Click the box next to <i>Time horizon</i> . Change the value to <b>7</b> and press <i>Alt+Enter</i> .	Time horizon Discount rate Rate of inflation	(years) 7 (%/year) 6 (%/year) Normal	Buying price Percent down payment Mortgage interest rate	(\$) (%) (%/year)	140K 20 9.5
	Monthly rent	(\$) 1200	Appreciation rate	(%/year)	Normal
	ē 1	Costs of buying and rer	nting (\$) Result	Ь	

The main *Enter* key and the numeric keypad *Enter* key are not interchangeable. They have different functions in Analytica. *Alt+Enter* is equivalent to the numeric keypad *Enter* key.

As soon as you change an input, the **Result** button changes to a **Calc** button, indicating that *Costs of buying and renting* needs to be recomputed.



Now you are ready to recompute to see the new results.

	🗊 Diagram - Ren	t vs. Buy			
	Time horizon Discount rate Rate of inflation	(years) 7 (%/year) 6 (%/year) Normal	Buying price Percent down payment Mortgage interest rate	(\$) : (%) (%/year)	180K 20 9.5
4. Click the <b>Calc</b> button to compute the comparison of the cost of buying to the cost of renting.	Monthly rent	(\$) 1400 M Costs of buying and re	Appreciation rate	(%/year)(	Normal
	ō 4				▼ \ ↓

The graphs show that the cost of renting, given these changed inputs, is between \$90,000 and \$120,000, while the cost of buying is between \$135,000 and a gain of \$70,000.



### Examining and changing uncertain input

When an input is defined as a probability distribution, a button with the name of the distribution appears next to the input's name. Clicking this button opens the **Object Finder** window, in which you can see details and change the distribution's parameters or type of distribution.

Rate of inflation's button says Normal, indicating that it is defined as a normal distribution.



The **Object Finder** window appears. It shows that *Rate of inflation* is defined as a normal distribution with a *mean* of 3.5 and a *standard deviation* of 1.3.

You will now modify the probability distribution that defines *Rate of inflation*. Rather than using the normal distribution, you will use the uniform distribution, and assume that inflation has an equal probability of being anywhere between 3% and 4% per year.







The graphs show that the uncertainty in the cost of renting has narrowed to between about \$105,000 and \$109,000, while the uncertainty in the cost of buying has flattened to between about \$135,000 and a gain of \$37,000.

#### **Displaying alternative uncertain views**

Analytica offers a variety of views to display uncertain values, including selected statistics, *probability bands*, the *probability density* function, the *cumulative probability* distribution function, measures of central tendency, and the table of random numbers from which the uncertain distribution is estimated.

You will now examine several of these views.

In the upper-left corner of the **Result** window is the Uncertainty View popup menu.



The miniature probability distribution indicates that **Probability Density** is selected.



The **Result** window now shows two cumulative probability curves. Along the vertical axis, these curves give the probability that each cost is less than a given value along the horizontal axis.



There appears to be about a 50% probability that the cost to buy is below \$70,000, while the cost to rent has a 50% probability of being below about \$110,000.

Sometimes you might want to see an uncertain value expressed as a single number — a measure of central tendency. Analytica computes the *mid value* (sometimes called the *deterministic value*) by fixing all input probability distributions at their *median* (50% probability) values. The mid value is the only uncertainty view available for nonprobabilistic results.



The Result window now displays bar graphs for the two mid values.

Under the Uncertainty View popup menu are two buttons, 🔟 and 🛄. The 🛄 is highlighted, indicating that the Result window is displaying a graph view. The Result window can also display numeric values in a spreadsheet-like table view.

mid <b>v</b> M	id Value of Co uy or rent 🔻	osts of buying and renting (\$)	
<b>⊾al</b> ⊽			
Buy	-67.2K		
Dant	-107K		

Analytica also provides the *mean* (or average) value.



💓 Result	- Costs of l	ouying and renting	
μ ▼ Me II2 Bu	an Value of ( y or rent 🔻	Costs of buying and renting (\$)	
∽			
			*
Buy	-64.92K		
Rent	-107K		
			-

3. Click the **table** view button 12 to select the table view.

µ from the Uncertainty View popup menu.

You can also view a set of statistics, including both the median and mean, the ranges (minimum and maximum), and the standard deviation.



The **Result** window now displays the minimum, median<sup>1</sup>, mean, maximum, and standard deviation for *Costs of buying and renting*.



The statistics might not be exact, because they are estimated from a sample of values from the distribution.

<sup>1.</sup> Note that the median value is slightly different from the mid value. The mid value is composed of nonprobabilistic results generated by using the mean value for each input. The median value is calculated using probabilistic inputs and taking the median of the resulting distribution.

Finally, you see the sample values.



The table above lists the 100 sample values that Analytica randomly generated from the probability distribution to estimate the statistics.

A sample size of 100 is adequate for most applications; however, if you need more precise estimates, you can increase the sample size. See "Uncertainty Setup dialog box" in Chapter 13 of the *Analytica User Guide*.

10.Click the Result		
window's close button to return to	V Result - Costs of buying and renting	
the <b>Diagram</b>	Sample of Costs of buying and renting (\$)	XY
window.	Iteration (Run) 🔽 🗌 Totals	
	Buy or rent  Totals	

#### Using the Rent vs. Buy model: summary

You have now used the *Rent vs. Buy* model to calculate the results of a model, change input values and probability distributions, and display the uncertain results in a variety of ways. These are the basic techniques for using any quantitative model.

After you create your own models, you might want to give them a top-level input and output diagram like the one used in this chapter. For information about customizing a model for end users, see the *Analytica User Guide*, Chapter 9.

In the next chapter, you will navigate the details of the *Rent vs. Buy* model, exploring its structure and contents.

#### Saving your model

If you want to save changes to your model, you can do so at this point. (For instructions on quitting without saving, see the next section.)



If you wish to save your model as a different file, so that you do not change the original model, select **Save As** from the **File** menu.

## **Quitting Analytica**

When you have finished using a model, you might want to quit Analytica.

	File Edit Object Definition Resu	ılt D <u>i</u> agram
	New Model	Ctrl+N
	Open Model	Ctrl+O
1. Select Exit from	Add Module	Ctrl+L
the File menu.	Add Library	
	Close	Ctrl+W
	Close Model	
	Save	Ctrl+S
	Save As	
	Save A Copy In	
	Import	
	Export	
	Print Setup	
	Print Preview	
	Print	Ctrl+P
	Print Report	
	Rent vs Buy Model.ana	
	Mo1.ANA	
	Rent vs Buy Model2.ana	
	Rent vs Buy Model.ana Copy.ANA	
	My Expenses at work.ANA	
	EW 5723[1].ANA	
	- Exit	Ctrl+Q

# **Chapter 2**

## Exploring the Rent vs. Buy Model

This chapter shows you how to explore a model by examining its:

- Influence diagrams
- · Variables
- Attributes
- · Definitions
- Results



This chapter assumes you have started Analytica and have opened the *Rent vs. Buy* model. If this is not the case, see "Opening the Rent vs. Buy model" on page 8. If you are using the model as modified from Chapter 1, change the value of *Time horizon* back to **10**, the value of *Monthly rent* back to **1200**, and the value of *Buying price* back to **140K**. Also change the *Rate of inflation* back to a normal distribution with a mean of **3.5** and a standard deviation of **1.3**.

In this chapter, you will examine the structure and contents of the Rent vs. Buy model.

The *Rent vs. Buy* model uses financial flow conventions: funds flowing in (received) have positive values; funds flowing out (expended) have negative values.

#### **Recognizing influence diagrams**

In this chapter, you will delve into some of the details of the *Rent vs. Buy* model. You will not use the top diagram that you used in Chapter 1.



The details of an Analytica model display in an *influence diagram* window. An influence diagram (shown on the next page) is a graphical representation of a model, showing how different variables in the model interact with each other. A typical influence diagram consists of a number of *nodes* connected by *arrows*.



**Nodes** represent variables and appear as boxes, ovals, hexagons, and other shapes. Different node shapes represent different types of variables. Analytica uses the term **variable** broadly to include anything that has a value or can be evaluated. Note that many of the variables have the same names as the inputs and output at the top diagram that you used in Chapter 1. The top diagram provides an easy way to see and change these nodes' values.

**Arrows** connecting different variables indicate a relation between the variables. The arrow connecting *Rate of inflation* to *Appreciation rate* indicates that the value of the *Appreciation rate* variable depends on the value of the *Rate of inflation* variable. In the *Rent vs. Buy* model influence diagram, *Cost to Buy* depends on the *Buying price*, *Rate of inflation*, *Appreciation rate*, *Discount rate*, and *Time horizon* variables.

The following figure illustrates different types of nodes.

A **general variable** is represented by a rounded rectangle. It can represent any type of variable and is useful when you don't know what the type is. Typically, a general variable is used to represent a deterministic quantity or functional relationship.



A *module* is represented by a thicklined rounded rectangle. A module contains its own influence diagram, allowing nesting of multiple modules within a model. An **objective variable** is represented by a hexagon. This variable is the model's "goal" and evaluates the overall value or desirability of possible outcomes. In this model, the goal is to evaluate the cost difference between renting and buying. A decision model usually contains a single objective variable.

A *decision variable* is represented by a rectangular node. A decision variable is directly under\_\_\_\_ the control of the decision maker.

A *chance variable* is represented by an oval node. A chance variable cannot be controlled directly by the decision maker. It has an uncertain value represented by a probability distribution.

### **Opening Object windows**

Every object in Analytica has an associated *Object window* containing detailed information about it. You can display the **Object** window of any variable by double-clicking its node in the influence diagram.



Information about a variable is provided in a list of attributes. Attributes include the variable's class (for example, decision, chance, or constant), identifier, units, title, description, definition, inputs, and outputs. See the illustration on the next page.

Analytica Tutorial

This variable's <i>class</i> is decision variable.	This variable's <i>identifier</i> is <i>Pric</i> identifier is used to refer to this definitions of other variables. It of tain up to 20 characters and car tain spaces.	e. TheThe Unitsvariable inunits of measuredcan con-able. The Buyunot con-measured in con-	ribute indicates the urement for the vari- <i>ring Price</i> variable is dollars.
	Object - Buying price		
	Decision Price	Units: \$	-
The <b>Title</b> describes briefly what the variable represents. The title is also shown in the node on the influence dia- gram.	Description: Buying price	'house.	
The <b>Description</b> pro- vides more complete documentation (unlimited length) about this vari- able.	Outputs: Downpay Insurance Maintenar Mortgage Moving_c Sell_price	rmt Down payment Insurance Ince Maintenance Mortgage Ioan amou costs Moving costs tax Property taxes Selling price	nt
	•		
The <b>Definition</b> specifies the variable value, or how to compute the value, sometimes using other variables as inputs. The definition might also be a probability distribution or any other math- ematical expression.		<i>Outputs</i> ar depend on For each ou title are sho	re other variables that this variable. utput, its identifier and own.

**Tip** You can enter numbers with a suffix abbreviation, so *Buying Price* can be defined as either 140K or 140000. A quick reference for these suffixes is given on the back (last) page of this tutorial.

### Moving between Object windows

You have opened the **Object** window of a variable (*Buying price*) by double-clicking its node in the influence diagram.

The Object window contains a list of the variable's *inputs* and *outputs*, if there are any.
You can open the **Object** window for any input or output variable by double-clicking the one you wish to view.



Analytica opens the Object window for Mortgage loan amount.

🜒 Object - Mort	gage	loan amount		
🔘 Variable 🔍	Mort	gage	Units: \$	*
Title:	Morte	gage loan amount		
Description:	Total	mortgage (loan) amo	unt received.	
Definition:	expr Price	+ DownPaymt		
Inputs:	$\bigcirc$	Downpaymt Price	Down payment Buying price	
Outputs:	0000	End_mortgage Interest_pay Payments Princ_pay	Mortgage principal remaining Interest payments Mortgage payments Principal payments made on m	ortgage
•				

Note in the figure above that the *Title* of *Mortgage loan amount* is different from the variable's *identifier*, *Mortgage*. The title is what the model user normally sees; the identifier is used as a mathematical symbol in the definitions of other variables that depend on this variable.

The *definition* of the *Mortgage loan amount* is an *expression*, the sum of *Buying price* and *Down payment* (which is a negative amount). The definition refers to these variables by their identifiers.

*Inputs* lists the identifiers and titles of the variables in the definition. *Buying price*, the variable you just examined, is one of the inputs. The other input of *Mortgage loan amount* is *Down payment*.



The Object window now displays the attributes of Down payment.



### Using the Attribute panel

As an alternative to viewing a variable's attributes in a separate window, you can inspect them in the *Attribute panel*, which is an auxiliary window pane that you can open below the influence diagram.

The **Attribute** panel allows you to rapidly examine one attribute at a time of any variable in the model. You select the variable you wish to view and select the attribute to examine from a popup menu.

The variable *Buying price* should be highlighted with a title in white, indicating that it is selected; if it is not, select it by clicking it once.

### Chapter 2 Exploring the Rent vs. Buy Model



By default, Analytica displays the *description* of the selected node (e.g., *Buying price*) in the **Attribute** panel.



### Inspecting definitions in the Attribute panel

The Attribute panel allows you to inspect any attribute of a variable.

In this section, you will see the definition of two variables that you viewed in the top-level diagram in Chapter 1.

	<u>e</u> 1	
1. Click Description	Buying price: Description	
to view the Attribute	Buying price of house.	A
popup menu.		
		<b>~</b>
		1

.



When a variable is defined as an *uncertainty distribution*, a button appears in the **Definition** field.



In Chapter 1 you saw that *Rate of inflation* is defined as a normal distribution with a mean of 3.5 and a standard deviation of 1.3. These are the input parameters to the normal distribution, and they display to the right of the **Normal** button.

# **Opening modules**

Analytica models generally contain *modules*. Each module contains the details of a part of the model, also represented as an influence diagram. In the *Rent vs. Buy* model, *Cost to Buy* and *Cost to Rent* are both modules.

Modules can also contain other modules. In this manner, a large model with hundreds of variables can be organized into a hierarchy of modules, each small enough to be easily understood.



Analytica displays the influence diagram of the *Cost to Buy* module. This module contains three additional modules: *Out-of-pocket costs to own*, *Future sales proceeds*, and *Opportunity cost*.



The *input arrowhead* (without a trailing line) shows that the node to the right of the arrow has one or more inputs from outside this module.

The *output arrowhead* shows that the node to the left of the arrow has one or more outputs outside this module.



Analytica limits the number of open windows at each level of the model hierarchy to minimize clutter on your screen. See "Managing Windows" in Chapter 19 of the *Analytica User Guide* for information on how to open more than one module **Diagram** window at a time.



Combined arrowhead

The combined arrowhead, shown above, indicates that the node has one or more inputs from outside this module, plus the input variable in this module.

You can also navigate the model by tracking a variable's inputs or outputs.



The Out-of-pocket costs to own module diagram is brought to the front, with the Insurance node selected.

 Click the Diagram button Storeturn to the parent diagram, Model.



## Inspecting values in the Attribute panel

The **Attribute** panel allows you to view certain attributes, such as a variable's *value*, that are not (initially) displayed in an **Object** window.



You can use the **Attribute** panel in this manner to examine the mid value of any variable in the model.

It is faster to compute a mid (deterministic) value than an uncertain (probabilistic) value, so it is useful for conducting initial checks of a model before performing any uncertainty analysis.

# **Displaying results**

When you are viewing a model's influence diagram, you can evaluate any variable and display its value in a **Result** window.



1. With Present value of cost to buy still selected, click the **Result** button to evaluate it.



A **Result** window displays the probability density function graph for this variable. Analytica displays the uncertainty view that was most recently selected from the Uncertainty View popup menu, or that was saved with the model.



3. With Present value of cost to buy still selected, select the **Result** menu. The check mark next to **Probability Density** indicates that the **Probability Density** was last displayed. Select **Cumulative Probability**. As an alternative to clicking the **Result** button **and** then selecting an uncertainty view, you can use the **Result** menu to evaluate a variable and select the uncertainty view of the result.

1	<u>R</u> esult	Djagram	<u>W</u> indow	<u>H</u> elp
	Shov	v <u>R</u> esult	(	Ctrl+R
	<u>M</u> id ۱	/alue		
	Mear	n <u>V</u> alue		
	<u>S</u> tati	stics		
	Prob	ability <u>B</u> and	ds	
	✓ Prob	ability Den	sity	
	<u> </u>	ulative Pro	bability	
	S <u>a</u> m;	ole		
	<u>G</u> rap	h Setup		
J	<u>N</u> um	ber Format	(	Ctrl+B

The **Result** window appears displaying the variable's cumulative probability distribution.



### Chapter 2 Exploring the Rent vs. Buy Model



A single mid value appears in table view.

Uncertainty View	👽 Result - Moving costs	
Popup Menu	Mid Value of Moving costs (\$)	*
	<b>€</b>	



The mid value in table view is the only result view available for a nonprobabilistic variable with a single value.



## Exploring the Rent vs. Buy model: summary

You now have browsed the *Rent vs. Buy* model by examining its influence diagrams, variables, attributes, definitions, and results. These are the basic techniques for exploring any Analytica model.

The next chapter shows you how to analyze the Rent vs. Buy model.

OK

You can quit Analytica at this point. See "Quitting Analytica" on page 24.



# **Chapter 3**

# Analyzing the Rent vs. Buy Analysis Model

This chapter shows you how to:

- Perform importance analysis
- Perform parametric analysis
- · Set up and compare alternative decisions



In this chapter you will analyze the *Rent vs. Buy Analysis* model, a modified version of the model that you used in Chapter 1, "Using the Rent vs. Buy Model" and Chapter 2, "Exploring the Rent vs. Buy Model." You will identify its key sources of uncertainty through *importance analysis, perform parametric analysis*, and *compare alternative* decisions.

For instructions on how to open a model, see "Opening the Rent vs. Buy model" on page 8. In this case, however, open the *Rent vs. Buy Analysis* model by double-clicking the file labeled **Rent vs. Buy Analysis.ana**.

### Examining the difference between renting and buying

The *Rent vs. Buy Analysis* model is the module called *Model* that you explored in Chapter 2, "Exploring the Rent vs. Buy Model," with the addition of nodes to help you understand the importance of the uncertain inputs to the uncertainty in the output.

In Chapter 1, "Using the Rent vs. Buy Model," you saw that evaluating *Costs of buying and rent-ing* produces a graph of two uncertain values. To understand whether it would be financially advantageous to rent or buy, the *Rent vs. Buy Analysis* model includes the objective node, *Difference between buying and renting*.



The difference between the two uncertain values is also uncertain. The difference is positive if buying costs less over the time period, and negative if renting costs less over the time period.



### Importance analysis

In the *Rent vs. Buy Analysis* model, as in most complex models, several of the input variables are uncertain.

It is often useful to understand how much each uncertain input contributes to the uncertainty in the output. Typically, a few key uncertain inputs are responsible for the lion's share of the uncertainty in the output, while the rest of the inputs have little impact.

Analytica's *importance analysis* features can help you understand which uncertain inputs contribute most to the uncertainty in the output. You can then concentrate on getting more precise estimates or building a more detailed model for the one or two most "important" inputs.



Analytica defines *importance* as the rank order correlation between the output value and each uncertain input. Each variable's importance is calculated on a relative scale from 0 to 1. An importance value of 0 indicates that the uncertain input variable has no effect on the uncertainty in the output. A value of 1 implies total correlation, where all of the uncertainty in the output is due to the uncertainty of a single input.



It is clear in the figure above that the input *Appreciation Rate* is contributing most of the uncertainty in the *Difference between buying and renting*.



For more information about importance analysis and the steps to create an importance variable in your own model, see "Scatter plots" in the "Sensitivity and Uncertainty Analysis" chapter of the *Analytica User Guide*.

Analytica Tutorial

## Performing parametric (sensitivity) analysis

**Parametric analysis** (also called **sensitivity analysis**) involves varying the value of an input variable to examine its effect on a selected output. Performing sensitivity analysis often provides useful insights into how small changes in input variable values affect the desired outcome.

Because the importance analysis in the section "Importance analysis" revealed that *Appreciation rate* caused most of the uncertainty in *Difference between buying and renting*, you will start the parametric analysis with that input variable. You will change *Appreciation rate*'s definition from a probability distribution to a list of alternative values, and analyze the effect on the *Difference between buying and renting* output.

Before proceeding, click the edit button **\** in the toolbar to switch into edit mode. In edit mode you can modify the model: adding and removing nodes, and modifying existing nodes. Then click the key icon **e** to open the **Attribute** panel, then select the *Appreciation rate* node, and then select **Definition** from the Attribute popup menu to view its definition.



When the **Definition** attribute is displayed, the Expression popup menu  $\blacksquare$  appears. The distribution icon  $\blacksquare$  in the menu indicates that the definition is a probability distribution.

Before proceeding, click the **edit** tool **\** to switch to edit mode.

The Expression popup menu allows you to change the definition of a variable to one of several different types of expressions.

Expression types include:

- Expression, or mathematical formula
- List 📃 🔻
- List of Labels =
- Table 🛅 🔻
- Probability table
- Distribution

#### Choice

You will now use the Expression popup menu to change the definition of *Appreciation rate* from a probability distribution to a list. You will redefine *Appreciation rate* as a list of alternative values from -10% to 10%.



When a definition is first changed to a list, a cell (indicated by a box around it) appears in the definition. The first cell in the list initially contains the expression that was previously in the definition. In this case, you see the expression for a normal distribution (Normal (Inflation, 3)).

You will replace the entry with a number and add cells to perform parametric analysis.

6. Select the cell by	P  Appreciation rate:	Definition V	
the value <b>-10</b> and press the <i>Enter</i> key.			×
Tin		to a list by pressing the main Enter	

In Analytica, you add cells to a list by pressing the main *Enter* key, not the numeric keypad *Enter* key.

A new cell appears with the value -9. Change its value to -5. After you have entered two values, as you press *Enter* to add a new cell, Analytica automatically fills in the new cell with a value based on the difference between the last two values. You can override the automatic value by typing the desired value.



Pivot the graph as follows:



The resulting graph shows the mid value of buying and renting as a function of *Appreciation rate*, which varies from -10% to 10%, as you just entered.

Appreciation rate is informally called an **index** because it characterizes a dimension of another variable's value, in this case, *Costs of buying and renting*.

The graph shows that at an *Appreciation rate* of about -5% per year, renting and buying costs the same. If it is less than -5%, it would be better to rent; if it is greater than -5%, it would be better to buy.



🖉 expr

The table shows the values computed for each parameterized value of Appreciation rate.

11.Click the **Diagram** button **5** to return to the *Rent vs. Buy Analysis* **Diagram** window.

Q <b>7</b> R	📭 Result - Costs of buying and renting							
mid <del>▼</del>	Mic	d Value of Co	osts of buyi	ng and renti	ing (\$)		X	Y
1.2	Bu	iy or rent		▼ To	tals			
Lal	Appreciation rate (%/year) V Totals							
		-10	-5	0	5	10		*
Buy		-144.4K	-126.2K	-97.06K	-51.33K	18.81K		
Rent		-126.6K	-126.6K	-126.6K	-126.6K	-126.6K		
_								1
-							•	

35

# **Evaluating alternative decisions**

Analytica allows you to perform sensitivity analysis on several variables simultaneously.

In this section, you will change *Buying price* to compare results based on alternative decisions. In doing so, you will perform parametric analysis on both *Buying price* and *Appreciation rate* at the same time.



The first cell in this list contains the expression for the previous definition, **140K**. You will change this value, and add additional cells, as you did in Step 6 on page 51 and Step 7 on page 52.



The **Result** window appears displaying the variable's mid value. The *Difference between buying and renting* variable is three curves, one for each *Buying price*. Below the graph is a key to identify each curve.

When you examine the mid value results, you can see that only a 160K home, coupled with an appreciation rate of -2%/year or less, or a 140K home, coupled with an appreciation rate of -6%/year or less, results in renting being cheaper than buying. So, what is the best buy, a 120K home or a 160K home? That depends on what you anticipate the appreciation rate will be. For appreciation rates less than 9% per year, the less expensive home is the better investment. For higher appreciation rates above 9%, the more expensive home provides a larger return.



Remember that the cost of renting has been held constant. To further investigate the effect of this, you will examine the *Costs of renting and buying* node.





The result has three dimensions, Buying price, Buy or rent, and Appreciation rate, shown in the figure above.

Ó

Appreciation rate (%/year)

— Rent

ź

À.

6

8

10

Because only two dimensions can be shown in the graph, Analytica chooses one value of the third dimension to display, in this case, Buying price equals \$120K.

Use the navigating arrows to display different values of the Buying price index.



-100K -120K -140K

-10

-8

-6

-4

-2

Buy or rent — Buy





14.Select *Buying Price* (\$) from the Row index popup menu.

Buy or Rent becomes the third dimension with one value (Buy) displayed.

💓 Res	Result - Costs of buying and renting								
mid <del>v</del>	Mid Value of Coate of huming and renting (\$)       XY         Buying price (\$)       ▷ ①         Appreciation rate (%/year)       □ Totals         Buy or rent       ar) ▼ ▷ □ Totals								
		-10	-5	0	5	10	<u> </u>		
Buy		-165K	-144.3K	-110.9K	-58.67K	21.5K			
Rent		-126.6K	-126.6K	-126.6K	-126.6K	-126.6K			
₹							▼ ▶[∠		
🕥 Res	sult	- Costs of I	buying and	l renting			- 0 🛛		
Res mid <del>v</del>	sult Mid Buy o Bu	- Costs of I IValue of Co or rent . ying price (\$	buying and osts of buyin Buy \$)	l renting ng and renti 문 업 ▼ □ To	ing (\$) tals				
Res mid <del>v</del> Lall	sult Mid Buy o Bu	- Costs of I Value of Co or rent 🕹 🗍 ying price (\$ Apprecia	buying and osts of buyi Buy \$) tion rate (%	l renting ng and renti 문 업 マ 디 To Iyear) マ 🖓	ing (\$) tals □ Totals				
©¶ Res mid <del>v</del> III2 B Lall	sult Mid Buy o Bu	- Costs of I Value of Co or rent 🖓 [ ying price (\$ Apprecia -10	buying and osts of buyin Buy \$) ition rate (%	l renting ng and renti 다 요 (year) 도 () 0	ing (\$) tals Totals 5	10			
Res mid Lall	sult Mid Buy o Bu	- Costs of I Value of Co or rent ↓ ying price (9 Apprecia -10 -123.8K	buying and osts of buyin Buy \$) tion rate (% -5 -108.2K	I renting ng and renti 다 요 () () () () () () () () () () () () ()	ing (\$) tals Totals 5 -44K	10 16.13K			
Res mid Lal 120K 140K	sult Mid Buy o Bu	- Costs of I Value of Co or rent ↓ ying price (\$ Apprecia -10 -123.8K -144.4K	buying and osts of buyin Buy \$) tion rate (% -5 -108.2K -126.2K	I renting ng and renti 다 요 () () () () () () () () () () () () ()	ing (\$) tals Totals 5 -44K -51.33K	10 16.13K 18.81K			
Res     mid     I  I     I	sult Mid Buy o Bu	- Costs of I Value of Co or rent ♥ ( ying price (\$ Apprecia -10 -123.8K -144.4K -165K	buying and osts of buyin Buy (5) (-5 (-108.2K) (-126.2K) (-144.3K)	1 renting ng and renti 原 ① (year) 0 -83.19K -97.06K -110.9K	ing (\$) tals Totals 5 -44K -51.33K -58.67K	10 16.13K 18.81K 21.5K			

This table shows the mid value cost of buying for the parameterized values of *Buying Price* and *Appreciation Rate*.

Q <b>7</b> F	V Result - Costs of buying and renting							
mid <del>▼</del>	Mid Value of Costs of buying and renting (\$)							
1.2	112 Buy or rent 🖓 Buy 🛱 외							
المط	Buying price (\$) Totals							
	1~	Apprecia	tion rate (%	/year) 🔻 ▷	Totals			
		-10	-5	0	5	10	-	
120K	[	-123.8K	-108.2K	-83.19K	-44K	16.13K		
140K	[	-144.4K	-126.2K	-97.06K	-51.33K	18.81K		
160K	(	-165K	-144.3K	-110.9K	-58.67K	21.5K		
•								

This table shows that Cost to Rent does not vary with Buying Price or Appreciation rate.

15.Click the navigating arrow g to show the corresponding table for *Rent*.

mid▼       Mid Value of Costs of buying and renting (\$)       XY         Imid▼       Buy or rent       Imid▼       Rent       Imid▼         Buy or rent       Imid▼       Rent       Imid▼       Imid▼         Buy or rent       Imid▼       Imid▼       Imid▼       Imid▼         Buying price (\$)       ▼       Imid▼       Totals							
Appreciation rate (%/year)							
	-10	-5	0	5	10	4	
120K	-126.6K	-126.6K	-126.6K	-126.6K	-126.6K		
140K	-126.6K	-126.6K	-126.6K	-126.6K	-126.6K		
	400.01/	400.01/	100 CV	100 CV	100 GV		

## Analyzing the Rent vs. Buy Analysis model: summary

In this chapter, you have:

- Performed importance analysis.
- Performed parametric analysis.
- Set up and compared alternative decisions.

The next chapter introduces you to creating a new Analytica model.

You can quit Analytica at this point. See "Quitting Analytica" on page 24.

# Chapter 4

# **Creating Models**

This chapter shows you how to:

- · Create a new model
- · Create new variable nodes and enter attributes
- · Move and delete variable nodes
- · Draw influence arrows to define dependencies between variables
- · Define variables as explicit values, functions and lists
- · Invoke a built-in function to define a variable
- Do a simple Parametric Analysis



This chapter shows you how to create a new Analytica model.

In the process of building a model to analyze the costs of owning and operating an automobile, you will create variables, define dependencies, add documentary text, and compute results.

If Analytica is not open, start it by double-clicking its icon. If Analytica is already open with an active model go to the **file** menu, select **close model**, then select **new model**.

### Creating a new model

When you start up a new Analytica session it shows an Object window for an untitled model. Behind the Object window you will see an empty Diagram window.

First you should enter a Title for your model:

- Click in the Title attribute field (to the right of Title). Type in Car cost model and press Altenter. In the space just above the Title you entered, you will see that the Identifier field automatically changes to Car\_cost\_model.
- Press Tab to go to the Description attribute and type in:
   A demonstration model to show how to calculate the cost of running a car
- **Tip** If this is not a first-time entry for Title information, a dialog box will appear to confirm an automatic change to the Identifier.



#### Tip

You can either press the *Tab* key or use the mouse to move between fields.



### **Editing a diagram**

In most of the three previous chapters you were in the browse mode, with the **browse tool** highlighted in the tool palette. In browse mode you can view an existing model without changing its structure. When you create a new model the **edit tool** is selected by default. You use the edit tool to create or change a model.

Be sure to note which tool is selected throughout the remainder of this tutorial.



When the edit tool is selected, a menu of icons is displayed in the *node palette*. These icons represent the different node types and allow you to add nodes to the diagram.

### **Creating variable nodes**

In this chapter you will create variables in the Car Cost model.

Each variable is represented in the influence diagram as a shape that depicts the Class of Variable. These shapes are generally referred to as *nodes*. Select the node shape based on what you know about the variable. If you are not sure what kind of variable to use, choose a General variable (

See "Recognizing influence diagrams" on page 26 for a description of the node shapes.

The first variable you will create is for the cost of fuel.



#### qiT

As you build a model, you should select descriptive titles for your variables. Descriptive variable titles remind you of the model's logic and help to inform others about how the model operates.

# 3. Type *Fuel cost* for the variable title.

Press *Alt+Enter* or click any other location in the diagram to accept the title.

🗊 Diagram - Car cost mo	iel					
Eucl Cost	:	:	-	:	:	

Tip

*Fuel cost* is filled with a diagonal line pattern around its text, indicating that it does not yet have a valid definition.

Repeat Steps 1 and 2 four times to create four more chance variables that affect fuel cost. Title these variables as follows:

- Fuel price (price per gallon of gasoline)
- Annual miles (number of miles driven each year)
- Mpg (miles per gallon of gasoline)
- Age (driver's age)



Title text wraps to fit within the node as you type. You can manually create a new line in a title by pressing the *Enter* key at the desired break point(s). You can also expand the size of the node by dragging one of the corner handles.



# Saving your model

Analytica automatically saves each change you make to a backup file. If your computer (or Analytica) should terminate unexpectedly, it will offer to recover your changes the next time you start Analytica. Even so, it's a good idea to save your changes periodically.

- Select Save from the File menu (or press control-s). The first time you try to save a model, it shows a Save As dialog, offering to save the model in the My Documents folder using the model Title as the default file name. You can select another folder and modify the file name
- 2. Click Save or press Enter to save the model in the selected folder.


## **Deleting a variable**

Sometimes you might want to delete a variable that you previously created.

In this example you realize that the driver's age is not relevant to your understanding of the *Fuel Cost* variable. Therefore, you will delete the *Age* variable.



The Delete command cannot be undone; Analytica asks you to confirm that you want to delete.



#### **Moving nodes**

When you create a model you should try to structure the layout to make the influence diagram easy to understand. As you refine your model, however, you will undoubtedly want to group nodes in different ways to achieve this goal.

In this case we anticipate that *Fuel cost* will be derived from the other three variables. Therefore we want to place it apart.

Moving nodes is a simple matter of dragging them to the desired position. Try moving the nodes into the new configuration below.

Тір

You can select multiple nodes by holding down the *Control* or *Shift* keys, or by placing the cursor in a blank area and dragging diagonally to draw a rectangular frame across the nodes you want to select.



**Tip** You can undo or redo a drag operation by selecting **Undo/Redo** from the **Edit** menu, or by typing the keyboard shortcut, *Control+Z*.

#### **Editing variable titles**

The name displayed inside each variable node is referred to as a *Title*. In this example you will expand the title *Mpg* to *Miles per gallon*:



When you change the title of a node, Analytica asks you if you want the Identifier to be automatically changed as well.

4. Click **No** to close this dialog box and keep the identifier as *Mpg*.

Chapter



**Tip** You can change this behavior, to either turn off automatic updating of the identifier or to make it fully automatic, so that you are not asked. See the "Preferences dialog" section in Chapter 4 of the *Analytica User Guide* for details.

#### Drawing arrows between nodes

Creating Models

One of Analytica's most powerful features is its ability to show relationships between variables in the influence diagram. *Influence arrows* are used to specify the dependencies between variables.

Because the *Miles per gallon* variable influences the *Fuel cost* variable, you will draw an arrow connecting the two nodes.





in the nodes are not connected by an arrow, repeat Steps #1 through

#### **Deleting an arrow**

Occasionally, you might need to delete an arrow because of an earlier mistake or a change in your understanding of the model. This section shows you how to delete the arrow that connects *Miles per gallon* to *Fuel cost*.

You can delete an arrow using either the edit tool or the arrow tool.

First, make sure you have either the edit tool or arrow tool selected.



Chapter 4 Creating Models



#### **Connecting multiple arrows**

When one variable is influenced by several other variables, you can draw multiple arrows at once. This example shows you how to connect the three variables contributing to the *Fuel cost* variable.

First make sure the arrow tool is selected.









#### diagram that is not on a node.



1

Chapter 4 Creating Models

#### Entering attributes into the Object window

Each variable (or other Object) has an *Object window* that lets you see and edit its Attributes - including its Identifier, Title, Units, Description and Definition.

In this section we will use the Object window to enter attributes for the Annual Miles variable.

Make sure to select the **edit** button ( **)** before continuing.



You can also open a variable's Object window by double-clicking the node using the browse or arrow tools. If you are using the browse tool, you will not be able to enter or change documentation.



The identifier in the Object window shown above is **Annual\_miles**. Analytica assigns the identifier when the title is created. It uses the first 20 characters of the title except for spaces or punctuation, which are replaced by underscores (\_). Analytica does not differentiate between uppercase and lowercase letters in identifiers.

You can directly edit both the identifier and the title.

First, you will change the variable's identifier to a short abbreviation so that it can easily be used later in the definitions of other variables. You will then document the variable more fully.





#### Defining a variable as an explicit value

Analytica uses a wide range of variable types. In this section we simply enter an explicit value for the variable. Functional expressions and lists are described later in this chapter. Other variable types are addressed in later chapters.

For variables as functional expressions see "Defining a variable as a function of other variables" on page 78.

For variables as lists see "Defining a variable as a list" on page 83.

For variable as tables see "Working with Arrays (Tables)" on page 91.

For a demonstration of built-in functions see "Defining a variable using a built-in function" on page 86.

First let's define Miles per year as 12,000

	🜒 Object - Miles per year	
1. Click in the Definition field to enter a	Variable         Mpy         Units: miles/year           Title:         Miles per year	A
mathematical expression for the variable: type <b>12K</b>	Description: Average miles driven per year	
A warning icon indicates that this variable's definition has not yet been accepted.	Definition: Outputs: Fuel_cost Fuel cost	

**Tip** Numerical suffixes like μ and K are used extensively throughout Analytica. A quick reference for these suffixes is given on the back page of this tutorial.



	💓 Object - Miles	s per yea	r			
2. Click the check button or	◯ Variable ▼ Title:	Mpy Miles per y	/ear	Units:	miles/year	<u> </u>
accept the new definition.	Description:	Average n	niles driven per year			
The warning icon disappears because the variable now has a valid definition.	Outputs:	12k	cost	Fuel cos	t	
If you want to cancel what you entered, click the cancel button 🔀.	4					¥ Þ

Whenever another variable's definition includes the *identifier* (*Mpy*) of *Miles per year*, this defined value, **12K**, is used as its value.



*Miles per year* is no longer filled with a diagonal line pattern around its title, as shown in the figure below. The clear node indicates that *Miles per year* now has a valid definition.



Chapter 4 Creating Models

#### Defining a variable as a function of other variables

When one variable is dependent upon another variable, you must provide an expression that describes the relationship between the variables. Influence arrows connecting other nodes to *Fuel cost* show the direction of this dependency.

In this section, you will enter a definition for *Fuel cost* in terms of the values of *Miles per year*, *Miles per gallon*, and *Fuel price*.





·	👽 Object - Fuel	cost		_ 🗆 🛛
3. Enter the variable's units as <i>\$/year</i>	🔵 Variable 🔻	Fuel_cost	Units: \$/year	<u> </u>
and description as	Title:	Fuel cost		
Annual cost of	Description:	Annual cost of fuel		
1061.		expr 🔻		
	🚺 Definition:	1		
4. Click in the	Inputs:	Fuel_price	Fuel price	
Definition field to		🔘 Mpg	Miles per gallon	
enter a		🔘 Мру	Miles per year	
mathematical				
expression.				-
	•			▶ //

Because Fuel cost is equal to fuel price times miles driven, divided by miles per gallon, you will enter the following expression into the Definition field:

Fuel\_price \* Mpy/Mpg

An asterisk (\*) represents multiplication; a slash (/) represents division.

5. From the Inputs	🗊 Object - Fuel cost	
popup menu select	Variable     Fuel_cost     Units	:: \$/year 📥
variable that you	Title: Fuel cost	
want to add, in this	Description: Annual cost of fuel	
case, Fuel price. Fuel_price appears	expr 🔻 🗶 🖉 🕞 Fuel price	
in the Definition	Definition:     OMiles per ga.     Miles per ga.     Miles per un.	llon
ncia.	Inputs: Fuel_price	
	Miles, Miles, Miles, Miles,	ber year
6. Type an asterisk		-
(*).		<b>v</b>



optional).



Based on the definition you just entered, the value of *Fuel cost* is calculated by multiplying the values of *Fuel price* and *Miles per year*, and then dividing the result by the value of *Miles per gallon*.



Chapter 4 Creating Models

#### **Entering attributes using the Attribute panel**

Sometimes you may find it more convenient to view or edit attributes of a variable in the *Attribute Panel* as part of the Diagram view instead of using a separate Object Window.

In this section, you will enter data for the Fuel price variable in the Attribute panel.



The Attribute panel appears below the diagram. You can use this view to enter or edit data for the currently selected variable in the influence diagram.







Now that you have entered attributes for the *Fuel price* variable, you will enter its definition in the Attribute panel.

In this example we will assume that Fuel price has a fixed value of \$3 per gallon.

Select *Definition* from the Attribute popup menu and enter 3.







#### Defining a variable as a list

In this section you will enter attributes for the *Miles per gallon* variable and define it as a sequence of numbers. You will use this sequence later to perform a Parametric analysis to show how the *Fuel cost* is affected by *Miles per gallon*.

Using the Attribute panel, enter **Average number of miles per gallon** for the description and **miles/gallon** for the units.

1. Choose <b>Description</b> from the Attribute popup menu and enter: <b>Average</b> <b>number of miles per</b> <b>gallon.</b>	₹ ◀ Miles per gallon: Average number of miles per gallo	Identifier Title Units <b>Description</b> Definition Indexvals Domain Heln	]		
		Domain Heln			

2. Choose **Units** from the popup menu and enter: *miles/gallon* 

: :	Class		:	 	
· · · ·	Identifier		•		. <b>_</b>
<u>e</u> 1	Title				▶€
Miles per gallon:	🗸 Units	J			
miles/gallon	Description				<u> </u>
	Definition				
	Indexvals				<b>T</b>
	Domain				11.

Now that you have entered attributes for the *Miles per gallon* variable, you will define it as a sequence of integers between 20 and 50, by increments of 10.

Select **Definition** from the Attribute popup menu. You will notice a second popup menu appears to the right. This is the Expression popup menu. Open the Expression popup menu and select **list**.

1. Select Definition from the Attribute popup	<u> </u>	· · · ·	· · · · · · · · · · · · · · · · · · ·	 : : :	▼ € <u>∢</u>
The Expression popup menu appears next to the Attribute	Miles per gallon:	Definition	▼ expr ▼		× ×





Although the auto-fill feature makes it convenient to enter a simple linear sequence, you are free to edit the values as you please.

Now you will use the *Expression view* to see the variable's definition in a different form. The Expression view shows the full syntax of the definition regardless of the type of variable.





## Viewing results in the Result window

Now that you have entered attributes and definitions for all variables it is time to see the result. The **Results button** calculates values for all selected variables.

Select the Fuel cost node and click the Results button ( provide the cost node and click the Results button ( provide the cost node and click the results button ( provide the cost node and click the cost node and click the cost node and click t



The result window appears. Icons in the upper left corner of the Result window control the view mode. Graph view (

The result window appears in graph mode when the Graph icon is selected.



**Tip** The default view for the Results window can be changed. See the "Preferences dialog" section in Chapter 4 of the *Analytica User Guide* for details.

Click the Table button ([1.2]) to view the results in tabular form.



#### Defining a variable using a built-in function

Analytica offers a wide array of built-in functions to simplify the process of defining variables. In this example we will take advantage of the **Sequence** function to re-define the *Miles per gallon* variable.

Let's suppose you want to change the sequence such that the interval between *Miles per gallon* values is 5 instead of 10.

Select the *Miles per gallon* variable. Make sure that the Attribute window is open and **Definition** is selected.

Next, open the Expression popup menu and select **Other** at the bottom of the list. This opens the **Object finder** where you will find a large collection of built-in functions. Analytica will prompt to confirm that you want to replace the current definition of the variable. Click **OK**.



The **Sequence** function is contained in the Array library. Choose **Array** from the Library popup menu.

Scroll down the list and select Sequence.

Enter **20** for the *start* value, **50** for the *end* value, and **5** for the *step*. (Leave the *strict* field blank.) Click **OK**.

	👽 Object Finder	$\mathbf{X}$
<ol> <li>Select Array from the Library popup menu.</li> </ol>	Library:       Array       Find         2157       Postoonminatex       (A, 0, 1)         205       Product       (X, I, IgnoreNaN:Igno	
4. Scroll down and choose the <b>Sequence</b> function.	Image: Solution of the second of t	
5. Enter start value <b>20</b> , end value <b>50</b> and step value <b>5</b> .	Sequence(Start,End,Step) returns a list of numbers from «start» to «end». If «step» is not specified, it returns a list of successive integers. Otherwise, it returns a list of numbers, each differing from the one before by «step».	-
6. Click <b>OK</b> to finish.	Cancel OK	



#### The new definition is displayed in the Attribute panel.

	÷	÷	÷	:	÷	÷	÷	- E -
	2 1							▶⊜
The Function button	Viles per gallo	n:	Definition	-Σ				
takes you back to	 Sequence	(20,50,5)						<b>▲</b>
the Object Finder								
window								-
								1.

Select the *Fuel cost* variable and click the Results button ( **P**).

The result shows improved precision with the smaller *Miles per gallon* intervals.



#### Saving your model

After you have created part or all of a model, you should save it. Select **Save** from the **File** menu (or press *control-s*). Because you previously saved your model, it is saved with the original name. You can quit Analytica by choosing **exit** from the **file** menu or closing the Analytica window.

## **Summary: Creating Models**

In this chapter you have:

- Started a new model
- · Created new variables
- Entered attributes for variables in two different ways: using the Objects window and the Attributes window
- · Re-arranged variable nodes to improve the appearance of your influence diagram
- Drawn arrows to establish relationships between variables
- · Defined variables as explicit values, functions and lists
- · Used a built-in function to define a variable
- · Displayed the result of a simple parametric analysis

In the next chapter, you will extend the Car Cost model to include tables of data.



## **Chapter 5**

# *Working with Arrays (Tables)*

This chapter shows you how to:

- Create and define an Index
- Define an array variable as a Table
- Understand principles of array abstraction when combining arrays in an expression
- Use conditional expressions and logical values when defining an array
- Define variables using Expression syntax
- · Use local variables to simplify an expression
- · Analyze a multi-dimensional result by pivoting indexes
- · Reduce an array using subscripts
- Use array reducing functions such as Sum() and NPV()



This chapter demonstrates *Intelligent Arrays*, one of the most powerful features of Analytica. An array can be generally defined as a variable to which multiple values are assigned simultaneously. For example, in the previous chapter you assigned a list of values to a single variable, **Miles per gallon**. This is an example of a simple one-dimensional array. When you defined **Fuel cost** using the **Miles per gallon** array variable as an input, it *also* became an array. This demonstrates the concept of *array abstraction*. Array variables can be used just like ordinary variables in expressions. Whenever you expand an index of the array to include more values, or even add an entirely new index along a new dimension, all dependent variables downstream will be extended automatically! *Intelligent arrays* allow you to scale your model without making any changes to the design.

This Chapter is rich in content and covers lots of ground. The example model is still somewhat simplified, but it is chosen to be complex enough to demonstrate as many important array concepts as possible. The workflow will be streamlined to allow you to concentrate on the ideas without getting bogged down with procedural details. Therefore, you should already be familiar with the basic mechanics of Analytica's user interface. The prerequisite skills include:

Creating a new model; Opening an existing model; Save; Save As... (See Chapter 1)

Creating and defining new variables; Entering attributes in Attribute or Object windows; Drawing influence arrows between nodes. (See Chapter 4)

#### Summarizing variables using Expression syntax

Although Analytica offers a convenient and visually intuitive interface with which to define variables, it is often helpful for users to be able to enter definitions directly using *Expression syntax*. Every variable type and every functional expression can be represented this way. In addition to its usefulness in building models, expression syntax is a convenient and efficient way to summarize examples in the documentation. This efficiency is evident in the following four-line summary of the **Car cost** model from the previous chapter:

```
Variable MPY := 12K
Variable MPG := Sequence(20,50,5)
Variable Fuel_price := 3
Variable Fuel_cost := MPY*Fuel_price/MPG
```

In order to expedite the process of building the model, we will summarize new variables in this format throughout the rest of this chapter. It is useful to be familiar with Expression syntax since you will also see it in User Guide and Wiki examples:

- The first term indicates the Class of the object being defined. There is a Class identifier for each type of node found in the node palette. These include: Decision, Variable, Chance, Objective, Module, Index, Constant and Function
- The second term contains the *Identifier* for the object. (Keep in mind that identifiers are not allowed to contain spaces.)
- A colon followed by a equal sign (:=) is referred to as the assignment operator.
- The expression to the right of the assignment operator defines the object. Conveniently, this portion of the summary line exactly matches the syntax that Analytica requires in the definition field. In fact, you can copy this directly into Analytica if you wish! For your convenience, the portions of the summary line that can be copied into the definition field will be highlighted in blue.

#### **Fast Tony's Generic Wheels**

In this chapter you will extend the **Car cost** model to address an important decision scenario: the purchase of a new car. There are three cars to choose from: **Standard**, **SUV** and **Hybrid**. There are also three finance options: **Cash purchase**, **Lease**, or **Loan**. As you can see, Fast Tony has presented you with an array of decision possibilities, a 3 x 3 array to be exact. Your objective is to determine the option with the lowest total cash outflow over a 24-month period, including fuel. (Maintenance costs are covered under warranty as long as Fast Tony's cousin, Greasy Tony, is on his feet that day.) Ownership equity will be represented as a positive cash flow on the last period.

#### Creating an index variable

Index variables define the categories along a dimension of an array. They are represented by index nodes (parallelogram shapes) in the influence diagram. In this example, your decision will be arrayed by **Car type** and **Finance Option** so you will need to define an index for each of these dimensions. Index variables are generally defined as a *list of labels* or a *list of values* representing categories in the array.

(For the finance options you will leave out "Loan" for now. It will be added later.)

```
Index Car_type := ['Standard','SUV','Hybrid']
Index Finance option := ['Purchase','Lease']
```



Тір

As an alternative to selecting *List of Labels* in the Expression pop-up menu, you can select ( expression ) and enter the definition directly using Expression syntax. Simply list the values separated by commas and encase them in square brackets []. Note that all text values in Expression syntax must be enclosed in quotes (single or double).

## Defining a variable as a table

Each of the cars has a unique purchase price. You will define **Car price** as a **Table** indexed by **Car type**. In this context, a "table" does not necessarily have two dimensions. It can have one (as in this case), two, three or more.

```
Variable Car_price := Table(Car_type)(22K,40K,24K)
```



After you close the Indexes window an *edit table* will appear. Enter the following values for **Car price**:

Standard: 22K		
SUV:	40K	
Hybrid:	24K	

Click the Index button if you want to go back to the Indexes window.	Carty	e - Car price able of Car price /pe 🕶	
Note that index categories appear as table headings.	Standard	22K	<u> </u>
	SUV	40K	
Press <b>Tab</b> or <b>Shift-</b> <b>Tab</b> to move through the cells.	Hybrid	24K	
			- //

#### Chapter 5 Working with Arrays (Tables)

**Tip** You can draw influence arrows from index nodes to table variables to pre-populate the Indexes window with the chosen indexes. Influence arrows from index nodes are invisible by default but can be made visible by choosing the *Diagram* menu and selecting *Set diagram style*.

Next you will create a variable for lease payments. Fast Tony lists the following monthly payments for the two-year lease option:

Standard:	\$400
SUV:	\$700

Hybrid: \$500

**Lease Payment** is similar to the **Car price** variable. But this time you will enter the definition directly using expression syntax instead of using the edit table.

Variable Lease\_payment := Table(Car\_type)(400, 700, 500)



As you can see, Table definitions follow a specific syntax. The **Table** declaration is followed by two lists enclosed in parentheses. The first list contains the indexes by which the table will be arrayed. (In this simple example there is only one index but there can be many.) The second list contains the values.

It is important for the values to be in the same order as the index categories. Recall that the Car type index was defined as:

Index Car type := ['Standard','SUV','Hybrid']

which matches the respective order of values in the **Lease payment** variable. The same principle applies when there is more than one index. For example, a two dimensional array might look like:

```
Table (Index_abc, Index_123)
('a1', 'a2', 'a3', 'b1', 'b2', 'b3', 'c1', 'c2', 'c3')
```

It is generally easier to use an edit table when multiple dimensions are involved.

Finally, re-define the existing **Miles per gallon** variable as a table indexed by **Car type**. The MPG values for Standard, SUV and Hybrid are 28, 23, and 45 respectively.

Variable Mpg := Table(Car\_type)(28, 23, 45)

Select the Miles per gallon variable.

Open the Definition field and select ever Expression from the Expression popup menu.

Enter the new definition as shown above (blue text).

#### **Combining arrays**

Now that you have established purchase and lease payments, you can combine them in one variable. This time the index will be Finance Option.

```
Variable Payments :=
```

Table (Finance\_option) (Car\_price, Lease\_payment)

Create a new variable titled Payments.

Open the definition field and select **Table** from the Expression pop-up menu.

The Indexes window appears. Select the Finance option index and transfer it to selected indexes list. Click OK. An edit table will appear.

- 1. Enter Car price next to Purchase
- 2. Enter Lease payment next to Lease
- 3. Press Enter

🔍 Edit Tal	ble - Payments	
Edit X ▼	Table of Payments ance option	
Purchase Lease	Car_price Lease_payment	<u> </u>
4		× F/

You may have noticed an important difference between this table and the previous tables. In the previous tables you entered number values into the table cells, but this time you are entering expressions! Expressions are valid entries for table cells. With very few exceptions they can be as complex as anything you might enter in a standard definition line, including formulas, logical expressions and conditional expressions. You will see more examples of this later in the chapter.

Now look at the result of this new variable. Select the Payments variable and click the Results button ( p)

Select the table view mode	<b>Q7 Result</b> mid <b>▼</b> Mid	I Result - Payments mid▼ Mid Value of Payments				
Change vertical and horizontal indexes if		r type Finance o	▼ □ Tot ption ▼ ♪	als 🔲 Totals		
necessary to pivot the		Purchase	Lease		A	
table as shown.	Standard	22K	400			
	SUV	40K	700			
	Hybrid	24K	500			
Notice that the <b>Payments</b> array has two dimensions!						

Something interesting has happened! Notice that the array contains two dimensions even though only one index is called out in the definition of the array:

```
Variable Payments :=
Table (Finance option) (Car price, Lease payment)
```

Why is Car type included in the result when Finance option is the only index included in the definition of the table?

The Car type index is included because it is an index of the input variables Car price and Lease payment.

You have just encountered one of the most powerful features of Analytica's array abstraction: The dimensions of arrayed input variables will automatically be incorporated into the resulting output of an expression. The general principle of array abstraction can be summarized as follows:

In Analytica, the result of an expression is arrayed by the *union set* of dimensions from all input variables, and the definition of the expression itself.

#### Adding a new dimension to an array

So far, the **Payments** variable is not very useful for comparing the purchase and lease options. Lease payments are paid every month instead of just once, and there is still ownership equity to consider. In order to represent payments as a stream of cash flows over time, you will need to add a new dimension to the **Payments** array:

Create and define a new index titled **Period**. Define it as a sequence of months from 0 to 24.

Index Period := Sequence(0,24)

**Tip** There is a special shortcut syntax for sequences that have a step value of one: Type the starting value, followed by two periods (..), followed by the final value. For example, the **Period** index can be defined as: **Index Period** := 0..24

Next, you will edit the **Payments** definition to include the new index. Try using the edit table for this:

1. Select the <b>Payments</b>	🔰 Diagram - Car cost model	
variable and open the definition field.		
2. Select Table from the		*# Expression
menu.	e •	∃ List
3. Click the <i>Edit Table</i>	Payments: Definition	E List of Labels
button	Edit Table indexed by Finance option, Period	Probability Table

There is a button in the top left corner of the edit table, labeled with a parallelogram. Click this button to open the Indexes window. Then add **Period** to the list of selected indexes.





The edit table should now look like this:

The **Period** index has been added to the **Payments** array

Change vertical and horizontal indexes if necessary to pivot the table as shown.

🖤 Edit Table - Payments 🔚 🔲 🔼								
$\square$	Edit Table of Payments							
~	Period <b>T</b>							
$\widehat{}$		Finance o	ption 🔻 🕨					
		Purchase	Lease	<b></b>				
0		car_price	lease_payment					
1		car_price	lease_payment					
2		car_price	lease_payment					
3		car_price	lease_payment					
4		car_price	lease_payment					
5		car_price	lease_payment					
6		car_price	lease_payment					

The subset of an array corresponding to a singe index value is referred to as a *slice*. When you expanded the **Payments** array to include a new index, the original values (expressions in this case) were copied into all new slices along the **Period** index.

The **Payments** array is not yet accurate. Under the Purchase column you should have zero values for all periods except Period 0. Lease payments should be included in periods 1 through 24 but not Period 0. It would not take too much effort to edit all the cells to be the way you want them to be. The final definition of the array would look something like this:

👽 Edit Table - Payments 📃 🗖 🔀							
Edit Table of Payments							
Period							
	$\overline{}$	Finance o	ption 🔻 ▷				
		Purchase	Lease	<u> </u>			
	0	Car_price	0				
	1	0	Lease_payment				
	2	0	Lease_payment				
	3	0	Lease_payment				
	- 4	0	Lease_payment				
	5	0	Lease_payment				
	6	0	Lease_payment				
	7	0	Lease_payment				
	8	0	Lease_payment				
	9	0	Lease_payment				
	10	0	Lease_payment	-			
•			1				

Although this would work, it would not be a very efficient approach. In general, whenever you find yourself editing tables in the same way you would edit a spreadsheet, you are not benefiting from the advantages of array abstraction.

#### Using conditional expressions

Expressions can include conditional statements using If...then...else syntax. The condition can be based on a variable or an index value. This is a very useful way of defining array variables. For example, the cash flow for purchasers can be represented as:

If Period = 0 then Car\_price else 0

Likewise, the cash flow for lease holders can be represented as:

If Period = 0 then 0 else Lease payment

Specifying a condition based on **Period** will automatically add the **Period** index to the array. This would have been a better way to add a new dimension to the **Payments** variable, compared to the example above.

Let's revert the Payments variable to the way it was before adding the Period index:

Variable Payments := Table (Finance option) (Car price, Lease payment)

As you did in the section above, Select the **Payments** variable, open the edit table, and click the Index button in the top left corner.

Select the **Period** index in the Selected Indexes list and transfer it back to left hand box. Click **OK**. Answer **Yes** when the warning appears:

Warning	3
?	WARNING: Removing an index from an edit table may result in the loss of data. Proceed anyway?



This time you will add the **Period** index by including it in a conditional expression. Edit the cells to include conditional expressions:

```
Variable Payments := Table(Finance_option)
(If Period = 0 then Car_price else 0,
If Period = 0 then 0 else Lease payment)
```

Enter conditional expressions in the edit table cells as shown.

The edit table should be back to its original

one-dimensional form

👽 Edit Table - Payments					
C     C Edit Table of Payments     Finance option ▼     ▼     ▼     ▼     ▼					
		*			
Purchase	If Period = 0 then Car_price else 0				
Lease	If Period = 0 then 0 else Lease_payment				
4		▼ ▶ //			

Let's take a step back to consider how many indexes are now included in the Payments array:

- Finance\_option is called out specifically as a table index
- Period is the basis for a condition statement within an expression
- · Car\_type is an index of the Car price and Lease payment input variables.

Therefore, you can expect that **Payments** will be a three-dimensional array.

Conditional expressions can have nested IF...THEN...ELSE statements. In fact, it would be possible to define the **Payments** array using only one conditional expression:

Variable Payments :=
If Finance\_Option = 'Purchase' then
if Period = 0 then Car\_price else 0
else
if Period = 0 then 0 else Lease payment

This would be equivalent to the table definition above.

Logical statements can also be used to specify a condition. They are enclosed in parentheses and include an equal sign. When used in a mathematical expression, a logical statement assumes a value of one if true, or zero if false. For example:

#### Viewing the results of a multi-dimensional array

Representing a multi-dimensional array on a two-dimensional screen presents a challenge. When viewing results in tabular form, Analytica will display only a two-dimensional slice of the data. You can change the orientation and selection of data by *pivoting* the table. To do this, select the desired row and column indexes from the row and column pop-up menus. Any leftover indexes become *slicer indexes* for which only slice of data (corresponding to a single index value) can be displayed at a time.

Select the Payments variable and click the Results button ( p).

Select the table view button ( 12).

You can experiment by selecting different row and column indexes, and by changing the value of the slicer index.

The row index pop-up menu selects the	③ Result - Payments       □ ☑         mid       Mid Value of Payments       XY         Car type < Standard       ▷ 의	The slicer menu button displays a pop-up menu of all slicer index values.
The column index pop-up menu selects the index of columns.	Period     Totals       Finance option     Totals       Purchase     Lease       0     22K     0       1     0     400       2     0     400	Slicer steppers change the value of the slicer index sequentially.
	Now click on the graph view button (	

The vertical axis of the graph represents data values. The graph indexes can be pivoted to select the desired horizontal axis, key, and slicer index. You can experiment with various graph configurations and slicer values.



Tip

You can explore various chart types and options by selecting *Graph Setup...* from the *Result* menu. For more details about graphs reference Chapter 2 of the User Guide.

#### Adding a new value to an index

Fast Tony's loan financing terms require 10% down and 2% of the purchase price per month for 60 months. His financing manager, Big Anthony, explains that at a 12% nominal interest rate (1% per month compounded monthly), the load will be paid off in 60 months. There are severe penalties for delinquency but none of them are expressed in dollar values.

One of the advantages of *intelligent arrays* is that they are easily expandible. So far, you have set up cash flows for purchasers and lease holders. Adding a third financing option is a simple matter of adding a new value to the **Finance option** index.

Index Finance\_option := ['Purchase','Lease','Loan']

Select the *Finance option* index and open the Definition field. Select *List of Labels* from the Expression pop-up menu. You will see a list of current values in the definition field. Select the bottom value (Lease) and press the Enter key. A new box appears at the bottom of the list. By default the previous label is copied down. Change the new value to *Loan*.



Now select the Payments variable and click the Results button ( p).

A new column appears with zero values by default.

	🕅 Result - Payments						
1. Click the table view	mid <b>√</b> Mi III2 Car	id Value of Pay type  Ҿ   Si	/ments tandard	២ឯ	XY		A new column appears for <b>Loan</b>
button	Lal P	eriod Finance	▼	als > 🔲 Totals		l	
2. Pivot the table as		Purchase	Lease	Loan	▲		
shown	0	22K	0	0			
	1	0	400	0	]		
	2	0	400	0			
	3	0	400	0	<b>–</b>		
					▶ //		

Now you will need to add an expression for loan payments in the edit table:

#### Car\_price \* (If Period = 0 then 10% else 2%)

Select the **Payments** variable. Open the Definition field, then click the **Edit table** button.

<b>–</b> <i>i i</i> <b>–</b> 1	💓 Edit Tal	ble - Payments	
Enter the new expression for Loan payments as shown.	Edit	Table of Payments Ince option ▼	
			*
	Purchase	if period = 0 then car_price else 0	
	Lease	if period = 0 then 0 else lease_payment	
	Loan	Car_price * (If Period = 0 then 10% else 2%)	
			-
	4		
Recall that the input variable **Car price** is indexed by **Car type**. Therefore, your new expression will be evaluated separately for the Standard car, the SUV and the Hybrid. The new expression also references the **Period** index, so it will be evaluated separately for each period as well.

Loan payments have				
been added for all				
values of Car type				
and Period.				

Q <b>7</b> R	esult	- Payments				
mid <del>v</del>	Mid Value of Payments Car type ♥ Standard □ □ ① Period ▼ Totals					
		Finance Purchase	option	> 🗖 Totals	<b>^</b>	
0		22K	0	2200		
1		0	400	440		
2		0	400	440		
3		0	400	440	-	
					▶ //	

### Using local variables and indexes in an expression

Now that you have established all the cash outflows, you can start thinking about how much ownership equity you will have at the end of the 24-month period. Unavoidably you will need to calculate the remaining loan balance at that time. The financial dynamics of a typical loan include compound interest offset by fixed payment amounts. Although the formula for loan balances can be derived fairly easily, this section will focus on how to apply the formula rather than explaining the formula itself. Readers are invited to verify on their own if they wish:

Assuming that a constant amount is paid and nominal interest is compounded every month:

```
B_0 = Starting balance of the loan

12% = Nominal interest rate

60= The total number of periods required to pay off the loan

Period = A number from 0 to 24 representing the current period

B (Period) = The remaining loan balance for the current period

Let A = (1 + 12% / 12)

B (Period) = B_0 * (A^60 - A^Period) / (A^60 - 1)
```

It is easy to verify that  $B(0) = B_0$  and B(60) = 0 as required.

The quantity "A" appears several times in this formula so it makes sense to define it as an intermediate variable. To do the same thing in Analytica, you could define a new variable called A and use it as an input to the loan balance variable. But this would clutter your diagram with an unnecessary node.

Analytica allows *local* variables and indexes to be used temporarily within a definition. In this case you will define a local variable.

Create a new variable titled Loan balance and enter the following definition (copy blue text only):

```
Variable Loan_balance :=
var A := (1 + 12%/12);
Car_price * (1 - 10%) * (A^60 - A^Period)/(A^60 - 1)
```

Syntax rules for local objects are as follows:

- The instruction line starts with var or index to declare a local variable or index.
- The declaration is followed by an identifier. This can be anything you choose but it must not • be identical to any other input contained in the expression.
- The assignment operator comes next (colon followed by an equal sign), followed by an expression defining the object.
- A semicolon (;) is required to end the instruction line. You may choose to have a visual break (Enter key) after the semicolon for appearance purposes but this is optional. Analytica only looks at semicolons to mark line breaks in code. Each local variable declaration must be on a separate code line.
- The final line of instruction contains the definition as usual. All declared local variables and ٠ indexes will be available to use in expressions.

Local objects are used temporarily and then forgotten after the expression is evaluated. Therefore, the same local identifier (i.e. "A") can be used in any number of nodes without conflict.



A final note about the expression for Loan Balance:

Although **Period** is an index, you have used it here as a variable in a mathematical expression. This is possible because **Period** is a list of numerical values. It would not have been possible to use Car type or Finance option in a mathematical formula since they are lists of labels (although they could be used in logical or conditional statements). In general, you can think of an index as a one-dimensional array that uses its own values as an index.

By the principles of array abstraction, you should expect Loan Balance to be a two-dimensional array indexed by Car type (an index of Car price) and Period.

mid     Mid Value of Loan Balance       Image: Period     Totals					
┶┛	Car typ Standard	e 🔻 🕨 🗆 suv	Totals Hybrid		
0	19.8K	36K	21.6K		
			24.2417	1	
1	19.56K	35.56K	21.34N		
1	19.56K 19.31K	35.56K 35.11K	21.04K		

Tip

The Future Value function FV() is a convenient way to calculate loan balances and annuity values without using formulas. Arguments in order are: Interest rate per period, Future period, Payments (negative for payouts), Initial value. For example, Loan Balance could be defined as: FV(1%, Period, -Car\_price\*2%, Car\_price\*90%) Reference User Guide Chapter 13.

shown:

Loan Balance is a two-dimensional array indexed by Car type

and Period

### Reducing an array using subscripts

Sometimes you may want to reference part of an array variable without using all of its available indexes. Subscripts allow you to reference a *slice* of an array, effectively eliminating one or more dimensions. The subscript specifies indexes and their desired values for the slice. It is enclosed in square brackets placed immediately after the identifier for the array. For example:

Variable Final\_period\_balance := Loan\_balance[Period = 24]

This refers only to the **Loan Balance** values that correspond to Period 24. Recall that **Loan Balance** is a two-dimensional array indexed by **Period** and **Car Type**. The subscripted reference above will eliminate the **Period** dimension and return a one-dimensional array indexed only by **Car\_type**.

The subscript has reduced a twodimensional array to a one-dimensional array

	<b>Result</b>	: - Final per	iod balanc	:e (			•		
	mid <b>y</b> Mi	d Value of Fin Car typ	nal period b e 🔻 Þ 🗖	<b>alance</b> Totals	X	⊻I ·		al period	 ]
		Standard 13.26K	<b>SUV</b> 24.11K	<b>Hybrid</b> 14	.47K	* *		ialance	).
2	<				Þ		•		_
Final <sub>I</sub>	period balan	ice:	Definition	•	expr 🔻				
1	la el el el el el <b>C</b> D en de					-			

Loan\_balance[Period=24]

It is possible to eliminate multiple dimensions by including multiple indexes in the subscript, separated by commas. For example:

```
Variable Final_period_balance :=
Loan balance[Period = 24, Car type = 'SUV']
```

The result of this expression will be a single value corresponding to the loan balance at Period 24 for the SUV: 24.11K

An Index value can also be selected according to its position in the index rather than the actual value. To make a positional reference, place the "at" symbol (@) in front of the index identifier. For example, 'SUV' is second in the order of values for the **Car type** index.

The following subscript references are equivalent:

Loan\_balance[Car\_type = 'SUV']
Loan\_balance[@Car\_type = 2]

The verbal terminology for this reference would be: **"Loan\_balance** sliced at position of **Car\_type** equal to 2"

### **Completing cash flows**

Now you can add a variable to represent the amount of ownership equity you will have after 24 months. Of course this will depend on the finance option.

Assume that the value of every car depreciates by 35% over two years.

- Cash purchasers' equity will be: Car\_price \* (1 35%)
- · Lease holders' equity will be zero
- Loaners' equity will be the difference between car value and the loan balance at Period 24: Car\_price \* (1 - 35%) - Loan\_balance[Period = 24]

You can define the **Equity** variable as a table indexed by **Finance option**. Each of the expressions above can be entered into the appropriate cell in the edit table:

```
Variable Equity := Table(Finance_option)
(Car_price*(1-35%),0,(Car_price*(1-35%)-Loan balance[Period=24])
```

Alternatively, you can use conditional and logical statements as follows:

```
Variable Equity := If Finance_option = 'Lease' then 0 else
Car_price*(1-35%)-(Finance_option='Loan')* Loan_balance[Period=24]
```

Once again, consider how many dimensions your new variable will have. At first you might be tempted to list the indexes as follows:

Finance option (Specified as a table index or used in a conditional expression)

Car type (Index of the input variables Car price and Loan balance)

**Period** (Index of the input variable **Loan balance**)

But **Loan balance** is not an input to this expression; only a slice of it is used. The slice is arrayed only by **Car type**. Therefore, the Equity variable will be indexed by **Finance option** and **Car type** but not by **Period**.

💓 Resu	🗊 Result - Equity					
	X					
	Purchase	Lease	Loan	A		
Standard	14.3K	0	1039			
SUV	26K	0	1890			
Hybrid	15.6K	0	1134	-		
<u>ا</u>				► Z		

**Combining dissimilar arrays** 

The **Equity** variable has only two

dimensions: **Car type** and **Finance option**. It refers to a single slice of the **Period** 

index.

Now that you have established payments and ownership equity, you can combine them into a single cash flow variable. **Payments** will be represented as negative cash flows. **Equity** will be represented as a positive cash flow on the last period.

Create a new variable titled Cash flow and enter the following definition:

Variable Cash\_flow := If Period = 24 then Equity-Payments else -Payments

In this expression you have combined arrays with different numbers of dimensions:

Payments is indexed by Car type, Finance option and Period.

Equity is indexed only by Car type and Finance option.

There is no ambiguity here since (Equity-Payments) applies to a slice along the **Period** index. The slice is called out in the conditional statement. Notice that Equity and Payments [Period=24] have the same dimensions.

There are other situations where you may want to use a scalar variable (not an array) as an input to an array. Similarly, you may want use an array as an input to another array that has more dimensions. In this situation Analytica will repeat the values of the smaller array for each slice along the new dimensions.

For example, suppose you want to incorporate monthly fuel cost into the Cash flow variable. Here again you are combining two dissimilar arrays:

Cash flow is indexed by Car type, Finance option and Period

Fuel cost is indexed only by Car type

Create a new variable titled Cash flow with fuel and define it as follows:

Variable Cash flow with fuel :=

If Period = 0 then Cash flow else Cash flow - Fuel cost/12

In this example, Fuel cost is applied to multiple slices along new dimensions:

- All Period values except Period 0
- · All three Finance option categories.

Select Cash\_flow\_with\_fuel and click the Results button (

You will notice "Totals" check boxes next to the row and column index pop-up menus. Checking the box next to Period will allow you to see totals along that index.

1. Pivot the table as	🔍 Result	- Cash flow	with fuel		
shown.	mid <del>v</del> Mic	l Value of Ca	sh flow with	n fuel	<u>XY</u>
2. Check the "Totals" box next to the row index menu	Car ty	ype ↓ S riod Finance o	tandard Tol ption	러 tals Totals	
(Period index)		Purchase	Lease	Loan	<b></b>
	20	-107.1	-507.1	-547.1	
	21	-107.1	-507.1	-547.1	
	22	-107.1	-507.1	-547.1	
	23	-107.1	-507.1	-547.1	
	24	14.19K	-507.1	492.3	
	Totals	-10.27K	-12.17K	-14.29K	•
					► //

### **Array Reducing Functions**

A function that reduces one or more indexes of an array is referred to as an array reducing function. The output of an array reducing function will have fewer dimensions than the input array. For example, the following expression will determine the sum of cash flows over all periods:

Variable Total cash flow := Sum(Cash flow with fuel, Period)

The input array is indexed by Car type, Finance option and Period. The output will be a twodimensional array indexed by Car type and Finance option. In this example the Period dimension has been reduced.

The **Period** index has been reduced by the Sum() function.

🔍 Result	- Total casi	n flow			
Mid Value of Total cash flow					
للمل	Finance o	ption 🔻 🕨	Totals		
	Purchase	Lease	Loan		
Standard	-10.27K	-12.17K	-14.29K		
SUV	-17.13K	-19.93K	-24.44K		
Hybrid	-10K	-13.6K	-14.39K	-	

- The first argument of the Sum() function is the identifier of the variable to be operated on.
- This is followed by a list of indexes separated by commas. These are the indexes over which the function will operate.

In this example you have taken a sum over a single index.

Similar examples of array reducing functions include Max(), Min(), Product() and Average().

## Performing Net Present Value (NPV) analysis

If someone offered you a choice of receiving \$100 today or receiving \$100 two years from now, which would you choose? If you choose to receive it immediately, you can invest in a low risk bond with an annual return of, say, 6%. In two years the investment will be worth about \$112. Clearly these two alternatives do not have equal value. Conversely, you would probably prefer to pay an obligation later rather than sooner.

*Net present value* (NPV) analysis is a way to compare various scenarios that involve inflows and outflows of money at different time periods. It converts a stream of cash flows to an equivalent scenario where all money is exchanged in a single transaction at the present time. The interest rate that can be achieved in a low risk investment is referred to as the *discount rate*. For example, given a discount rate of 6%, the NPV of \$112 paid two years in the future would be \$100.

By taking a simple sum of cash flows as in the example above, you have ignored the time value of money. A Net Present Value analysis is more useful in this case. The **NPV()** function in Analytica makes this easy. It is another example of an array reducing function.

Assume the discount rate is 0.5% per month.

Create an objective node titled **Cash flow NPV**. (Objective nodes are represented by the hexagon shape on the node palette.)

Apply the following definition:

Objective Cash\_flow\_NPV := NPV(0.5%, Cash\_flow\_with\_fuel, Period)

- · The first argument of the NPV function is the discount rate per period.
- The second argument is the identifier for the variable containing cash flows.
- The third argument is the index containing period values.

The analysis is complete!

🕅 Result - Cash flow NPV 📃 🗖					
Mid Value of Cash flow NPV					
Finance option  Totals					
	Purchase	Lease	Loan	*	
Standard	-11.67K	-11.39K	-13.56K		
SUV	-19.78K	-18.64K	-23.2K		
Hybrid	-11.61K	-12.72K	-13.66K		
				-	
•					

# Summary: Working with arrays

In this chapter you have:

- · Learned Expression syntax
- Created and defined index variables
- · Created array variables as tables dimensioned along established indexes
- Expanded arrays by adding new indexes
- · Expanded indexes by adding new index values
- Created examples that demonstrate the basic principle of array abstraction: The result of an expression is arrayed by the *union set* of dimensions from all input variables, and the definition of the expression itself.
- · Used conditional and logical statements within an expression
- · Established local variables in the definition field
- · Analyzed a multi-dimensional result by pivoting indexes
- · Reduced array variables using subscripts
- · Applied array reducing functions to arrays



# **Chapter 6**

# Creating the Party Problem Model

This chapter shows you how to:

- · Define a variable as a probability table
- Define a variable as a deterministic table



In this chapter you will create a new Analytica model called *Party Problem*. (For information about how to create a new model, see the beginning of Chapter 4, "Creating Models".) The **Party Problem** model illustrates the use of discrete probability distributions.

You should study this chapter if your models use discrete or conditional probabilities.

In many kinds of models, your variables can be described using probability distributions based on expert judgment or on empirical data. On those occasions when the outcomes are discrete or qualitative (for example, low, medium, or high), you might need to use *discrete probability* distributions.

In the **Party Problem** model, the key uncertain variable is weather: it could be sunny or rainy. The weather has an impact on the decision about the location of a party — indoors, on a porch, or outdoors.

# **Documenting the model**

Specify the information shown in this model's Object window.







## **Creating the Party Location, Weather, and Utility variables**

Using the techniques introduced in "Creating variable nodes" on page 63, you will create a **Party Location** decision variable, a **Weather** chance variable, and a **Utility** objective variable.



Your diagram should now look like this:

### Chapter 6 Creating the Party Problem Model



# Drawing arrows between variables

In this section, you will draw arrows from *Party Location* and *Weather* to *Utility* using the techniques introduced in "Connecting multiple arrows" on page 72.



Your diagram should now look like this:



# **Defining Party Location as a list of labels**

Consider that there are three possible locations where you could hold your party — indoors, on the porch, and outdoors. You will define *Party Location* as a list of labels identifying each location.

*Party Location* is used to index the *Utility (value to me)* objective node, so it is similar to the *Car Type* index variable created for the *Car Cost* model in the section "Creating an index variable" beginning on page 93. (*Party Location* is a decision variable, rather than an index variable, because it is directly under your control.)







# Defining Weather as a probability table

In this model, as in real life, weather is unpredictable.

In this section, you will characterize weather as having two possible discrete outcomes, either sunny or rainy. In addition, you will assign probabilities for each possible outcome. This is done by defining weather as a *probability table*. A probability table is Analytica's function for describing discrete probabilities.

### Chapter 6 Creating the Party Problem Model



The **Indexes** dialog box opens to confirm your choice of index for the table. *Weather (Self)* appears in the Selected Indexes list. *Self* indicates that the index — the possible outcomes of the discrete distribution — is contained within the probability table. *Self* is required as an index of a probability table.

4. Click the <b>OK</b> button	💓 Indexes			
	Preview:	Domains: All Variables	Selected Indexes:	F
				4
		Cancel	OK	

An **Edit Table** window appears. In this table, the first column holds the outcomes and the second column holds their probabilities. You will enter the possible outcomes in the first column.

5. Click in the cell labeled **Item 1** to select the first label for Weather. Type *Sunny* into the cell, replacing **item 1**, and press the *Enter* key.

💓 Probat	bility Table - Weather	
	eather	
item 1	0	*
▲		

A second row should be added to the table, containing the same label as the first row, *Sunny*. If a second row does not appear, make sure you have the text for *Sunny* selected, and press the *Enter* key again.



💓 Probat	pility Table - Weather	
	eather	
<mark>Sunny</mark> Rainy ∢	0	×

In the second column, you will enter the probabilities of the possible outcomes.



The mid value is Rainy, since more than 50% of the probability was assigned to Rainy.



# Defining Utility as a deterministic table

The utility of a party location decision depends on the outcome of the weather.

In this section, you will define *Utility* as a *deterministic table* (or *determtable*) using both *Party Location* and *Weather*.

A deterministic table appears similar to an edit table or probability table. At least one index of a determinable must be a discrete probabilistic variable (probability table). The result of evaluating a deterministic table takes into account the probability distribution described by the probability table index.



### Chapter 6 Creating the Party Problem Model

Because the *Utility* variable hasn't been defined yet, the first function in the first library is displayed. Libraries hold the functions available for you to use. For an overview of Analytica's libraries and their functions, see the section "Definition menu" in Appendix A of the *Analytica User Guide*.

You will select the Determtable() function, which is in the Array library.



#### Tip

The **Object Finder** window gives a brief description of the selected function.

5. Scroll down the list	🜒 Object Finder		Ð	<
and select Determtable.	Library: Array	Find	1	
6. To specify the indexes for the table, click the <b>Indexes</b> button.	Image: Second system     Cubicinterp       Image: Second system     Cumproduct       Image: Second system     Cumulate       Image: Second system     Indexnames       Indexvalue     Indexvalue	(D, R, X, I) (X, I) (X, I) (11In)(u1um (A) (I)		
	Determtable(I1, I2,In)(u1, u2,u outcomes of discrete uncertain va across its probabilistic index(es).	m) defines a condit riables, and returns u1, u2,um give tl	tional dependency on the s an array that is reduced he deterministic outcomes.	

Chapter 6 Creating the Party Problem Model

*Party Location* and *Weather* are already selected as indexes because you drew arrows from them to *Utility* and they are defined as lists.



An Edit Table window opens for you to specify the dollar values for Utility.

You will give a value for each combination of party location and weather. These values describe the amount of money it is worth to you if you use a given party location and the weather turns out a certain way. Nominally, it is most valuable to have the party outdoors if it is sunny; it is least valuable if it is rainy and you are outdoors. Other values fall between these extremes.



# **Computing Utility**

In this section, you will compute the value of Utility.



The utility of each party location corresponds to the values you just entered for *Rainy* in the *Utility* deterministic table, because the mid value of *Weather* is *Rainy*. With these outcomes, a deterministic assessment leads you to conclude that your best bet is to hold the party indoors.



Chapter 6 Creating the Party Problem Model

The mean value gives you a very different assessment: the porch gives you the greatest expected utility. The mean value as estimated by the sample is approximately 40 for outdoors, 48 for the porch, and 46 for indoors.



The exact expected utility for each party location can be calculated by multiplying the probabilities of the outcomes by the values of *Utility*:

Outdoors = (100) \* 0.4 + (0) \* 0.6 = 40Porch = (90) \* 0.4 + (20) \* 0.6 = 48Indoors = (40) \* 0.4 + (50) \* 0.6 = 46

#### Note to those with a background in discrete modeling

Analytica simulates all probability distributions and calculates the expected (mean) value of a distribution by computing the average of the samples. For a discrete distribution, the computed mean converges, with increasing sample size, toward the value obtained by multiplying the probabilities by the discrete outcome values.

### **Creating the Party Problem model: summary**

In this chapter, you have:

- Defined a variable as a probability table, a discrete distribution.
- Defined a variable as a deterministic table, a function that defines a conditional dependency on the outcome of a discrete uncertain variable.

#### Exercise

As an exercise, extend the model to examine how the utility of each party location varies as the probability of rain varies from 0 to 100%.

- 1. Create another chance node, titled **p**, the probability of sunshine. Define it as the range of probabilities from 0 to 100%, as **Sequence (0, 1, 0.5)**.
- 2. Redefine the probabilities for Weather as p, for sunny, and (1-p), for rainy.
- 3. Recalculate the mean value of *Utility*. Display the result as a graph.





# Chapter 7

# Creating the Foxes and Hares Model

This chapter shows you how to:

- Use the Dynamic() function and the system variable Time
- · Customize the appearance of variable nodes
- · Organize a model using modules
- · Make duplicates of nodes and modules
- · Create aliases of variable nodes
- · View the results of two variables simultaneously



Before starting this chapter you should know how to perform the following actions which will no longer be described in detail:

Create a new model; Open an existing model; Save; Save As... (See Chapter 1)

Create and define new variables; Enter attributes in Attribute or Object windows; Draw influence arrows between nodes. (See Chapter 4)

You should also be familiar with Array variables and Index variables. (See Chapter 5)

### Using the Time index

In this model you will set up a dynamic system to model a predator/prey relationship. The populations of foxes and hares will be set up as state variables: one-dimensional arrays indexed by Time.

Start by opening a new model and titling it Foxes and Hares Tutorial.

Create a general variable titled *Hare population*.

Using either the Attribute window or the Object window, place the cursor in the definition field and choose Table from the expression popup menu. The Indexes window will appear.

Notice that *Time* is listed as one of the indexes in the left hand window. You did not have to define this index before using it. *Time* is a system index in Analytica that is always available to you. Note that it is distinguished by the system variable icon (()). Although it is a system variable, the values of *Time* can be edited just like any other index.

Select the *Time* index and click the transfer button (>>>) to select it as an active index in the right-hand window. Click **OK** to exit the Indexes window.



Analytica will show an edit table for the Hare population variable. Notice that the default index values for *Time* are 0,1, and 2. You will need to have more than just three time points in your dynamic simulation.



Go to the **Definition** menu and select **Edit time**. Click the Expression popup menu and select **Sequence**. Analytica will prompt to make sure you want to change the Time index to a Sequence. Click **OK**.



Edit the sequence by keeping 0 for the start value and entering 10 for the end value. Click **OK** to exit the Object finder window.





If the edit table for Hare population is not already open select the Hare population node and click on the Result button ( ). Notice that our time index now goes from 0 to 10. We will leave the values of the Hare population zero the moment.



### Setting up the Hare sub-model

Create three new general variables titled *Initial hare population*, *Hare fertility*, and *Hare births*. Draw influence arrows as follows:

- from Hare fertility to Hare births
- from Initial hare population to Hare population
- from Hare population to Hare births

Define Initial hare population as 500. Change its Identifier to Hare\_zero.

Define *Hare fertility* as **60%**. We will take this to mean that the number of newborn hares will be equal to 60% of the total population during the previous time period!

Define *Hare births* as *Hare\_population \* Hare\_fertility*. This is the total number of births during a time period.



### Using the Dynamic() function

Now we consider how the hare population will develop over time. The hare population will be influenced by the number of hare births, which will be influenced by the hare population during the previous period. Ultimately the value of Hare population depends on the value of itself during the previous time period. We can address this situation using the Dynamic() function.

Using either the Attribute window or the Object window, open the Definition field of the Hare population variable. Click on the Expression popup menu and select - expression... Analytica prompts to make sure you want to replace the current definition. Click OK.

Delete the existing table expression and replace it with the following:

| -

Dynamic(<u>hare\_zero</u>, self[time - 1] + hare\_births[time - 1])

The first term of the Dynamic() expres- sion specifies the initial value at the first <i>Time</i> value.	self, when used within a dynamic expression, refers to the same variable that is defined by the Dynamic expression. Circular refer- ences are avoided by specify- ing a <i>Time</i> value other than the current time step	Square brackets placed after an array variable call a specific index value. In this case the index is <i>Time</i> and the specified index value is one less than the current time step.
	and dan one and dep.	

The Dynamic() function can be entered directly as an expression or accessed as a built-in function (by selecting Other ... in the expression popup menu). It is listed under the Special library heading.

Note that the Dynamic() function automatically incorporates the Time system variable. It was not necessary to initially define our variable as a table indexed by Time, although this step was included in the first section of this chapter to illustrate the *Time* index.

Select the Hare population node and click the Result button (



This is a simple exponential growth curve. It represents a rapidly multiplying population of immortal hares with no natural predators and an unlimited food supply. You will need to introduce a limiting factor to avoid this buried-in-bunnies scenario.

# **Completing the Hare sub-model**

Quickly before it's too late, create four new general variables as follows:

•	Title: <i>Hare carrying capacity</i> Identifier: <i>Hare_capacity</i> Definition: <i>1000</i>	•	Title: <i>Hare crowding</i> Identifier: <i>Hare_crowding</i> Definition: <i>hare_population / hare_capacity</i>
•	Title: <i>Hare natural death rate</i> Identifier: <i>Hare_ndr</i> Definition: <i>hare_fertility * hare_crowding</i>	•	Title: <i>Hare deaths</i> Identifier: <i>hare_deaths</i> Definition: <i>Hare_population * hare_ndr</i>

Finally you need to change the definition of *Hare population* as follows:

```
Dynamic(hare_zero, self[time -1] + hare_births[time - 1]
- hare deaths[time - 1])
```



Now we have accounted for mortality and limited food supply by introducing a crowding factor. When the crowding factor is equal to one, the hare population has reached the carrying capacity for the habitat. At this point the death rate will be equal to the birth rate. Select the Hare population node and click the Result button (



# Using the color palette

In order to make an influence diagram easy to understand it is often useful to color code nodes according to function. The **color palette** is used for this purpose. You can access it in two ways:

- · Right-click the node and select Show/hide color palette from the context menu
- Go to the Diagram menu and select Show/hide color palette

In the color palette you can select from standard colors or click **Other...** to select from the entire 24-bit RGB color space.



**Tip** The **node style** and **diagram style** windows are also useful for customizing the appearance of your diagram. They can be accessed in the same manner as the color palette.



## **Creating a module**

**Modules** are an important feature of Analytica. They allow you to place a collection of nodes inside a single object, a module, which has the appearance of a single node. In this way, the top level of your diagram can be a simplified view showing influence arrows between modules. Each module can be opened as its own diagram window to show detailed interactions of the variables inside. Modules can even be placed within modules to create a nested hierarchy of detail.

Tip If you have several diagram windows open at once you can click the Diagram window button ( 🔜 ) to return to the top level diagram at any time.

Creating a new module is just like creating a variable node. Drag the Module node from the node palette to the diagram window. A module looks similar to a node but it has a thick border around it and displays the title in bold print. Whereas double-clicking a variable node will open an Object window, double-clicking a module will open a new diagram window. Attributes for the module can be entered using the Attribute window at the bottom of the diagram. Your new module will have the following attributes:

#### Title: *Hare module* Identifier: *Hare\_module* Description: A dynamic sub-model of the hare population

To populate your new module, start by making a multiple selection of all the nodes except for the module itself.

Reminder: To make a multiple selection hold down the Control or Shift keys, or drag a rectangular frame around the nodes you want to select.



Drag one of the selected nodes to the module and release.

Your top level diagram should now contain just the module by itself. Double-click the module to see the variables in a separate window.



**Tip** If a single diagram window takes up the entire workspace press the maximize/un-maximize toggle ( ) near the upper right corner of the window.

# **Duplicating a module**

Now you will make a similar sub-model for the fox population. Since the basic structure will be similar to the hare sub-model, you can save time by duplicating it automatically.

Select the hare module in the top level diagram window. Select **Duplicate nodes** from the **Edit** menu. A duplicate module will appear.

Edit the Title and Identifier of the duplicate to read Fox module

Edit the Description attribute to read A dynamic sub-model of the Fox population



Double-click the Fox module to open its diagram window.

The diagram appears to be identical to the original but you will notice some important differences in the Identifiers. Open the Attribute window and check the identifier for the Hare population node. Notice it has been changed to **Hare\_population1**. Analytica has appended the **1** to ensure that the identity of the new variable is distinct from the original. Different variables are allowed to have identical titles but they must always have different identifiers

Identifiers in functional expressions are modified accordingly. This ensures that the duplicate variables belong to a self-contained group that does not interfere with the original variables.

Analytica appondo a 1	Hare population:	Identifier 🔻	
to keep the identifiers	Hare_population1		*
of duplicated variables			
distinct			-
uistinct			

### **Completing the Fox sub-model**

Edit the titles and identifiers in the fox module as follows: (These edits mostly involve substituting the word Fox for Hare.)

- Title: Fox population
   Tildentifier: Fox\_population
- Title: Fox carrying capacity
   Identifier: Fox\_capacity
- Title: Fox natural death rate Identifier: Fox\_ndr
- Title: Initial fox population
   Identifier: Fox\_zero
- Title: Fox crowding
   Identifier: Fox\_crowding
- Title: Fox deaths
   Identifier: Fox\_deaths
- Title: Fox births
   Identifier: Fox\_births
   Title: Fox fertility
   Identifier: Fox\_fertility

Change the definition of input variables as follows:

- Initial Fox population: 120
- Fox fertility rate: 35%
- Fox carrying capacity: 200

The fox population is now a self-contained sub-model.

Select the Fox population variable and click on the Result button (

Due to a lower fertility rate, the fox population approaches its carrying capacity more slowly than the hare population.



# **Creating aliases**

Although it is useful to organize a model with modular structure, accessing variables inside modules can be less convenient than having them all in the same window. To address this problem Analytica allows you make an *alias* of a variable and place it anywhere you wish. The alias provides local access to the variable but it is merely a representation, not a duplicate, of the original node.

In this case it will be convenient to access the *Hare population* and *Fox population* nodes on the parent diagram without having to open the modules.

Click the Diagram button ( .) to open the top level diagram. Open the *Fox module* and arrange the windows so that both are visible.

Select the *Fox population* variable. Go to the **Object** window and select **Make alias**. The alias looks similar to the original node but the title will be shown in italics. Drag the *Fox population* alias to the parent diagram.

Fox

population

٠



Influence arrows are automatically drawn

ð 📢

Hare

population

# Drawing influence arrows across modules

Now you are ready to introduce predatory interaction! Create a new general variable titled *Predations*. This will represent the number of hares eaten by foxes in a given time period. The predation level is assumed to be proportional to the product of fox and hare populations.

Draw influence arrows from the *Hare population* alias to *Predations*, and from the *Fox population* alias to *Predations*. Enter the following expression to define the new variable: *Hare population \* Fox population / 600* 



Unfortunately for the hares, each predation will count as a death for their team. Open the *Hare module* and arrange windows so that the *Hare module* diagram and its parent diagram are both visible. Draw an influence arrow from *Predations* to *Hare deaths*.


Re-define Hare deaths as: Hare population \* Hare ndr + Predations



if you look closely at the Hare population and Hare deaths nodes you will notice small arrowheads on the margins. These indicate influence relationships with other nodes outside the module.



Predations are a food source for fox population and have a positive effect on their numbers. This can be modeled by making the Fox carrying capacity proportional to the Predations variable.

Re-define Fox carrying capacity as: Predations\*1.6

rrying	• 4	Fox carrying capacity	
n field	Fox carrying capacity: Predations * 1.6	Definition V Paper V XV	

Analytica will allow you to use a variable in an expression before drawing its influence arrow. The variable will not be listed in the Inputs popup menu so you must type the exact identity correctly. Influence arrows will automatically be drawn after you finish editing the expression.

7. Re-define Fox ca capacity directly b typing Predations \* 1.6 into the Definition

influences directed outside the module.

#### Tip

#### Viewing multiple results simultaneously

Your model is now complete. Click the Diagram button ( 20) to open the top diagram. As you already know, you can view the results of the fox and hare populations separately by selecting either one of the population aliases and clicking the Results button ( 20). But there is an easy way to combine both variables on the same graph.

Select both alias nodes simultaneously (holding down the *Control* or *Shift* keys while selecting). Now when you click the Results button a dialog box will appear asking if you want to compare more than one result. Click **OK**. Analytica will automatically create a *comparison node*. A comparison node is essentially a list variable with the variables to be compared as elements of the list.

The default title in this case will be Compare1.



#### **Foxes and Hares Act III**

How does the Fox/Hare drama end? You can extend the simulation by simply adding more values to the *Time* index.

Go to the **Definition** menu and select **Edit time**. Extend the sequence to go from **0** to **100**. Click **OK** to exit the Object Finder.

1. Select <b>Edit time</b> from	👽 Object Finder			
the <b>Definition</b> menu.	Library: Array 💌 Find			
2. Click the Sequence	🔊 Min (X, I, IgnoreNonNu			
button in the Definition	Star (R1, R2, I)			
field.	B Positioninindex (A,U,I)			
	🔊 Product (X, I, IgnoreNaN:Ig			
	🔊 Rank (X,I,type,KeyInda			
3. Set end step to <b>100</b>	📨 Sequence (start, end, step, s ▼			
	start end step strict			
	Sequence 0 100			
	Sequence(Start,End,Step) returns a list of numbers from «start» to «end». If			
	«step» is not specified, it returns a list of successive integers. Otherwise, it			
	returns a list of numbers, each differing from the one before by «step».	-1		
		_ <u> </u>		
	Cancel OK			

Select the *Compare1* node and click the Results button ( **P**) again.



Now you can experiment by changing input values to see how they impact the result.

If you would like to see a more complete Foxes and Hares example, open **Foxes and Hares.ana** in the **Tutorial Models** folder.

## **Summary: Creating the Foxes and Hares Model**

In this chapter you have:

- Used the Dynamic() function to model a feedback loop in a dynamic system.
- Edited the system variable Time which is used as an index in the Dynamic() function
- · Customized the appearance of nodes using the Color palette
- · Grouped nodes into Modules
- Used the Duplicate command to create a new module with similar structure to the original
- · Created aliases for convenient access to nodes contained within modules
- Established influence relationships between modes in different diagram windows
- · Created a comparison node to view the results of two variables simultaneously.

# Chapter 8

## Sharing Models with Others

Once you have built your own model, others can view and use it using Analytica Player, or you can make it available on the web with Analytica Web Player (AWP).

In this chapter, you will learn how to share models with others. In particular, you will:

- · Learn how to instruct someone to install Analytica Player
- Set up an AWP account.
- Upload a model to your AWP account
- Send an invite yourself or a friend to view your model on the Web.
- · View and navigate your model in AWP.

![](_page_148_Picture_9.jpeg)

Once you have created an Analytica model, you may wish to share it with others. Other stakeholders will find an Analytica model to be dramatically richer and more informative than a static report showing your computed results. The visual influence diagrams enable people to understand how results have been computed, assumptions used, and variables and interrelationships that impact the analysis. An ability to change inputs and recompute results interactively enables stakeholders to easily question assumptions, try their own, and understand the impact of different assumptions. And the ability to interactively pivot multi-dimensional result tables and graphs allows others to visualize your results in ways not easily facilitated by static reports.

There are two straightforward methods for sharing your model:

- Send your Analytica (\*.ana) model files to them either as an email attachment, or by posting on a shared file system or file repository.
- Post your model to the Analytica Web Player server and send your colleagues a URL.

In the first case, your colleagues will need to have Analytica installed, or will need to install the free Analytica Player, in order to view your model. In the second case, your users need only have internet access with a Flash-enabled browser.

#### **Analytica Player**

Anyone can download the free Analytica Player edition and install it on a Windows computer. If you have already installed any edition of Analytica, then you already have Analytica Player. If you have installed the 30-day Trial edition, once your trial expires, you will still be able to use it as the Player edition.

The Analytica Player allows people to view your model, navigate your influence diagram hierarchy, view object windows, compute and view results, change inputs and re-evaluate results. It does not allow users to change your model (other than inputs), save their changes to inputs, or make use of any features available in only in Analytica Enterprise or above, including for example the ability to import data from external live databases after the model is loaded.

A non-free Analytica Power Player edition provides addition features for users of models who do not need to build or make changes to the model itself. The Power Player allows users to save changes to inputs, and make use of Enterprise-level features such as importation of data from live databases after a model is loaded.

#### **Distributing your model**

To share your model with users who either have Analytica or Analytica Player already installed, or who are willing to install Analytica Player on their Windows-based computer, simply email them your model file as an attachment. However, in the email you should include the following text:

To view this model, you will need to install the free Analytica Player. To obtain the Analytica Player, please visit:

http://lumina.com/products/free-player/

You can also post your Analytica model on a web page using HTML such as the following:

<a href="My Model.ana">My Model</a>

When you do this, you should include the same text instructing users how to download the free Analytica Player. Users who already have the Player installed can launch the model just by clicking on the hyperlink.

#### Analytica Web Player (AWP)

In this section, you will sign up for an Analytica Web Player account, upload a model to your AWP account, send an invite to view the model to yourself, and then view and navigate a model in AWP.

#### Sign up

To post your model to the Analytica Web Player, you'll need an AWP account. Signing up for an account is free and includes 25 session credits just for signing up. You'll also receive 25 additional session credits per month once you purchase Analytica, for as long as your support is active. Unless you have already signed up for an account, you should do so now.

	Help
1) Select <b>Analytica</b> <b>Web Player</b> on the <b>Help</b> menu.	User guide F1 Optimizer Tutorial Analytica Wiki Wiki login info Analytica Web Player N
	Web tech support Email tech support Contact Lumina Update license About Analytica

Since you don't yet have an account, sign up for one:

![](_page_150_Picture_6.jpeg)

On the next page, read the information at the top, then scroll down to the form and fill in your own information. Make sure your email is valid, this will be used as your login id. Also, the email address is used to match your account against your active support after the first month.:

	First name	Last name
Name:	Jane	Doe
Email address:	jdoe@gmail.com	
Organization:	Doe & Doe Consulting	
Password:	******	
Retype Password:	*******	
	Sub	mit Already have Sign in.

#### Logging in / Model Listing

As you did in Step 1 of the previous section, jump to AWP by selecting **Analytica Web Player...** from the **Help** menu, and this time enter your email and password:

	Lumina. analytica web
	Welcome to the Analytica Web Player, which lets you models via a web browser. Email Lumina at Awp@lur problems or suggestions.
1.) Enter your login credentials	Individual Account Sign In Don'
	Password ******
	Log In Forgot password Sign in to Group Plan

The next screen displays the models already uploaded to your account. AWP automatically populated your list of models with one example model, which you can immediately view in a browser.

	Lumina. analytica	web player
	Welcome to the Analytica Web Player, v Analytica models via a web browser. Ple	which lets you view and run ease let us know what you think
	of it: Email Lumina at Awp@lumina.com	about any problems or Account info
	suggestions for new features.	Buy Credits
	Click a model to select it, and then click selected model. Or upload a model by c below.	k a button below to apply to the liking the Upload model button
2.) Click on the model	Account: jdoe@gmail.com	
name.	Title	Author(s)
	Rent vs Buy Example Model.ana	Max Henrion
3.) Press Run Model.	Run model Upload model Download mod	el Delete model Email invite
	Sign out Change password	

#### **Exploring a Model in AWP**

The Rent vs. Buy Analysis model launches in a browser. Using the outline view on the left, you can quickly explore the module organization of the model. Clicking on a variable node displays its graph:

![](_page_152_Figure_6.jpeg)

Here we see the probability density result graph for Costs of buying and renting. Just like in Analytica desktop, you can view the result as a table or graph, using the tabs at the top to select the desired view, and can switch between different uncertainty views.

![](_page_153_Figure_2.jpeg)

You can also pivot multidimensional result tables or graphs.

	🕼 Dia	gram 🖸	Object		Edit Tabl	e 🕜 Table
<ul> <li>i.) Pivot the table by electing the Statis- cs index for the row</li> </ul>	Cost	ts of buying and	l renting (\$	Statisti	cs	•
abels.	Buy or r	ent		•		
.) Copy this table to	₽	Statistics			• ¢	
ne clipboard	(C)	Min	Median	Mean	Max	Std. Dev.
into Excel)	Buy	-115.2K	-67.57K	-62.55K	65.31K	33.24K
	Rent	-150.5K	-126.6K	-126.9K	-106.8K	8452

Chapter

8

Sharing Models with Others

7.) Return to the top model diagram.	Lumina.	🕒 🎼 Diagra	m 🧧	Dbject	Edit Table	Table	CLOSE MODEL
	Rent vs. Buy Analysis	Costs	of buying an	d renting (\$)	Statistics	•	
8.) After you finish	Cost to Buy Future sales proceeds	Statistics	Buncor rept	•	- 15		
model.	Opportunity cost		Buy	Rent	3		
	O Cost to Rent	Min	-115.2K	-150.5K			
	O Parametric Analysis	Median	-67.57K	-126.6K			
	- Furdine the Anatysis	Mean	-62.55K	-126.9K			
		Max	65.31K	-106.8K			
		Std. Dev.	33.24K	8452			

Spend some additional time navigating the model on your own.

#### Uploading a Model to AWP

Now you will upload one of your own models. For illustration of the steps, you will upload one of the models from the Example Models folder where you installed Analytica. The model selected here is one that contains input entry controls -- fields your end users will be able to change when they are using the model in AWP.

![](_page_154_Picture_6.jpeg)

In the file open dialog, navigate to the **Example Models** directory where you originally installed Analytica, and then enter the **Business Examples** subfolder. For most people, this is located at:

![](_page_155_Picture_1.jpeg)

	Select file to u	pload by www.a	analyticawebplayer.con	1			? 🔀
	Look in:	🗀 Business Exa	mples	•	3 🕫 🛙	• 📰 🕈	
2.) Select the Project portfolio planner model.	My Recent Documents Desktop My Documents My Computer	Bond Model.an Breakeven Ana Expected R&D Financial State Market Models Plan_sched_co Project portfoll Sales Effective Subscriber Price	a alysis.ana Project Value.ANA ment Templates.ANA ana nitrol.ana <b>io planner.ana</b> ing Sodel.ana ing Model.ana				
	My Network Places	File name: Files of type:	Project portfolio planner.ana Analytica Models			• •	Open Cancel

C:\Program Files\Lumina\Analytica 4.3\Example Models\Business Examples

The model is copied to the AWP server and the model listing now reflects the fact that the model is uploaded and ready to be viewed.

3.) Click on the	Title	Author(s)	
newly uploaded	Rent vs Buy Example Model.ana	Max Henrion	
4.) Run the model	Pup model Upload model Download model	Delete model Empil invite	
	Sign out Change password		

The model you just uploaded is now presented in the web browser. You can change inputs, view results, and navigate the model details. Next, you will change a few inputs and view results based on those new inputs.

![](_page_156_Figure_3.jpeg)

The attribute weights indicate how important each attribute is the overall multi-attribute score for each potential project being considered for the project portfolio. Next, you will change the relative importance of these.

7) Set the Strategy	🔁 🤃 Diagram 🗧	Object	🤯 Edit Table
Fit weight to 50%	Edit Table of Attribu	ute weights	
	Attributes for scores		
8.) Set staff develop-		30%	
ment weight to 30%	Staff development		
	Public good will	40%	
9.) Return to the dia- gram.	Net revenues	90%	

![](_page_157_Picture_1.jpeg)

Click the result button to view the efficient frontier of project portfolios at different budget levels.

![](_page_157_Figure_3.jpeg)

The result reflects the changes you made to discount rate and attribute weights.

![](_page_157_Figure_5.jpeg)

#### **Sending Invitations**

You are now ready to invite a colleague to view your model. To experience the invitation yourself, you will send the invitation to yourself here, but if you wish, you can repeat the steps here and send an invitation to a friend.

1.) Click the model	Title Author(s)		
to share.	Rent vs Buy Example Model.ana Max Henric	Max Henrion	
2.) Click <b>Email</b>	Run model Upload model Download model Delete m	odel Email invite	
	Sign out Change password		

#### Chapter 8 Sharing Models with Others

You can customize the email message before sending it out. It also works fine to copy/paste the URL that appears in the suggested message text into an email you compose in your own email program, and send the email from there.

![](_page_158_Figure_3.jpeg)

Next, since you sent the email to yourself, bring up the program you use to read your email. The message usually arrives within a few seconds. Read the message to get an idea what your colleagues will see when they receive the invitation. Here is one example.

#### Invitation to review Analytica web model Inbox | X

♪ DoNotReply@analyticawebplayer.com to me       show details 4:52 PM (0 minutes ago)         Hi,       I invite you to review and run an Analytica model called: Project portfolio planner.ana         You can run it in a web page using Analytica Web Player (AWP).         Simply click this link         http://www.AnalyticaWebPlayer.com/2.5/Client/AwpClient.aspx?inviteId=2&inviteCode=123456&         subName=jdoe%40gmail%2Ecom         I would appreciate your comments.         Thanks,         Jane Doe         jdoe@gmail.com						
Hi, I invite you to review and run an Analytica model called: Project portfolio planner.ana You can run it in a web page using Analytica Web Player (AWP). Simply click this link <u>http://www.AnalyticaWebPlayer.com/2.5/Client/AwpClient.aspx?inviteId=2&amp;inviteCode=123456&amp;</u> <u>subName=jdoe%40gmail%2Ecom</u> I would appreciate your comments. Thanks, Jane Doe <u>jdoe@gmail.com</u>		DoNotReply@analyticawebplayer.com to me	show details 4:52 PM (0 minutes a	go) 🤸 Reply 🔻		
I invite you to review and run an Analytica model called: Project portfolio planner.ana You can run it in a web page using Analytica Web Player (AWP). Simply click this link http://www.AnalyticaWebPlayer.com/2.5/Client/AwpClient.aspx?inviteId=2&inviteCode=123456& subName=jdoe%40gmail%2Ecom I would appreciate your comments. Thanks, Jane Doe jdoe@gmail.com	Hi					
You can run it in a web page using Analytica Web Player (AWP). Simply click this link <u>http://www.AnalyticaWebPlayer.com/2.5/Client/AwpClient.aspx?inviteId=2&amp;inviteCode=123456&amp;</u> <u>subName=jdoe%40gmail%2Ecom</u> I would appreciate your comments. Thanks, Jane Doe <u>jdoe@gmail.com</u>	Li	wite you to review and run an Analytica model called:	Project portfolio planner.ana			
Simply click this link <u>http://www.AnalyticaWebPlayer.com/2.5/Client/AwpClient.aspx?inviteId=2&amp;inviteCode=123456&amp;subName=jdoe%40gmail%2Ecom</u> I would appreciate your comments. Thanks, Jane Doe jdoe@gmail.com ★ Reply   → Forward	Y	You can run it in a web page using Analytica Web Player (AWP).				
◆ Reply → Forward	Si <u>ht</u> Su I v Th Ja jd	Simply click this link http://www.AnalyticaWebPlayer.com/2.5/Client/AwpClient.aspx?inviteId=2&inviteCode=123456& subName=jdoe%40gmail%2Ecom I would appreciate your comments. Thanks, Jane Doe jdoe@gmail.com				
	•	Reply -> Forward				

#### **User Session Credits**

When you signed up for the Analytica Web Player, you automatically received 25 free user-session credits for signing up. If you keep your support active on your Analytica license, you'll also receive an additional 25 user-sessions per month (these expire at the end of each month if unused, but 25 new credits appear at the beginning of each month). These free credits allow for a moderate level of AWP usage at no charge. Each user session is good for up to one CPU minute of computation. Very occasionally, some models will contain very CPU-intensive computations. When these computations surpass 1 CPU minute, additional session credits may be consumed. If you have a excessively CPU-intensive model, then you should consider sharing it via Analytica Player instead. We want to keep the AWP server responsive for all users! Chapter 8 Sharing Models with Others

From the Project Directory page in AWP, you can click the **Account Info** button to view your user session credit balance.

	Lumina. ana	ytica web pla	Release 2.5.0.7
1.) Click Account Info	Welcome to the Analytica W Analytica models via a web to of it: Email Lumina at Awp@ suggestions for new features Click a model to select it, an selected model. Or upload a below.	v and run hat you think ns or Account info Buy Credits o apply to the model button	
	Titte	Author(c)	
	Rent vs Buy Example Model.ana	Max Henrion	
	Run model Upload model Sign out Change password	Download model Delete model (	Email invite
	Lumina.		
	Account info		
	Account name	jdoe@gma Indi	iil.com vidual
1.) Click <b>Project</b> Directory to	Number of credits remaining	Project dire	23 ectory
return.			

When you require a higher usage level than provided with the free monthly credits, you can purchase additional user session credits to your account by logging into AWP and pressing the **Buy Credits** button.

An AWP Group Plan subscription also exists with additional functionality for collaborative project support, higher included monthly user session levels, and additional features. Learn more on the Lumina Web Site.

#### **Summary: Sharing Models**

In this chapter, you have learned about sharing models files with people who do not have Analytica installed, or who can download and install the free Analytica Player edition. You have also established an account on the Analytica Web Player server, which you can use to share models over the internet with anyone who has a Flash-enabled web browser.

# **Chapter 9**

## **On Your Own**

This chapter describes the example models and libraries that are provided with Analytica.

![](_page_160_Picture_3.jpeg)

![](_page_161_Picture_0.jpeg)

Congratulations on completing the Analytica Tutorial. You are now ready to begin creating your own models.

For more detailed information on Analytica, see the *Analytica User Guide*. It is a reference on all aspects of Analytica, including descriptions of all available functions.

Within the Analytica folder are folders titled Example Models and Libraries, which contain a variety of Analytica models, including the examples illustrated in the Analytica User Guide. These resources are useful to include when building your own models. Many of the example models were created by users just like you. These models contain a wealth of ideas on using Analytica for practical applications. You should investigate these examples to see some of the different ways in which models can be constructed.

If you create models that you feel would be helpful or interesting to others, please send them to us for inclusion in a future Example Models folder; see the end of this chapter.

The Example Models folder is subdivided into these folders:

- Business Examples
- Data Analysis
- Decision Analysis
- · Dynamic Models
- Engineering
- · Function Examples
- Optimizer Examples
- · Risk Analysis
- User Guide Examples

#### **Business Examples**

**Bond Model** This model takes typical bond purchase inputs (purchase price, par value, interest rate, and life to maturity) and calculates bond cash flows, current yield, and yield to maturity.

**Breakeven Analysis** This model is an example of a breakeven analysis of a set of revenue levels, when the fixed expenses are set at one amount and the variable expenses are a constant fraction of revenue.

Expected R&D Project This model evaluates and compares the expected commercialization value of multiple proposed R&D projects.

**Financial Statement Templates** This model contains a complete set of standard financial statements: a profit and loss statement, balance sheet, and cash flow statement. It provides a step-by-step guide to using these templates to generate your own financial statements. You can enter values into the existing template and modify the variable definitions to reflect your own accounting standards.

**Market Model** This model explores a market for a new product, and the pricing and advertising budget decisions involved. This example also shows the use of "forms" for receiving input and presenting output for users of the model.

![](_page_162_Figure_8.jpeg)

 

 Plan\_Schedule\_ Control
 This model takes input data for activity paths required to complete a project, and calculates various outputs describing the critical path, timing, and costs for project completion.

 Project Portfolio Planner
 This model evaluates and prioritizes a portfolio of projects based on either the estimated net present value or a multi-attribute score, based on strategy fit, staff development, the generation of public goodwill, and estimated net revenue.

 Sales Effectiveness
 This model evaluates the effects of unit price on salesmen head count and production capacity.

The model contains an example of taking user estimates of uncertainty in a standard highmedium-low form, and transforming those inputs into a continuous distribution for propagation through the model.

Derived from *Principles of Systems* by Jay W. Forrester, 1968, ISBN 0-915299-87-9.

**Subscriber Pricing** This model determines the amount of revenue needed on a monthly basis from each subscriber of a service to just meet the weighted average cost of capital of the firm from the service release date to the end of the study horizon. In other words, it calculates the monthly unit revenue rate

![](_page_163_Picture_0.jpeg)

required from each subscriber of a service to give a return on investment at the end of the study horizon that is equal to the weighted average cost of capital of the firm.

## **Data Analysis**

Bootstrapping	Bootstrapping is a technique for estimating the confidence in a statistical estimator. This model demonstrates how a distribution for an estimated statistic can be obtained by resampling repeatedly.
Kmeans Clustering	This model shows an example of scatter plots in Analytica. A <b>K</b> -means clustering algorithm (where <b>K</b> is the number of clusters) is applied to some random data to partition points into groups (clusters) of similar points.
	This model also demonstrates the Iterate function.
Moving Average Example	This is a simple model that shows how to compute the moving average for a data stream. It defines a <b>Moving Average</b> function you can use.
Multidimensional Scaling	This model performs multidimensional scaling. It takes as input <b>N</b> , which is the dimensionality of the problem, and <b>Distances</b> , which is an <b>N</b> x <b>N</b> symmetric matrix of distances (or dissimilarities). It calculates and outputs a two-dimensional set of <b>N</b> points <b>XY</b> (or separately as <b>Xcoord</b> and <b>Yco-ord</b> ) that best approximates the spatial layout of points that could generate the input distances.
	Reference: <i>Multivariate Analysis</i> by K.V. Mardia, J.T. Kent, and J.M. Bibby, Academic Press, London, 1979, Section 14.2.2, page 400. Model supplied by Michael L. Thompson.
Principle Components	Principal components analysis (PCA) is a technique used to reduce multidimensional data sets to lower dimensions for analysis. PCA involves computing the eigenvalue decomposition or singular value decomposition of a data set.
	This model shows how to find the principle components in a uses an eigenvalue decomposition to compute the principle components of the covariance matrix of historical stock prices.
Regression Examples	This model demonstrates the use of generalized linear regression by best fit curves of various function forms to a set of $(x,y)$ points. It includes:
	Linear regression
	Quadratic regression
	Polynomial regression
	Discrete Fourier series     Begrossion with redundant basis
	<ul> <li>Regression using a large arbitrary collection of terms (useful in the situation where you)</li> </ul>
	do not have any reason to prefer one functional form over another)

• An auto-regressive series

![](_page_164_Picture_0.jpeg)

#### **Decision Analysis**

This folder includes models that illustrate the discipline of decision analysis.

Two Branch Party Tree

The author of this model wants to throw a party, and can't decide where to throw it. This model shows how to model a two-branch decision tree in Analytica.

![](_page_164_Figure_6.jpeg)

![](_page_165_Picture_0.jpeg)

Multi-attribute Utility Analysis	This model is an example of a multi-attribute utility analysis for cars, showing how to analyze an array of cars across an array of attributes, where different drivers assign differing weights to the importance of each attribute.
Newton-Raphson Method	This model implements the Newton-Raphson (or simply Newton's) method, one of the most powerful and well-known numerical methods for finding the root of $f(x)=0$ .
Nonsymmetric Tree	This model uses decision tree terminology to provide an example asymmetric decision tree in Analytica.
Party With Forecast	This model presents a problem facing a party host. In the face of uncertain weather, what is the best location to hold a party? The value the host assigns to the party is a function of both the location chosen and the weather outcome.
	This model augments the basic party model in order to show the value of imperfect information — in this case, a weather forecast — using Bayesian updating.
Plane catching decision with EVIU	The Expected Value of Including Uncertainty (EVIU) expresses the improvement in decision qual- ity obtained when we include uncertainty as probability distributions in our model, compared to using only deterministic estimates for parameters. This model illustrates how EVIU is computed using a model to assess what time I should leave my home to catch a flight at the airport.
Probability of Gaussian Region (Importance Sampling)	This model demonstrates the technique of <i>importance sampling</i> . Importance sampling is a variant of Monte Carlo sampling that can be used for extremely rare event sampling. Straight Monte Carlo with finite sample sizes will provide very low coverage of regions with very low probability. This example demonstrates by estimating the probability of a very small region within a Gaussian distribution.
Supply and Demand	This model calculates the required supply level to maximize profit when the profit function is asymmetric around the average demand value.
Tornado Diagrams	A tornado diagram is a common tool used to depict the sensitivity of a result to changes in selected variables. The fundamental analysis behind a tornado diagram consists of varying only one input variable at a time, keeping all other variables at their nominal values. Typically, a low and a high value are selected for each input, and the output variable is computed while only one variable varies at a time. This example model shows two methods for selecting high and low values: 1. By varying all inputs by the same relative amount, e.g., low=90% of nominal, high=110% of nominal, or 2. By varying all inputs between two given fractiles. This only makes sense if your inputs are uncertain variables. Example: low=10% fractile, high=90% fractile, nominal=50% fractile.

![](_page_166_Figure_2.jpeg)

![](_page_166_Figure_3.jpeg)

![](_page_166_Figure_4.jpeg)

### **Dynamic Models**

This folder includes models that use Analytica's **Dynamic()** function for performing dynamic simulation (modeling with cyclic dependencies).

- **Disease establishment** This model forecasts the population of fish and the establishment of a contagious viral disease within the population over time.
  - **Leveling** This example levels staff efforts over time according to staff available, computing both the work done over time and idle time.
  - **Markov Chain** This model demonstrates how to simulate a Markov process using dynamic time. The example estimates the number of hospital patients over time, modeled as a Markov process.
  - **Mass-Spring-Damper** This model simulates a typical free mass-spring-damper system. The term "free system" means that there is no time-dependent driving force or displacement acting on the mass. Ordinarily solutions to such a system are determined from a set of homogeneous second-order differential equations accompanied by the appropriate initial conditions. In this model, the kinematic variables (displacement, velocity, and acceleration) are related to the typical kinematic equations, and the dynamic variables (spring force and damper force) are related to the acceleration and the system mass by Newton's second law. You input the various initial state conditions (spring constant, damper constant, mass, initial displacement, and initial velocity) and the run time of the model. The graphical solutions generated by this dynamic model are comparable to the solutions determined by the corresponding differential equations.
- **Optimal Path Dynamic Programming** This model demonstrates a simple dynamic programming solution to a sequential decision problem. It computes the optimal finite-time step path to take in a deterministic environment where a known reward payout is given in the final time step and each transition has a known cost.
- Parking Space Selection A simple dynamic programming example, illustrating the solution to a sequential decision problem with uncertainty. You are to find the best parking space to minimize the time needed to get to your restaurant. The example demonstrates the use of the **Dynamic()** function over an index other than **Time** and the use of a reverse-recurrence in which the dynamic recurrence is based on future (rather than past) values.

![](_page_167_Figure_10.jpeg)

**Projectile Motion** An example demonstrating how to use the system variable **Time** and the **Dynamic()** function to model time-variant behavior — in this case, the motion of a projectile.

![](_page_168_Figure_3.jpeg)

# **Tunnel through earth** Imagine a tunnel passing through the earth, perfectly straight and directly through its center. If you step into it, how long will it take you to emerge on the other side? How fast will you be traveling as you pass the center of the earth? Find out with this simple dynamic simulation of the trip.

**Unequal time steps** This model gives an example of a dynamic variable that calculates growth over time, where *Time* is defined with unequal time steps. It is an example of exponential or linear growth or decay — that is, a dynamic variable whose values in one time period are exponentially or linearly dependent on the values in the previous time period.

## **Engineering Examples**

Adaptive Filter This model curve fits noisy time-sequence data using an adaptive filter.

Antenna Gain This model calculates the expected gain of an antenna looking at two different satellites.

Compression Post Load Capacity

Computes the load that a Douglas-Fir Large compression post can support.

Chapter 9 On Your Own

## **Daylight Analyzer** A demonstration showing how to analyze lifecycle costs and savings from daylighting options in building design.

) Diagram - Daylighting analyzer						
Daylight time a	and occupancy	1	Building form an	d glazing		
Nearest city	San Francisco 🔻		Gross area per floo	r (ft^:	2) 25k	<
Custom latitude	(degrees) 60		Floor length to width	n ratio	2	2
Occupancy start f	ime(Hours) 8		Daylight zone depth	ı (f	t) 1:	ō
Occupancy end ti	me (Hours) 18		Useful window ratio		Triangula	
Annual occupancy	/ hours <b>Normal</b>		Glazing transmittan	ce (V	F) (Triangula	
Lighting			Cost-benefit res	ults	(	<u>`</u>
Lighting load type	custom lighting 🛛 🔻		Electricity cost	(\$/kwł	n) <b>Triangula</b>	J
Custom lighting la	ad (w/ft^2) <b>Triangula</b>		Peak demand rate	(\$/kw-montl	n) <b>(Triangula</b>	
Selected lighting l	oad (vv/ft^2) <b>Calc</b> mid		Savings by type	(\$/yea	r) Calc	mid
Dimming factor	0.8		Energy cost escala	tion rate (/yea	r) (Triangula	
Illumination level	(fc) <b>50</b> 🔻					-
Lighting control ty	pe One-step 🔻		Payback horizon	(Years	s) 12	2
Daylight			Discount rate	(%/yea	r) 8%	ò
availability	Building form		NPV savings	(\$	6) Calc	) Ľ
Lighting calculations	Cost and savings		NPV savings Import	tance	Calc	) mid
•						

**Failure Analysis** This model provides a system simulation demonstrating a failure analysis with both parallel (bulbs) and series (bulbs and switch) components. The model shows the use of a **Determtable** instead of nested if...then statements to assess the state of the system. Both the switch and the bulbs use an exponential function to assess the probability of failure.

**Ideal Gas Law** Uses the ideal gas law, PV = nRT, to solve for one unknown given the other three. Each quantity can be specified in any of a variety of possible units.

#### **Function Examples**

This folder contains examples illustrating a variety of Analytica's functions and modeling techniques.

- Abstracted Subset Since the Subset() function returns a list, it normally cannot be applied to a 2-D or higher array (i.e., it cannot be array abstracted). This model demonstrates how it can be utilized in a matter that does array-abstract.
- Assignment from Button This model demonstrates how you can use a button to copy a computed result from one node into the edit table in another node. Analytica Enterprise users can create buttons by dragging a button node from the tool bar onto the diagram.
  - Autocorrelation This model calculates the auto-correlation coefficients of noisy time sequence data.
  - Choice and Determtables This model shows that when Choice nodes are indexed by "self," you can use Determtable functions to propagate the selected choice. This is cleaner than some other methods of using Choice outputs.
- **Correlated Distributions** This model reorders a group of probabilistic variables' samples so that they mimic a desired correlation structure as closely as possible.

![](_page_170_Picture_0.jpeg)

For more information on this method see R.L. Iman and W.J. Conover, "A distribution free approach to inducing rank correlation among input variables," Commun. Statist.-Simula. Computa. (Marcel Dekker, Inc.), 11(3), 1982, 311-334.

**Correlated Normals** This model demonstrates a method for creating two normal distributions with a specified correlation between them. The two resulting unit normals can be transformed to have any mean and standard deviation. From E.M. Scheuer and D.S. Stoller, "On the generation of Normal Random Vectors," *Technometrics*, 4:278-281, 1962.

**DBWrite Example** This model demonstrates how you can write data from an Analytica model to a relational database using ODBC. This model requires Analytica Enterprise; refer to Chapter 22 of the *Analytica User Guide*.

**Discrete Sampling** This model demonstrates how to generate a distribution from a discrete sample of numbers.

Extracting Diagonal This model demonstrates how to extract a diagonal from a matrix.

**Lookup Reindexing** This model demonstrates a simple re-indexing operation, essentially how to look up a value from another table. This is shown by the *Salary by person* node, and demonstrates how Excel's **VLOOKUP** function is performed in Analytica expressions.

Map images from<br/>internetThis flashy example reads and displays images of indicated areas from Google Maps in an image<br/>embedded in the model. Requires Analytica Enterprise, Optimizer, or Power Player.

Sample Size Input Node On occasion, you might want to provide an input node on your form for the sample size system variable, so that a user can adjust the number of samples directly from your form, rather than having to bring up the Uncertainty Options dialog. Because you cannot select the sampleSize system variable, it is not possible to do this from the Analytica menus. This module provides a way to create this input node — just select Add Module and then Embed, and you can drag the input node in the module to the form where you would like it to appear. After you do that, you can delete this module, which will then be empty.

**Sorting People by Height** This example sorts an index (*People*) by a table of values (*Heights*), and then uses the sorted index to created a sorted table of values (*Sorted heights*).

Subset of Array This model creates a subset array out of a larger array based on a decision criterion.

![](_page_170_Figure_12.jpeg)

Swapping y and x-index

This model swaps a computed or one-dimensional table value with its index, thereby making the computed value an index.

**Use of MDTable** This model demonstrates the use of the **MDTable** function, which converts records in table form into multi-dimensional arrays. Multi-dimensional arrays are often useful for visualizing large sets of records. By allowing data to be viewed either as a graph or in a pivot table, the geometric relationship between records often becomes immediately evident.

## **Optimizer Examples**

This folder contains examples of how to use Analytica with Optimizer. These models are fully functional only if you have purchased the Optimizer license along with Analytica.

**Airline NLP** This model gives examples of nonlinear programming optimization and Intelligent Arrays. The examples are:

- Simple airline decision problem to select the number of planes and fares to maximize profit; parametric analysis with respect to demand.
- · The same problem with uncertainty, to maximize expected profit.
- The same problem with uncertainty, to maximize profit, given value of uncertain variables
- A dynamic model optimization over multiple years
- A dynamic analysis with optimization in each year
- **Asset allocation** Given many possible investments with varying risk-versus-return trade-offs, one can often reduce risk through diversification. In the best case, investing in two assets with identical expected appreciation, **r**, but which are perfectly anti-correlated in their co-variation yields the expected rate of return with no risk. The more general problem is to select a portfolio that both maximizes return and minimizes risk. There are several possible formulations for this, and this model explores three:
  - 1. Minimize variance (risk) subject to a given expected return.
  - 2. Maximize return subject to a given variance (risk)
  - 3. Balance risk and return by maximizing expected utility, given a person's level of risk aversion.

## Automobile Production This model is a linear programming example, taken from "Quick Review of Linear Programming," *Management Science Techniques for Consultants,* by M.A. Trick (1996).

Its objectives show all the varies results from a linear program:

- · The optimal solution
- · The value of the objective function at the optimum
- The solution status
- The reduced costs (dual values for the variables) at the optimal solution
- · The slack or surplus values for the constraints at the optimal solution
- The shadow prices or dual values for the constraints at the optimal solution
- The range over which the objective function coefficient can vary in the linear program without changing the optimal solution
- The range over which a right-hand-side coefficient can vary without changing the dual value (shadow price) of the optimal solution
- **Big Mac Attack** This model addresses the issue of meeting one's daily dietary requirements at McDonalds. The objective can either be to minimize cost, total caloric intake, or total carbohydrates.

The model allows you to solve this problem to result in a Continuous, Integer, or Binary solution.

Selecting *Continuous* results in a computationally easier problem, but less realistic answer, since you cannot order 4.35 Big Macs.

- **Capital Investment** This model is an example of capital budgeting for four possible projects, where the objective is to decide which projects to choose in order to maximize the total return.
- **Labor production** A linear program to determine which product variants to produce and how labor should be allocated among the various production steps based on the workers' skill sets.
- **Magic Square** Simple demonstration of a grouped-integer domain. Fill in a square with the digits 1 through  $n^2$  such that the rows and columns all sum to the same value.
- **NLP with Jacobian** This model demonstrates the use of the Jacobian and gradient in a nonlinear optimization with constraints. When a Jacobian is available analytically, it can accelerate the optimization convergence.

The example is a simple geometric problem. Given a set of intersecting circles (where the intersection of all the circles is not empty), which point of those contained in all the circles is closest to a target point?

This model also features a node, *Abstractable NLP*, that is an example of a general mechanism for defining NLPs in an array-abstractable manner.

**Optimal can dimensions** This model is a simple example of using the NLP Optimizer in Analytica Optimizer. The model computes the optimal dimensions for a cylindrical can that must hold a given volume. The optimal can has the minimal surface area (and thus, uses the minimum material).

**Optimal Production** This model is a simple example of linear programming in Analytica Optimizer.

Allocation An integrated circuit manufacturer produces several different IC products (chips). Each chip is created by a sequence of processes, each carried out by a different machine. Every chip must pass through every process, but the time required for each process depends on the product. Some products require a lot of time at Process1, while other require very little time there but more time at other processes. The company's objective is to determine how much of each product to produce to maximize profit without exceeding the capacity of each process.

**Problems with Local Optima Optima** 

The optional **guess** parameter to **NIpDefine()** provides a way to seed the search to the general area of where you think the global optima might be. When the Optimizer converges to a local optima, it is likely to be in the vicinity of the guess. So by trying a variety of guesses, you might be able to locate a set of local minima. Using the best of those might increase your chances of finding the true global optima.

This model demonstrates this method.

**Production Planning LP** This model is an example of production planning linear optimization. A company manufactures four versions of the same product and in the final part of the manufacturing process there are assembly, polishing, and packing operations. For each version, the time required for these operations is different, as is the profit per unit sold. How many of each variant should the company make per year and what is the associated profit?

- **Quadratic Constraints** An example of a quadratically constrained optimization problem with a quadratic objective function.
  - **Solve using NLP** This model demonstrates how an nonlinear programming formulation can be used to solve a nonlinear equation. In this case, the equation is encoded as a constraint (this can be generalized to a system of nonlinear constraints), and the objective function is ignored (constant).

Sudoku with Optimizer Find a solution to a Sudoku puzzle. Sudoku is a regular feature in many newspapers.

**Traveling salesman** Find a minimal length tour through a set of cites. The problem is often cited as an example of an NP-complete problem, i.e., a problem solution can be verified in polynomial time, but cannot always be solved in reasonable (polynomial) time assuming, as is widely believed, that  $P \neq NP$ .

**Two Mines Model** This model is another production example. The *Two Mines Company* owns two different mines that produce an ore which, after being crushed, is graded into three classes: high, medium and low grade. The company has contracted to provide a smelting plant with 12 tons of high-grade, 8 tons of medium-grade, and 24 tons of low-grade ore per week. The two mines have different operating characteristics, in terms of cost to operate and production of each type of ore. How many days per week should each mine be operated to fulfill the smelting plant contract?

#### **Risk Analysis**

This folder contains applications relating to the field of risk analysis.

Earthquake expense risk This model projects cost assessments of damage resulting from large earthquakes over time. It demonstrates risk analysis with time-dependence and costs of events shifted over time. Chapter 9 On Your Own

- Seat belt safety This model compares the value of various policies for restraints on occupants of automobiles.
  - **Txc** This model demonstrates risk/benefit analysis, in this case regarding the benefits of reducing the emissions of fictitious air pollutant TXC.

![](_page_173_Figure_4.jpeg)

#### **User Guide Examples**

This folder contains the examples that are given in the Analytica User Guide.

Analyzing Unc & Sens	The examples in this model demonstrate Analytica's tools for analyzing the uncertainty of vari- ables, relationships between uncertain variables, and sensitivity of outputs to changes in inputs. These include statistical functions and sensitivity analysis functions.
	This model is used in the <i>Analytica User Guide</i> , Chapter 16, "Statistics, Sensitivity, and Uncer- tainty Analysis."
Array Examples	The examples in this model demonstrate the basics of working with multidimensional arrays.
	This model is used in the Analytica User Guide, Chapter 11, "Arrays and Indexes."
Array Function	The examples in this model demonstrate many more of Analytica's built-in array functions.
Examples	This model is used in the Analytica User Guide, Chapter 12, "More Array Functions."
Continuous Distributions	A continuous distribution is one that is defined for a continuous variable — that is, for a real-val- ued variable. The examples in this model demonstrate Analytica's built-in functions that create or modify continuous distributions.
	This model is used in the Analytica User Guide, Chapter 15, "Probability Distributions."
Discrete Distributions	A discrete distribution is a probability distribution for a variable that can result only in certain, discrete outcomes. The examples in this model demonstrate Analytica's built-in functions that create or evaluate discrete distributions.
	This model is used in the Analytica User Guide, Chapter 15, "Probability Distributions."
Expression Examples	The examples in this model demonstrate the building blocks for creating and editing variable defi- nitions — expressions, standard operators, and mathematical functions.
	This model is used in the Analytica User Guide, Chapter 10, "Using Expressions."
Input and Output Nodes	This model is used in the Analytica User Guide, Chapter 9, "Creating Interfaces for End Users."

Dynamic Models	
	A dynamic model is a model with one or more dynamic variables — that is, variables that can change over time. These models illustrate various uses of the <b>Dynamic()</b> function.
	These models are used in the Analytica User Guide, Chapter 17, "Dynamic Simulation."
Dynamic & Dependencies	This model is a dynamic model that finds the downward velocity and position of a dropped object over a six second time period.
Dynamic & Uncertainty	This model shows three ways to use uncertainty with the <b>Dynamic()</b> function. In the first case, uncertainty samples are calculated once, at the initial time period. In the other two cases, new uncertainty samples are created for each time period (i.e., the values are re-sampled).
Dynamic Example 1	This model is the most simple dynamic model, with one variable that changes over time. This example finds the gasoline price for each of five years, assuming a 5% growth rate.
Dynamic Example 2	This model is a slight increase in complexity over <b>Dynamic Example 1</b> . This model still uses one variable that changes over time. However, instead of assuming a fixed inflation rate, this example, looks at the price with three different inflation rates for comparison.
Dynamic on multiple indexes	Illustrates a dynamic loop involving simultaneous recurrences over two distinct indexes.
Dynamic on non-Time index	Use of the <b>Dynamic()</b> function to model a recurrence over an index other than <b>Time</b> .

### Libraries

	The libraries in this folder contain functions that can be added to your model and used similarly to Analytica's built-in functions. These libraries can be added to your model; see Chapter 19 of the <i>Analytica User Guide</i> for information on how to add a library to a model.
Base conversion library	Functions that convert between binary, octal, decimal integer and hexadecimal values.
<b>Bayes Function</b>	This library contains <b>Posterior()</b> , a function for calculating posterior probabilities using Bayes' Theorem.
Complex Library	This is a library of functions for working with complex numbers. It contains functions for basic arithmetic, polar representations of complex numbers, scalar functions for finding complex roots, logs, exponents, matrix functions, and trigonometric functions. Addition, subtraction, and scalar multiply are performed with the usual operators. Complex multiplication and complex division require the use of explicit functions.
	Complex numbers as seen by users of this library should always be in the Euclidean complex form, such as a + ьі, where a is the real part and ь is the imaginary part.
Concatenation	This library has been deprecated by extensions to the built-in <b>Concat()</b> and <b>ConcatRows()</b> func- tions, but is still included for backward compatibility for models that make use of its functions. This library contains functions to make concatenation more convenient. Functions <b>Concat3()</b> through <b>Concat10()</b> are generalizations of the built-in <b>Concat()</b> function which concatenate from 3 to 10 arrays in a single call (the built-in <b>Concat()</b> function concatenates two arrays). <b>ConcatRows()</b> concatenates all the rows of a single array.
Data Statistics Library	This library contains functions for calculating statistical quantities for a list of numbers over an explicit index other than <b>Run</b> , such as the index used for the statistics results in Analytica: the mean, variance, standard deviation, kurtosis, skewness, fractiles, covariance, correlation, frequency, etc.
Distribution Densities	The functions in this library return the probability densities (for continuous distributions) and prob- abilities (for discreet distributions) for the standard distribution functions that are built into Analyt- ica. It also includes Cumulative distribution functions for continuous distributions and some discrete distributions, and inverse cumulative functions for most continuous distributions.
Distribution Variations	This library contains various functions for defining standard distributions using different sets of parameters.

![](_page_175_Picture_0.jpeg)

- Expand Index This model contains the function **Change Index**. When this function is given an array indexed by one index, it returns an array indexed by another index. This model contains an example in which Change Index is used to combine cashflows over two different time periods into a single cashflow over a single time period. This model contains a variety of corporate finance functions: Black-Scholes Option Values (Cal-**Financial Library** IOption, PutOption), Capital Asset Pricing Model (CAPM), Miles/Ezzell Adjusted Cost of Capital (CostCapME), Modigliani/Miller Adjusted Cost of Capital (CostCapMM), Present Value of Perpetuity (**PVperp**), Present Value of Growing Perpetuity (**PVqperp**), and Weighted Average Cost of Capital (WACC). This library provides functions for writing data to and from flat files, particularly between two-Flat File Library dimensional tables and comma-separated value (CSV) files. Garbage Bin Library This library provides a **Recycle Bin** for your model (including a recycle bin icon). To use it, simply drag your discarded objects into the recycle bin module. Unlike deletion, items in your recycle bin can be retrieved, and the **Undo** command (Control+Z) works for items dragged into the bin. If an item you put into the bin has dependents outside the bin, it shows arrows from the bin — a signal that you should either retrieve the item, since it is being used, or also drag its dependent(s) into the bin. To delete the items in the bin permanently, open the bin, select all its contents (with Control+A), and delete them (press Delete key). Functions for Logistic, Probit and Poisson regression. While the Regression() function is used to
- **Generalized Regression** obtain a function that predicts the expected value of an output given a new data point, generalized regression functions fit a function that predicts the probability or probability distribution of an output given a new data point.
  - Linked List Library This library contains routines for manipulating linked lists.

The simplest linked list is just NULL — a linked list with zero elements.

Any other linked list is a reference to a record indexed by Linked\_List (an index defined in this library) with each cell containing a reference, to the element, and a pointer to the remainder of the list.

Linked lists are created and manipulated using functions in this library:

- · Use the function LL Push() to build the list.
- After a list is built, the easiest way to use and view it is to convert it back to an array using LL to RArray(). This reverses the order of items in the linked list (which has the last item "pushed" into the linked list as the first item in the list) so that the array has the items ordered the same as when they were added to the list.
- The function LL to Array() returns an array with the items ordered the same way as the • linked list (the last entered item is first in the list/array).
- Other functions provide the first item in the list, the N<sup>th</sup> item in the list, the list length, and allow you to remove (pop) the first item in the list.

Multivariate This library contains functions for creating several multivariate distributions: **Distributions Library** 

- Gaussian
- Dirichlet
- BiNormal and Multinormal
- Uniform Spherical and MultiUniform
- · Sample covariance and Sample Correlation
- · Functions for correlating distributions and results

**ODBC-Library** This library provides additional functionality (ValList, InsertRecSql, WriteTableSql) for using ODBC access to databases. Note that using ODBC requires Analytica Enterprise; refer to Chapter 22 of the Analytica User Guide.

**Optimization functions** Simple implementations of Newton-Raphson techniques for GoalSeek() and Solve(). These can be used to solve for a single value or for a vector of values in a non-linear model, and can be used from any edition of Analytica. The algorithms are not nearly as sophisticated and robust as those in the Analytica Optimizer edition.

Chapter 9 On Your Own

Performance Profiler	Use this library to see which variables and functions are taking most of the computation time when running your model. Consult the model's description for an explanation of how to use the library.
Structured Optimization Tools	Functions that are useful when creating structured optimization models (requires Analytica Opti- mizer). These include functions to set the decisions variables' definitions to the solution of an opti- mization, or to restore the definitions to their original values.
Тір	The ODBC and Profiling libraries require Analytica Enterprise, or ADE. They do not work with other versions of Analytica. Structured Optimization Tools require Analytica Optimizer.

Optimization Functions This library contains functions for optimization and equation solving, using a Newton-Raphson style search.

## Summary

If you have created a model that other Analytica users would benefit from, please send it to us for possible inclusion in future versions of the *Example Models* folder. Send your well-constructed, thoroughly documented models to:

#### support@lumina.com

Also, if you experience any problems with the example models, or if you feel that they need to be changed in some way, please contact us at the above email address.

You can also submit example models to the Analytica wiki, a web application that allows member of the Analytica community to collaborate and share information. Go to:

http://lumina.com/wiki/index.php/Example\_Models

Here you can view example models submitted by others and to submit your own examples, and download many additional example models not bundled with the Analytica installer.

Go to the Analytica wiki home page (http://lumina.com/wiki/) to find all sorts of information on Analytica including additional information on Analytica functions, frequently asked questions (FAQs) and their answers, guides to modeling, what's new in Analytica, and much more.

![](_page_177_Picture_0.jpeg)

# Glossary

This glossary includes a compilation of terms specific to Analytica as well as statistical terms used in this manual.

![](_page_178_Picture_2.jpeg)

#### Glossary

Array	A collection of values that can be viewed as one or more tables. An array has one or more dimensions; each dimension is identified by an index.
Arrow, influence arrow	Influence arrows (or arrows) from one variable node to another indicate that the origin node affects (influences) the destination node. If the nodes depict variables, the origin variable is an input to the destination variable, and the destination variable is an output of the origin variable.
Arrow tool	The tool for drawing arrows between nodes.
Attribute	A property of an object, such as its title, description, definition, value, or inputs.
Attribute panel	An auxiliary window pane that can open below an influence diagram. Use it to rapidly examine one attribute at a time of any variable, function, or module.
🙌 Browse tool	A tool for examining the structure and assumptions of a model, with limited ability to make changes to the model.
Chance variable	An uncertain variable that cannot be directly controlled by the decision maker. It is usually defined by a probability distribution. A chance variable is represented by an oval node.
Class	Analytica objects are organized into the following classes: module, attribute, function, and decision, chance, objective, index, and general variables.
Cumulative probability distribution	A graphical representation of a probability distribution. It plots the cumulative probability that the actual value of the uncertain variable $\mathbf{x}$ is less than or equal to each possible value of $\mathbf{x}$ . The cumulative probability distribution is a display option in the Uncertainty View popup menu in a <b>Result</b> window.
Decision variable	A variable that the decision maker can control directly. A decision variable is represented by a rectangular node.
Definition	A specification for computing a variable's value. The definition can be a number, a mathematical expression, a list of values, a table, or a probability distribution.
Description	Text explaining what the object represents in the system being modeled. The description is lim- ited to 32,000 characters in length.
Deterministic table	A function that gives the value of a variable conditional on the values of its input variables, where the inputs are all discrete variables.
Deterministic value	See Mid, Mid value.
Domain	The possible outcomes for a variable defined as a probability table.
Edit table	A definition that is an array (table) is also called an edit table because it can be edited.
Edit tool	A tool for creating or changing a model. Use it to move, resize, and edit nodes, and to expose the arrow tool and node palette.
Expression	A formula that can contain any combination of numbers, variables, functions, distributions, and operators, such as $0.5, a-b$ , or Min (x), combined according to the Analytica language syntax.
Expression type	Expression types include expression, list (of expressions or numbers), list of labels (text strings), table, probability table, and distribution. You select an expression type using the Expression popup menu, which appears above the <b>Definition</b> field. Note that any definition, regardless of expression type, can be viewed as an expression.
General variable	Any type of variable; useful when the variable type is unknown. The general variable typically represents a deterministic or functional dependency.
Lel Graph	Format for displaying a multidimensional result. To view a result as a graph, click the <b>Graph</b> button. See also <b>Table</b> .
Identifier	A short name for an object. A variable's identifier is used to refer to the variable in mathematical expressions in definitions of other variables. An identifier must start with a letter, have no more than 20 characters, and contain only letters, numbers, and the underscore character (_) (used instead of a space). Compare to <i>Title</i> .
Importance analysis	Shows the effect the uncertainty of one or more input variables has on the uncertainty of an out- put variable. Importance is defined as the rank-order correlation between the sample of output
# Glossary

	values and the sample for each uncertain input. This is a robust measure of the uncertain contri- bution because it is insensitive to extreme values and skewed distributions.
Index	Identifies a dimension of an array (table). An index is usually a variable defined as a list, list of labels, or sequence.
Indexes	Plural of index, indicates a set of index variables that define the dimensions of a table (in an edit table or value).
Index variable	A class of variable, defined as a list, list of labels, or sequence, that is used to identify the dimen- sions of a table, for example, in an edit table. An index variable is represented by a parallelogram node. See also <i>Edit table</i> .
Influence arrow	See Arrow, influence arrow.
Influence diagram	A graphical representation of a model, consisting of nodes (variables) and arrows (relationships between variables).
Input	An input of a variable $\mathbf{x}$ is a variable that has an arrow drawn to $\mathbf{x}$ , or appears in the definition of $\mathbf{x}$ . See also <b>Output</b> .
Input arrowhead	Shows that a node has one or more inputs from outside its module. This arrowhead is located on the left side of a node. Press the arrowhead for a popup menu of input variables.
List	A type of expression, consisting of an ordered set of numbers or expressions, available in the Expression popup menu. A list is often used to define index and decision variables.
List of labels	A type of expression, consisting of an ordered set of text labels, available in the Expression popup menu. A list of labels is often used to define index and decision variables.
Mean	The average or expected value.
Median	The middle number or value when the data values are ranked in order of size, i.e., the middle data point.
Mid, Mid value	A calculation of the variable's value assuming all uncertain inputs are fixed at their median values.
Model	A module, or a hierarchy of modules; the main, or root, module at the top of the module hierarchy. Between sessions, a model is stored in an Analytica document file.
Module	A collection of related objects, including variables, functions, and other modules, organized as a separate influence diagram. A module is represented by a rounded rectangular node with a thick outline.
Node	A box (rectangular, oval, or any other shape) that represents a variable in an influence diagram. Different node shapes are used to represent different types of variables.
Normal distribution	The bell-shaped curve, or Gaussian distribution.
Object Finder	A dialog box used to browse and edit the functions and variables available in a model.
Object window	List of the attributes for an object (variable, function, or module), including its class, identifier, title, and description.
Objective variable	A variable that evaluates the overall value or desirability of possible outcomes. The objective can be measured as cost, value, or utility. A purpose of most models is to find the decision or decisions that optimize the objective — for example, minimizing cost or maximizing expected utility. Most decision models contain a single objective node, although the objective can be composed of several sub-objectives. An objective variable is represented by a hexagonal node.
Output	An output of a variable $\mathbf{x}$ is a variable that has an arrow drawn from $\mathbf{x}$ , or whose definition refers to $\mathbf{x}$ . See also <i>Input</i> .
Output arrowhead	Shows that a node has one or more outputs outside its module. This arrowhead is located on the right side of the node. Press the arrowhead for a popup menu of the output variables.
Parametric analysis	A type of sensitivity analysis in which you specify a set of alternative values for one or more inputs, and examine the effect on selected model output variables. See also <b>Sensitivity analy-</b> sis.
Probabilistic variable	A variable that is uncertain and is defined with a probability distribution.

# Glossary

Probability bands	The bands that capture a certain portion of the total probability for a variable. For example, the 5% and 95% probability bands contain 90% of the total probability, while the 50% probability band corresponds to the median value. By default, the 5%, 25%, 50%, 75%, and 95% probability bands are shown. These bands are also referred to as <i>confidence intervals</i> or <i>fractiles</i> . Probability bands are a display option in the Uncertainty View popup menu on a <b>Result</b> window.
Probability density function (PDF)	A graphical representation of a probability distribution that plots the probability density against the value of the variable. The probability density at each value of $\mathbf{x}$ is the relative probability that $\mathbf{x}$ is at or near that value. The probability density function can be displayed for continuous, but not discrete, variables. It is a display option in the Uncertainty View popup menu on a <b>Result</b> window.
Probability distribution	Describes the relative likelihood of a variable having different possible values.
Probability table	A table for defining a chance variable with a set of outcomes and a discrete probability distribution (numerical probability for each outcome). If the variable depends on (that is, is conditioned by) other discrete variables, each of these conditioning variables gives an additional dimension to the table, so you can specify the probability distribution conditional on the value of each conditioning variable.
Self	A keyword referring to the index of a table that is indexed by itself. <b>Self</b> refers to the alternative values of the variable defined by the table.
Sensitivity analysis	A group of methods to identify and compare the effects of various input variables to a model on a selected output. Example methods of sensitivity analysis are importance analysis and parametric analysis. See also <i>Parametric analysis</i> .
Standard deviation	Reflects the amount of spread or dispersion in an uncertainty distribution. It is the square root of the variance.
in Table	A two-dimensional view of an array-valued definition or result. The array can have more than two dimensions, but only two can be seen at one time. A table is a type of expression available in the Expression popup menu. A definition that is a table is also called an <i>edit table</i> . In the <b>Result</b> window, click the <i>table</i> button to select the table view of an array-valued result. See also <i>Graph</i> .
Title	The full name of an Analytica object, briefly describing what the object represents. The title of a variable, function, or module is displayed in its node, in window titles, and in object lists. It is limited to 255 characters in length. The title can contain any characters, including spaces and punctuation. Compare to <i>Identifier</i> .
Uniform distribution	A distribution representing an equal chance of occurrence for any value between the lower and upper values.
Uncertainty View options	An uncertain result can be displayed as a <i>mid value</i> , <i>mean</i> , statistics, <i>probability bands</i> , <i>probability density</i> , <i>cumulative probability</i> , or sample. Select the option to display with the popup menu in the top left corner of the <b>Result</b> window or in the <b>Result</b> menu.
Units	The increments of measurement for a variable. Units are used to annotate tables and graphs, but are not used in evaluating a variable.
Value	A variable's value attribute is its mid value, computed by assuming that all uncertain inputs are fixed at their median values. It can be a scalar (single) number, a table of numbers, or a probability distribution.
Variable	An object that has a value, which can be a text string, a number, or a table. Classes of variable include decision, chance, and objective.

# **Analytica Windows and Dialogs**



Diagram Window: Inputs and Outputs



#### Diagram Window: Influence Diagram



Result Window — Graph View

t 🔻



Object Window



Diagram Style Dialog



Graph Setup Dialog



Attributes Dialog



Object Finder



Node Style Dialog

Analysis option: Uncertainty Sample 🔻				
(Applies to entire model) Sample Size: 100				
Sampling method: C Median Latin Hypercube C Random Latin Hypercube C Simple Monte Carlo C Knuth	thod:			
Fewer Options Random seed: 99 FReset once				
Cancel	Set Default			

Uncertainty Setup Dialog

Rent vs. Buy Analysis	V	
Modules Only		
Appreciation rate		
The Cost to Buy		
Present Value of C	ast to Buy	
Down payment		
Mortgage loan amo	ant	
Mortgage interest r	ate	
O Moving Costs		
Discount rate		
Foregone inter	est on down payment	
Savings interes	t rate	
Present value	if foregone interest	
Percent down new	oent.	
V Out-of-pocket co	sts to own	
Cash flow of o	wnershin costs	
~~~~~		
Rent vs. Buy Analysis:	Description 🔻	
Financial model comparing the	Net Present Value of renting vs.	buying a house.

**Outline Window** 

Suffix Exconential	Example: 123.5x	
Fixed Point Integer	- Contraction of the Contraction	
Percent Date	Number of digits: 📓 🚊	Show currency symbol
Boolean	<ol> <li>Show trailing zeroes</li> </ol>	

Result Window — Table View

Number Format Dialog

Windows of each kind:	Default result view:
Change Identifier:	Check variable class     Check value bounds     Show undefined:     Show undefined:     Show module hierarchy     Sho
Cancel	ок

Preferences Dialog



Find Dialog

# **Quick Reference**

#### The Tool Bar



It displays the node palette when you select the edit tool or arrow tool.

# **Numerical Formats (Output)**

Format	Description	Example
Suffix	letter denotes order of magnitude, such as M for 10 <sup>-6</sup> (see table below)	12.35K
Exponent	scientific exponential	1.235e+004
Fixed Point	fixed decimal point	12345.68
Integer	fixed point with no decimals	12346
Percent	percentage	1234568%
Date	text date	12 Jan 2008
Boolean	true or false	True

### Suffix format

Power of 10	Suffix	Prefix	Power of 10	Suffix	Prefix
			10 <sup>-2</sup>	%	percent
10 <sup>3</sup>	K	Kilo	10 <sup>-3</sup>	m	milli
10 <sup>6</sup>	М	Mega or Million	10 <sup>-6</sup>	μ	micro (mu)
10 <sup>9</sup>	G	Giga	10 <sup>-9</sup>	n	nano
10 <sup>12</sup>	Т	Tera or Trillion	10 <sup>-12</sup>	р	pico
10 <sup>15</sup>	Q	Quad	10 <sup>-15</sup>	f	femto