Logical Decisions

Decision Support Software

User's Manual

Logical Decisions, Fairfax, VA, USA

This manual supports Logical Decisions®, Version 7.1.

Logical Decisions would like to acknowledge the following people: and organizations:

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Pearson Design, Evergreen, CO	-- Graphic Design,
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Introduction

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Introduction

Real decisions aren't simple. Uncertainties, complicated alternatives, and varied preferences can make it hard to choose what to do. Once you decide, it may be hard to explain your choice.

Logical Decisions® for Windows (Logical Decisions) helps you evaluate your decisions. You define alternatives and variables to describe them. Next, Logical Decisions helps you formulate your preferences about the variables and uses the information to rank your alternatives.

You can rank your alternatives and create displays that clarify the rankings. Afterwards, the results should seem obvious, because the process helps you to think carefully about the choices and your preferences.

Logical Decisions gives you great flexibility in modeling your decisions. You define the alternatives and describe them in the way that makes the best sense to you. If your preferences are complex, or your choices have uncertainties, Logical Decisions can handle them.

Logical Decisions uses powerful methods from the field of Decision Analysis to help you quantify your preferences. Logical Decisions' interactive features let you evaluate alternatives instantly once you have quantified the alternatives and your preferences.

At the heart of Logical Decisions are sophisticated methods for assessing preferences. Logical Decisions provides a variety of preference assessment methods ranging from very simple methods to the "gold standard" of pairwise tradeoffs. With Logical Decisions you can select the method you feel most comfortable with.

Logical Decisions provides many features not found in other ranking programs:

- **Freedom in defining evaluation measures**. Scales can be discrete or continuous, increasing or decreasing, numeric or descriptive. There are no limits on the range or number of scale points you can have.

- **No limits** on the number of alternatives and evaluation measures you can have.

- Describe your alternatives using **probabilities**.

- **Organize your measures** into a hierarchy showing how the measures relate to your overall goals.

- Assess your preferences **graphically**.

- Model **interactions** between the evaluation measures.

- Quickly **find the important differences** between any two alternatives.

- Display the **effects of changes** in the weights for the measures.

You can use Logical Decisions for many types of problems. You can use it for personal decisions like choosing the best car or truck to buy, for business decisions like who to hire or what to invest in, or for large scale planning decisions, like the Air Force did to help them decide the mix of capabilities most useful to them in the next century. The possibilities are endless.

Organization of Manual

Section 2 tells you how to install Logical Decisions. Section 3 briefly describes the features of the program. Sections 4 and 5 are a tutorial introduction and Sections 6 through 8 describe in detail how to use the program. Section 9 is a more detailed discussion of the ideas behind Logical Decisions. Section 10 gives several real-life examples of how to use Logical Decisions. Section 11 is a summary of all of Logical Decisions' menus and options. Section 12 is the glossary. Finally, there is a brief bibliography and an appendix summarizing some of the mathematics used in the program.

S E C T I O N

Requirements and Installation

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Requirements and Installation

Equipment Requirements

Logical Decisions for Windows requires the following equipment and software:

- Windows compatible computer,
- Hard disk drive with at least 30 mb free space,
- CD drive or internet connection for installing program,
- Windows XP™, Windows Vista, Windows 7, or later.
- A valid license key provided by Logical Decisions

MS Office 2003 or later is recommended for export to Word or Excel.

Installation

Installing Logical Decisions is easy. Just put the Logical Decisions CD into your computer's CD ROM drive. Then start Windows and select the File::Run option in the program manager. Type the command **D:Setup** and press **Enter**. You may have to change this command slightly if your CD ROM drive is not the "D:" drive. This will start Logical Decisions' automatic installation process. The Setup program will prompt you for the name of the directory where the program files will be installed. We recommend that you accept the default directory name of "C:\Program Files\Logical Decisions\Logical Decisions v7.0".

If you have downloaded Logical Decisions from the internet, navigate to the directory where you downloaded the software and double click the file Logical Decisions70.MSI to start the installation process.

After you select a directory, the Install program will copy all of the files to the directory you selected. After the Setup program has completed copying the files, it will create a new program group called "Logical Decisions". This program group will contain the icon for the Logical Decisions program, which will also appear on your desktop. To start Logical Decisions, just double click the icon.

When you first start Logical Decisions, you will see a dialog box telling you that this is an evaluation copy. To activate your Logical Decisions copy, click the “Enter Key” button and enter the name and key provided to you when you bought the product. Logical Decisions will start up without the dialog box thereafter, even if you update the software later on.

SECTION

Quick Start

3

Introduction

This section gets you started with Logical Decisions for Windows (Logical Decisions) and points the way to additional information on Logical Decisions' more advanced features. It describes the steps needed to evaluate a set of alternatives and the options available at any step.

This section is an overview rather than a tutorial, and you will need to review the Tutorial and Using Logical Decisions sections to learn the details of the various commands.

What Logical Decisions does

Logical Decisions helps you evaluate **alternatives**. The alternatives can be anything you need to choose between -- jobs, potential employees, factory locations, or even what wine to have for dinner.

Logical Decisions lets you systematically look at your alternatives by following a series of steps. The steps help you define and describe your alternatives. They also help you think about the preference and value judgments that you need to make to be able to tell the best alternative from the rest of the alternatives.

When you complete the steps you will have a quantitative ranking of your alternatives.

You will also be able to review your results with a variety of displays that are specifically designed to help you feel confident that you are making the best choice.

The Steps of a Logical Decisions Analysis

Logical Decisions provides a great deal of flexibility in how you evaluate your alternatives, but you will need to do these basic steps:

- Structure your problem,
- Assess your preferences,
- Rank the alternatives and choose the best one.

Structuring Your Problem

You will structure your problem using three of the windows accessible under Logical Decisions' View menu -- the Matrix view, the Goals Hierarchy view and the Brainstorming view.

In these views you will define the **alternatives** you will evaluate. But just defining alternatives is not enough. You also need a way to describe what makes an alternative desirable or undesirable for your particular decision. In Logical Decisions you do this with goals and evaluation measures.

Evaluation measures (or just **measures**) are variables you use to describe your alternatives. They capture a specific aspect of your alternatives, such as their price. You will generally have many measures to describe your alternatives.

To organize your measures, you define **goals**. Goals are containers that can hold measures and other goals. For example, you might put related measures like purchase price and annual maintenance cost into a goal called Minimize Cost.

In Logical Decisions, you organize your goals and measures into a tree-like structure called a goals hierarchy. The goals hierarchy has the broad goals like make the best decision at the top and more specific goals beneath them. The evaluation measures are at the lowest levels of the goals hierarchy.

You will describe how well each alternative does on each of the evaluation measures and then use the goals hierarchy as a framework for combining the performance of an alternative on individual measures into an overall score for the alternative.

Defining alternatives. In Logical Decisions, you define alternatives in the Matrix view (the View::Matrix menu option) or the Brainstorming view (View::Brainstorming).

Initially you define an alternative with a just name and an optional ID number. Later, after you have defined your evaluation measures, you will describe your alternatives in detail by how well they perform on the measures.

Defining goals and measures. In Logical Decisions you define the goals and measures in the Goals Hierarchy view (View::Goals Hierarchy) or the Brainstorming view (View::Brainstorming). Both views have the tree structure of the goals hierarchy.

Goals and measures both have names and ID numbers. Measures also have a scale, which can be either numbers or text. Scales that use numbers are defined by their units and their most and least preferred levels. You define text scales with a set of short descriptions called **labels**.

Describing your Alternatives. You describe your alternatives by entering a score (called a **level**) for each alternative on each measure. You do this in the Matrix view (View::Matrix). The matrix view is a spreadsheet with rows representing alternatives and columns representing measures.

Each cell in the spreadsheet represents the level for a particular alternative and measure. The levels are either numbers or text, depending on how you defined the scale for the measure. You enter a numeric level by typing a number into the cell and enter a text level by picking from a list of text labels for the measure.

Two other types of levels are available in Logical Decisions – probabilistic and measure category. These are described further in the tutorials and elsewhere in this manual.

Assessing Your Preferences

After you have defined an alternative's levels on the measures, you need to tell Logical Decisions how it should combine the levels to compute the alternative's overall score.

You do this by describing your preferences about the relative importances of the measures and goals. The process of describing your preferences is called a **preference assessment**.

Assessing preferences in Logical Decisions has two main parts. First, you define how to convert measure levels to common units, and then you define the relative importances of the measures and (optionally) their interactions. This information lets Logical Decisions compute an overall score for each alternative that describes its relative desirability.

Storing your preference information

Logical Decisions stores your preference information in what are called **preference sets**. Logical Decisions creates a preference set for you when you start the program, but you can define many preference sets for a single decision (perhaps for different people). You can add more preference sets with the Edit::Add or View::Select/Change Preference Sets option.

Converting measure levels to common units

Logical Decisions converts an alternative's measure levels to common units called **utility** before it combines them.

Each measure's most preferred level is assigned a utility of one (1.0) while its least preferred level is assigned a utility of zero (0.0). Intermediate levels are assigned with what is called a utility function, or more specifically a **SUF** (for **Single-measure Utility Function**).

The easiest conversion is a straight line, where each unit change in a measure level results in an equal change in utility. This is the most common case, and the default. (Defaults are the initial settings used by Logical Decisions in various situations). **So, if you want a straight line conversion from a measure's original units to utility you don't have to do anything.**

Non-linear conversions

Sometimes a straight line SUFs isn't right. Suppose you are hiring employees and "years of experience" is one of your measures. You might feel that after a certain point additional years of experience aren't that helpful.

In this case you might think that the first few years of experience add more utility than the last few. You can use a curved ("non-linear") SUF to capture this idea.

In the example above, suppose two years experience is the least preferred level and 30 years is the most preferred level, but that you really want someone with around 5-10 years of experience. In terms of desirability, you might end up defining the preference mid-point of the 2-30 year range as five years. Figure 3-1shows the resulting curve for years of experience.

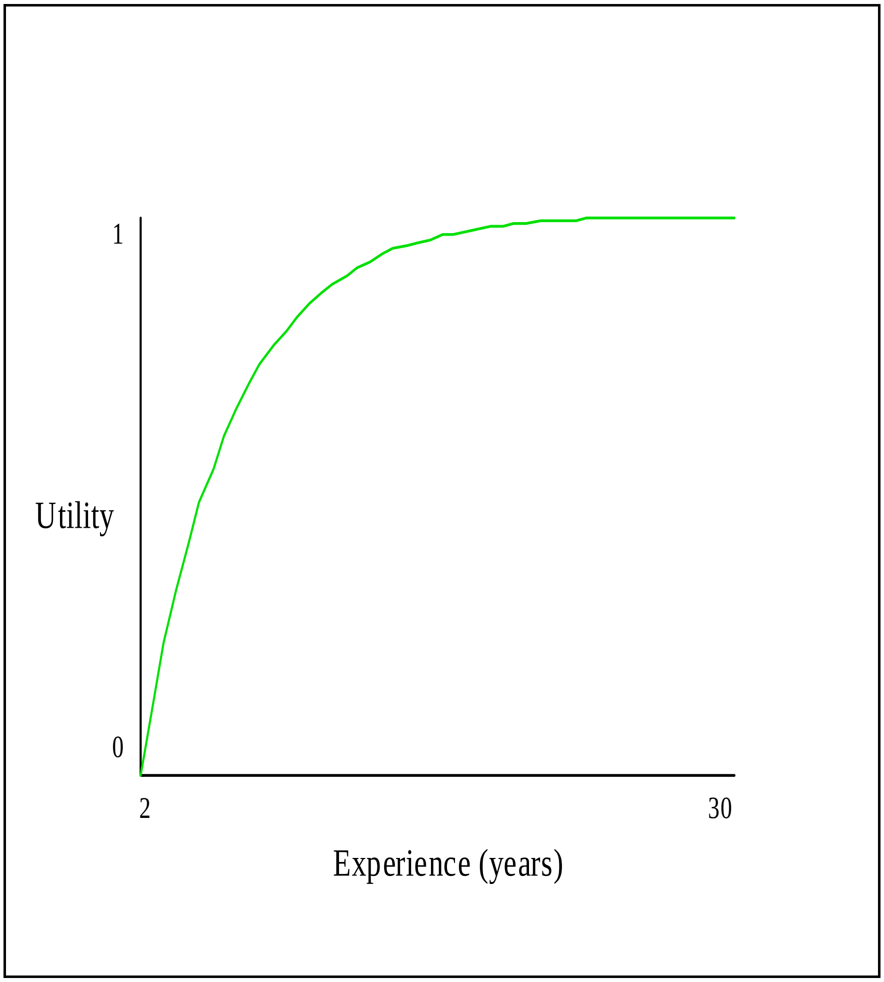


Figure 3-1 The SUF for "Years of Experience" converts years to utility. Two years is the least preferred level and 30 years is the most preferred. Five years is the mid-point in terms of preference.

Logical Decisions provides two interactive methods for identifying mid-preference levels. These are described in the In-Depth section, (page 293). Logical Decisions also provides several alternate methods for converting levels to common units. These include direct assessment and the Analytic Hierarchy Process.

Combining the measures' utilities into an overall score

As with measures, the desirability of each alternative on a goal is described by a number called **utility**. Logical Decisions computes an alternative's utility for a goal by combining its utility for each of the goal's members (measures or sub-goals) using a weighted average.

The influence of an alternative's level on a measure on the alternative's utility on the goal the measure belongs to is determined by the measure's weight.

Logical Decisions uses the structure of the goals hierarchy to aggregate measure utilities into utilities for the lower level goals and then continues aggregating lower level goals and measures until a utility for the overall (highest level) goal has been computed.

Logical Decisions provides several methods for assessing weights.

The easiest method uses a simple ordering of the measures' relative importances to compute a reasonable set of weights.

Other methods have you enter ratios of the measures' relative weights. The "Smart" method and the "Analytic Hierarchy Process" are examples of this type of approach.

The "Balance Beam" method has you identify equally desirable alternatives that have the most preferred level on one measure and the least preferred level on several other measures. Logical Decisions uses these alternatives to determine upper and lower bounds on the weights for the measures.

The most sophisticated method is to assess what are called tradeoffs. In the tradeoff method, Logical Decisions helps you define pairs of simple alternatives that you prefer equally. Then Logical Decisions computes weights that will give the equally preferred alternatives in each tradeoff pair equal utility scores.

Interactions. In addition to helping you assess the weights for the measures and goals, Logical Decisions also lets you define interactions between a goal's members. Interactions are an advanced Logical Decisions feature that you can use when the utility for a goal should not be a simple weighted average of the utilities of the goal's members.

Preference assessment menus. The options for assessing common units and weights can be found in the Assess menu in Logical Decisions. Many options and views for reviewing your preference assessments can be found in the Review menu.

Ranking Your Alternatives and Displaying Results

Once you have completed the steps above (or even before if you want preliminary results) you will be ready to rank your alternatives and display your results.

Logical Decisions provides many ways to review your results. You can rank the alternatives on the overall goal or on any other goal or measure with the Results::Rank Alternatives option. Logical Decisions sorts the alternatives by utility and displays them in a bar graph.

Other results options include a bar graph showing the utilities for a single alternative, a graph with a detailed comparison between two alternatives, and a graph of the effects of changes in the weights of the measures. All of the results options can be found under the Results menu.

Learning more about Logical Decisions

The rest of this User's Manual provides many resources for learning and using Logical Decisions:

- **Introductory Tutorial** (section 4) -- takes you through a simple example step-by-step.

- **Advanced Tutorial** (section 5) -- takes you through some of the more advanced features of Logical Decisions.

- **Using Logical Decisions** (sections 6 - 8) -- Describes Logical Decisions' user interface.

- **In Depth** (section 9) -- a more detailed discussion of the decision analysis approach that is the core of Logical Decisions.

- **Examples** (section 10) -- example applications of Logical Decisions.

- **Commands Reference** (section 11) -- Describes each menu item in Logical Decisions.

- **Glossary** (section 12) -- Defines the terms used in the program and manual.

- **Logical Decisions help system** -- Logical Decisions has an extensive help system that can answer your questions about specific parts of the software.

- **Logical Decisions Facilitator** – The Logical Decisions Facilitator is a wizard that acts as an interactive guide through the software.

- **If all else fails**... Call Logical Decisions at (800) 35-LOGIC (800-355-6442) or (703) 218-1801. You are also welcome to visit our web site at www.logicaldecisions.com

Final Comments

Logical Decisions is a powerful tool to help you analyze your decision problem, but it's only a tool. It isn't a black box that tells you what to do.

It helps provide insights into your alternatives and helps you think through difficult choices in a logical way. After you have ranked the alternatives and reviewed their differences, the reasons for the ranking results should be obvious. The results should reflect your preferences and intuition.

If you don't like the ranking, it often means that you could gain insights from more study of the results. Or, it may mean that you have not captured important considerations in the measures.

The quality of the answers generated by Logical Decisions depends critically on the quality of the data that it receives. In particular, you should take the time to

- Define your alternatives in detail.
- Make sure you have included all available alternatives.
- Think carefully about which measures are most appropriate for your alternatives.
- Make sure that your measures cover all of the important considerations for choosing alternatives, that they are not redundant, that you can measure them for each alternative and that they are meaningful for decision making.
- Think carefully when defining SUF curves and answering the weight assessment questions.

SECTION

Basic Tutorial

4

Basic Tutorial

This introductory tutorial guides you through a simple example using Logical Decisions (Logical Decisions). You will try to decide which of several small trucks is the best buy. You want to choose the truck that has the best *performance* for the *price*.

Tutorial Overview

In the introductory tutorial you will go through the steps needed to evaluate a simple set of alternatives -- three trucks that you are thinking about buying. Here's what you will be doing:

- **Defining the alternatives** by naming the trucks you will rank,
- **Defining the goals** that influence your decision,
- **Defining the measures** you will use to evaluate the trucks,
- **Entering the levels** on the measures for each truck,
- **Assessing preferences** to define how the measures should be combined,
- **Computing and displaying the results**.

Figure 4-1 summarizes these steps.

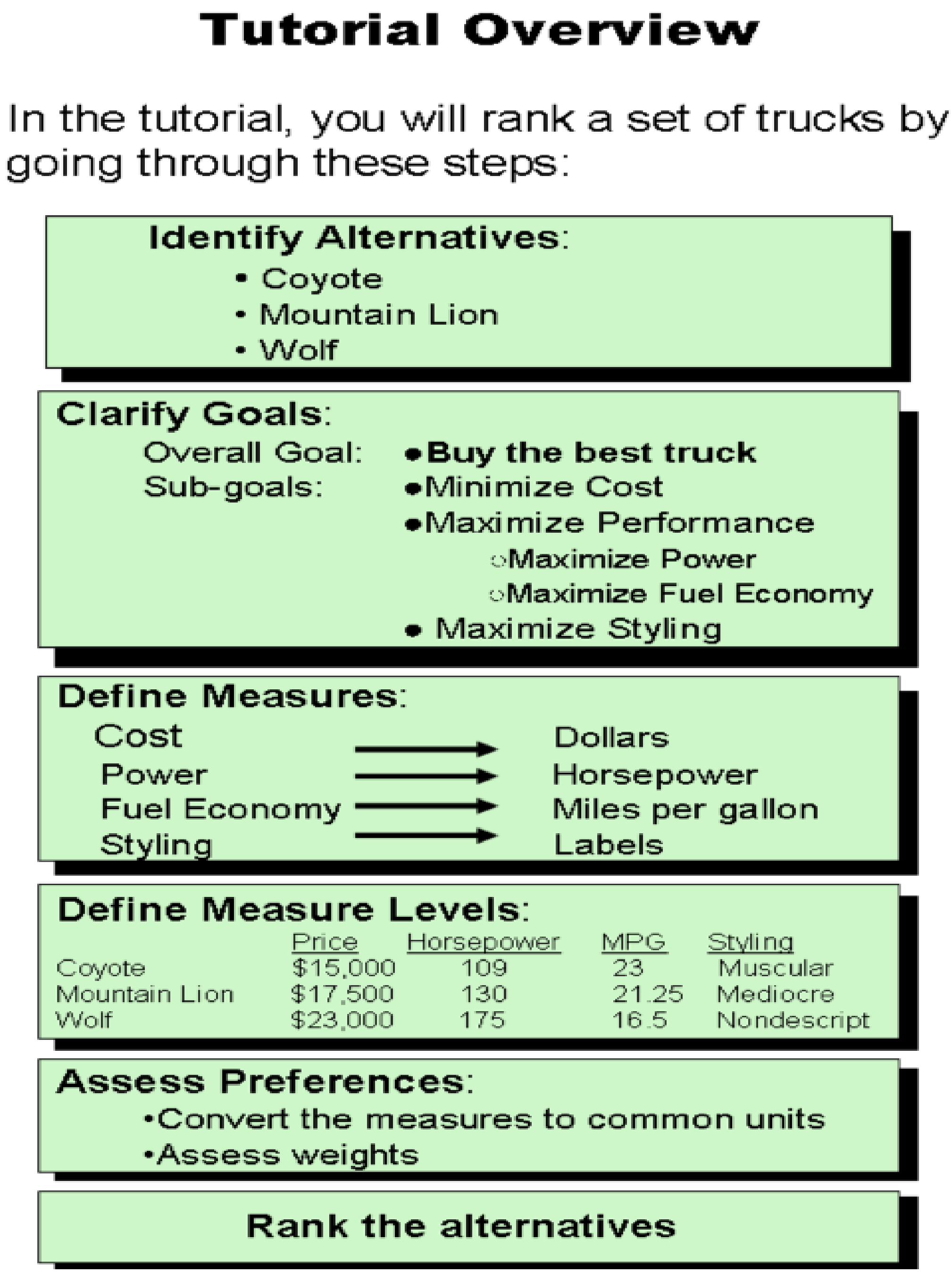


Figure 4- 1. Tutorial overview

Initial Steps

Before you can begin the analysis you need to install the program and start it. See page 15 for how to install Logical Decisions. To start Logical Decisions, just double-click its icon in the Logical Decisions program group. If you have opened one of the example files, you should select the File::New option to begin a new analysis.

Defining Alternatives

The first step in your decision analysis is to define the alternatives to be ranked. You will rank the following (hypothetical) small pickup trucks:

- Coyote
- Mountain Lion
- Wolf

The alternatives are new pickup trucks with roughly the same levels of accessories.

We will use the Logical Decisions Facilitator to help us navigate to the windows where we can add alternatives. The Facilitator is the window on the left side of the Logical Decisions screen. If you have closed the facilitator, re-open it by clicking the facilitator button. To open the windows for adding alternatives, click "Structure" in the Facilitator's tree view. This will open the items below Structure. You will see that "Define Alternatives" is one of the items. Click this and Logical Decisions will open two windows – the Matrix View and the Brainstorming View.

We could define the alternatives in either of the two views, but we will use the Brainstorming view.

The Brainstorming view has two sides -- the structured left hand side and the unstructured right hand side. You can add an alternative on either side. We'll do it both ways. Here are the steps:

1. First, there is already an alternative on the left hand side, so we'll rename it. Click the tree leaf labeled "New Alternative". If you click again, you can edit it in place. If you double click, you get its properties dialog box. You can rename it in either place.
2. Type the name "Coyote" into the name edit.
3. Close the dialog if it's open
4. Click the "A" button in the button bar to add a new alternative.
5. The edit box for the new alternative will be active, so type the name "Mountain Lion" and press Enter.
6. Now let's try the unstructured method. Click the right hand side of the window and then click the "I – add an Item" button on the button bar. (An Item is a name that has not yet been defined to be a particular Logical Decisions object type).
7. Rename the "New Item" that appears to "Wolf" and click Enter.
8. Now click and drag the Wolf item from the right hand side of the screen to the left hand side of the screen and drop it onto the word "Alternatives" This will convert the Wolf item to an alternative and add it to the list.

This completes the preliminary definition of the alternatives. We will describe them in detail by entering their levels (raw scores) after we have defined the measures.

Defining Goals -- How You Will Compare the Trucks

Goals let you define the concerns important to you when selecting a truck to buy. You will organize those concerns in a **goals hierarchy** with general concerns at the top and more specific concerns toward the bottom. Goals hierarchies are discussed more on page 299. In Logical Decisions, goals are collections of measures and other (lower level) goals.

Let's assume you have very simple requirements. Your overall goal is to *Select the Best Truck*, and you will do this by comparing price, performance, and styling. So, under the overall goal you have the sub-goals:

- Minimize Cost
- Maximize Performance
- Maximize Styling Quality

To represent this hierarchy, you can define four goals --

- Overall
- Cost
- Performance
- Styling

Logical Decisions predefines the *Overall* goal -- selecting the best truck -- so you do not need to add it explicitly.

The cost and styling goals will only have one measure each (price and styling) so you don't need to define separate goals for them. (Goals should generally have at least two members).

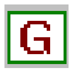
So, for this example, you only need to define the *Performance* goal, which will consist of measures of power and fuel economy.

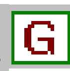
We will define the goals in the Brainstorming view. Initially, the top left side of the Brainstorming view shows a branch labeled "Overall" for the overall goal and a leaf labeled "New Measure" for the single evaluation measure in the new analysis.

If you have closed the Brainstorming window, you can get it back by clicking the Structure::Define Goals leaf of the Facilitator outline.

First you will change the name of the "Overall" goal to "Buy the best Truck”. Here’s how:

1. Click the box for the "Overall" goal
2. Logical Decisions will open an edit box in the tree.
3. Type "Buy The Best Truck" and press Enter.

Next we will add the "Performance" goal. We will do this with the  Add a Goal button. Here’s how:

1. Click the “Buy the Best Truck” box so that it is highlighted in blue.
2. Click the  Add a Goal button. Logical Decisions will add the new goal under the “Buy the Best Truck” goal
3. Type "Performance" in the edit box and press Enter.

Defining Measures

You have now defined the alternatives and goals for your decision. Next you will define the evaluation measures. The measures will describe how well each alternative meets one of the goals. The measures you will add are Price, Power, Styling and Fuel Economy.

Assume you have decided that you will measure cost by the price of each truck and that you can define Performance by two measures -- Power (with units of horsepower) and Fuel Economy (in miles per gallon). Assume that you can describe the styling of each truck with one of the following labels -- Attractive, Muscular, Nondescript, Mediocre or Ugly.

Finally, assume that you have collected the following data on your trucks:

Table T-1

Name	Fuel Economy (mpg)	Power (hp)	Price ($)	Styling (labels)
Coyote	23	109	15,000	Muscular
Mountain Lion	21	130	17,500	Mediocre
Wolf	16	175	23,000	Nondescript

With this information you can define these measures in Logical Decisions. We will again do this in the Brainstorming view.

First we will define the price measure, which is directly under the "Best Truck" goal. Since the "New Measure" measure is in this position, we will just modify it. Here's how:

1. Double click the box for "New Measure" to get its properties dialog box.
2. Change the "Name" field from "New Measure" to "Price".
3. Click the "Scale" tab where we will define the range and units for Price.
4. Change the "Units" field from "new units" to "dollars".

Next you will define the range for the Price measure based on the range in prices for the three alternatives.

Since a less expensive truck is more desirable, the most preferred alternative from a price standpoint is the Coyote at $15,000. The least preferred alternative is the Wolf at $23,000. We will use these two extremes to define the range of the Price measure. The range will go from a most preferred level of $15,000 to a least preferred level of $23,000. Tell this to Logical Decisions:

1. Enter 15000 into the "Most Preferred Level" edit box.
2. Enter 23000 into the "Least Preferred Level" edit box.

After you have entered this data, click OK and Logical Decisions will update the Brainstorming view to show the new name "Price".

Next we will define the "Styling" measure. Here's how:

1. If the "Price" measure is not still selected, click its box.
2. Click the  Add a Measure button
3. Logical Decisions will add a new measure next to the "Price" measure.
4. Double click the new measure to display its properties dialog box.
5. Change the "Name" field to "Styling".

There is no natural scale like dollars for "Styling", so you will define the various types of styling with labels.

Labels are brief text descriptions of the possible levels of achievement for a measure. Here's how to define the labels for "Styling":

1. Click the "Labels" tab in the properties dialog box.
2. Click the "Use Labels" check box.
3. When you do this, Logical Decisions will ask you to confirm. Confirm by clicking "OK"
4. Logical Decisions will show you a default (High, Medium, Low) set of labels for styling.
5. Select the entire list of labels by dragging over it with your mouse. Overwrite the list with the following list, pressing enter between each item:

   Attractive
   Muscular
   Nondescript
   Mediocre
   Ugly

6. Click the "OK" button to confirm and return to the

Brainstorming window.

Next we will enter the measures for the performance goal:

1. Select the "Performance" goal's box by clicking it. This will ensure that the new measures will be added below it.
2. Click the Add a Measure button
3. Logical Decisions will add a new measure under the "Performance" goal.
4. Double click it to display its dialog box.
5. Change the name of the new measure to “Power”.
6. Click the “Scale” tab.
7. Change the units to “horsepower”.

The range of horsepower for the three alternatives is from 109 hp to 175 hp. Describe this range to Logical Decisions as follows:

1. Enter 175 into the “Most Preferred Level” edit box.
2. Enter 109 into the “Least Preferred Level” edit box.

Notice that -- unlike the "Price" measure -- more horsepower is preferred to less. Logical Decisions will know this since the most preferred level for "Power" is more than the least preferred level.

Finally, we will define the "Fuel Economy" measure:

1. If the "Power" measure is still highlighted, click the Add a Measure button again
2. Logical Decisions will insert a new measure next to the "Power" measure (under the "Performance" goal).
3. Double click the new measure to open its Properties dialog box.
4. Change the name of the new measure to “Fuel Economy”.
5. Click the Scale tab.
6. Change the units to “miles per gallon”.
7. Enter 23 into the “Most Preferred Level” edit box.
8. Enter 16 into the “Least Preferred Level” edit box.

When you are finished, click "OK" and Logical Decisions will update the goals hierarchy to its final form. It should look like the hierarchy in

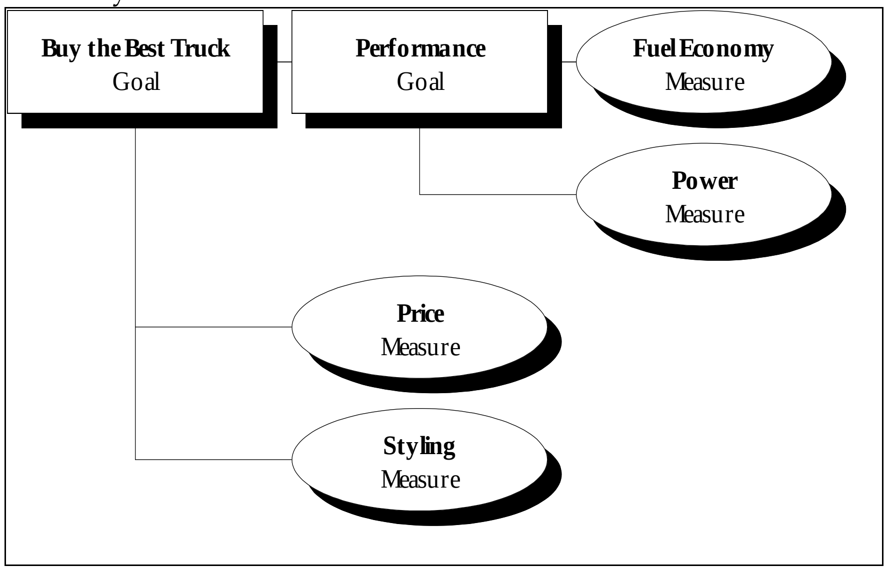


Figure 4- 2.

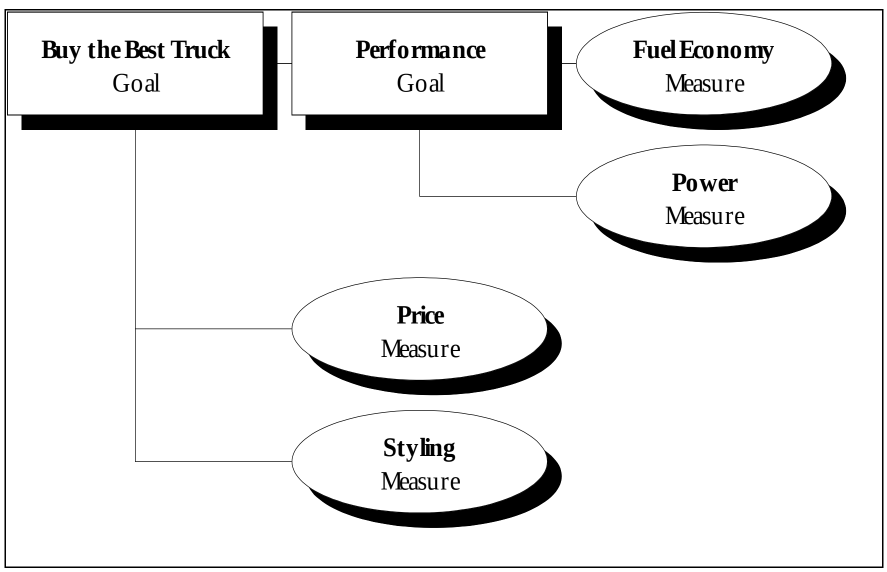


Figure 4- 2. Completed goals hierarchy for basic tutorial

Describing the alternatives in detail

Now it's time to enter the data for the alternatives. We will do this in the Matrix view. If you have closed the Matrix view window you can get a new one by selecting the View::Matrix option or clicking the Define Alternatives line in the Facilitator outline.

Next, you will enter the data in table T-1 above into the matrix. To enter a level in a cell (box for a level), just select the cell by clicking it and type in the proper number. You should tell Logical Decisions you have finished by pressing **Enter**. For the "Styling" measure, click the cell and you will see a pull down list of the available labels. Just select the label you want from the list. Your finished matrix should look like the one in Figure 4- 3.

	Fuel Economy	Power	Price	Styling
Coyote	23	109	15000	Muscular
Mountain Lion	21	130	17500	Mediocre
Wolf	16	175	23000	Nondescript

Figure 4- 3. Completed matrix for basic tutorial

This completes the measure and alternatives definitions. At this point you may want to save your analysis using the File::Save As option. The suggested name is **TUTOR.LDW**.

Defining Preferences

The alternative, goal, and measure definitions, along with the measure levels, represent the "objective" data for the decision (although we have made many subjective judgments in defining the alternatives and measures).

The next step is to characterize your *preferences* concerning various levels of the measures. This is a two-step process. First, you define preferences concerning individual measures (to convert the levels of the measures to common units). Then, you define preferences over goals — that is, weights -- to combine the measures' common units into an overall score.

Before you do this you need a place to store your preferences.

Defining a Preference Set

A preference set is where Logical Decisions stores the preference information for a single person.

You can define a new preference set using the Edit::Add or View::Select/Change Preference Sets option. But the skeleton analysis Logical Decisions creates when you start it already includes a preference set, so we'll just modify that.

You modify a preference set in its properties dialog box Here’s how:

1. Select the View::Select/Change Preference Sets option.
2. Click the “Properties” button.
3. Change the name for the preference set to "Tutorial”.

Next we will tell Logical Decisions which goals will have their own utility function (or MUF for multi-measure utility function).

Logical Decisions uses utility MUFs to combine the utilities of a goal's members into a utility (or overall score) for the goal. If you do not define a MUF for a goal, its members will be included in the next higher goal's MUF.

For the tutorial, we will define a MUF for both the "Best Truck" and "Performance" goals. You can do this in the Preference Set Properties dialog box. If you have closed it, reopen it using steps 1 and 2 above. Then:

4. Click the “Structure” tab in the Preference Set dialog box.
5. Click the "Performance" line in the box called "Goals with a

MUF". Both the "Best Truck" and "Performance" lines should be highlighted, showing that both goals will have their own MUF.

We will use the defaults for the other options in the dialog box, so click OK to close it.

Defining Preferences for Individual Measures

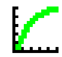
Next you will tell Logical Decisions how to convert different levels on each measure into common units (called utility). The formula to do the conversion is the measure's Single-measure Utility Function (SUF -- see page 23 for a brief discussion of SUFs).

Logical Decisions assigns the least preferred level on each measure a utility of zero (0.0) and the most preferred level a utility of one (1.0). The SUF defines how to convert intermediate levels to utility. As a default, Logical Decisions uses a straight line (linear) conversion. Intermediate levels are assigned utilities that are proportional to their distance from the endpoints, so that a graph of levels vs. utility is a straight line.

Assume that a straight line adequately models your preferences concerning Price and Fuel Economy. You could check this by using the mid-level splitting technique described on page 311.

Entering a Non-Linear SUF. Let's also assume that for Power you don't feel that a straight line SUF is right. Suppose you feel that 130 horsepower is about the right amount and that anything under about 115 horsepower is starting to get underpowered.

Using the mid-level splitting method, you find that you prefer a change from 109 to 130 hp and a change from 130 to 175 hp equally. Although the change from 175 to 130 is larger than from 130 and 109, horsepowers near 109 are starting to seem uncomfortably low, making each hp change more important in this range. This means that *130 hp is your <u>mid-preference level</u> for the* *range from 109 to 175 hp.*

To describe this to Logical Decisions, you use the 
Assess::Common Units option.:

1. Click the Assess::Common Units line in the Facilitator outline
2. Logical Decisions will display the Common Units dialog box that identifies the method used to define each measure's SUF.
3. Select "Power" from the list box at the top of the dialog box and make sure that the selected assessment method is "SUF".
4. Click the Assess button to begin the assessment process. You should see a display like the one in Figure 4- 4.

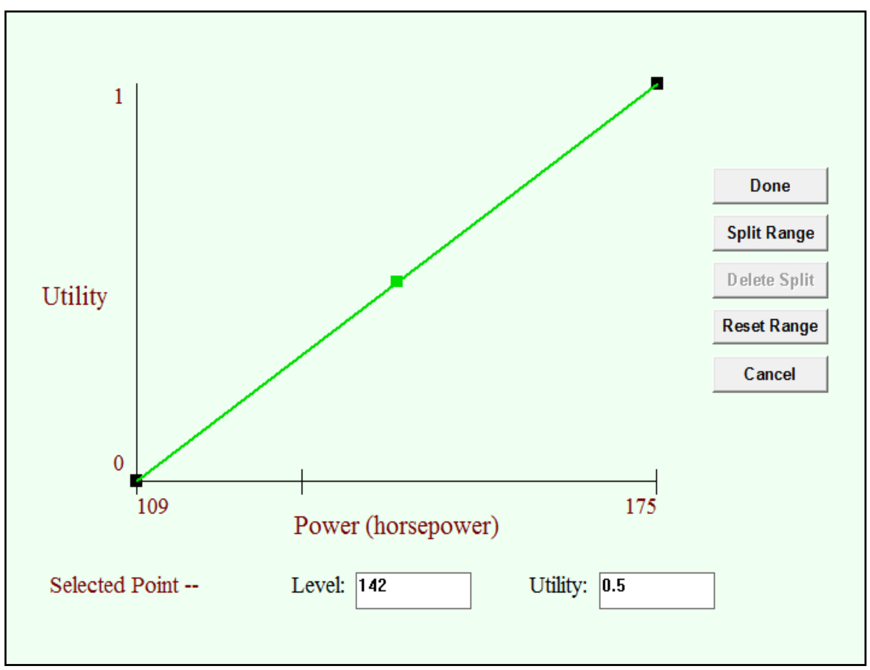


Figure 4- 4. Initial display for assessing Power SUF

Entering the Mid-Preference Level. To tell Logical

Decisions that your mid-preference level is 130 hp you will use the split range option. The split range option splits the current range (the range highlighted in green -- initially the whole range from 109 hp to 175 hp to start) into two parts. You want to split the range at the mid-preference level of 130 hp. This lets you tell Logical Decisions the utility to assign to 130 hp. It will also let you make further modifications to the SUF curve above and below 130 hp in a moment. Here's how to split the SUF:

First we will move the current mid-preference point from 142 to 130. You can see the mid-preference point as the green box in the middle of the current range.

1. Either drag the (142,0.5) point with the mouse to (130,0.5) or enter a new level in the "Level" edit box at the bottom of the window. The second way is more accurate. Just type 130 into this box and press **Enter**. The mid-preference point will move to (130,0.5) on the graph and the SUF will become a smooth curve that passes through it.
2. Next, click the "Split Range" button. Logical Decisions will split the current range in two at the mid-preference point. Logical Decisions initializes the two new sub-ranges to straight lines.

You should now see a screen similar to Figure 4- 5.

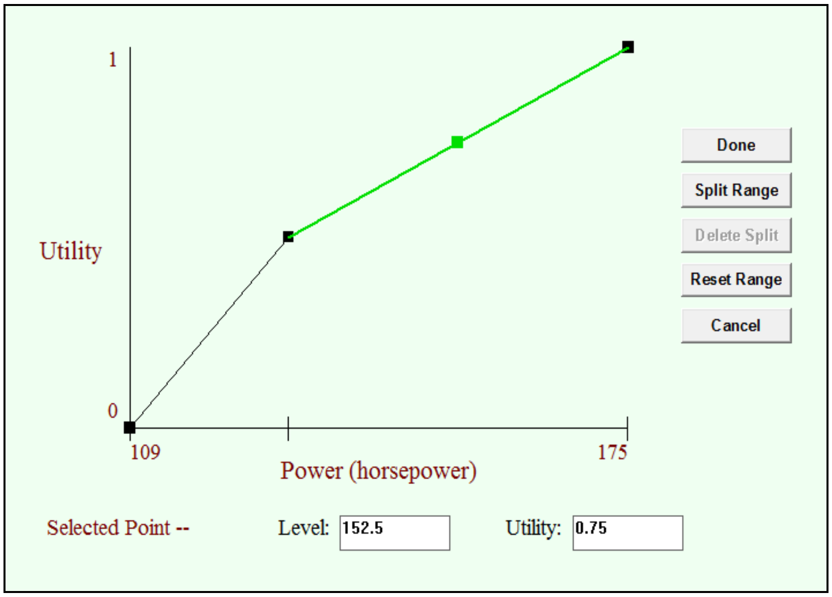


Figure 4- 5. Results after splitting range

Defining the SUF Curve for Low Power Levels.
Suppose you feel that powers between, say, 109 and 115 hp are so bad as to be almost equally unacceptable, while as power increases above 122 hp each additional horsepower really makes a difference. Suppose you again use the mid-level splitting technique and find that your mid-preference level for the range from 109 to 130 is 122 hp. We want to modify the lower SUF range to reflect this. Make the modification as follows:

1. Select the 109-130 range by clicking its line. You can also use the left arrow key to move the selection from the split point to the adjacent sub-range.
2. Set the mid-preference level by typing the number "122" in the "Level" edit box. This results in the SUF shown in **Figure 4-6**.

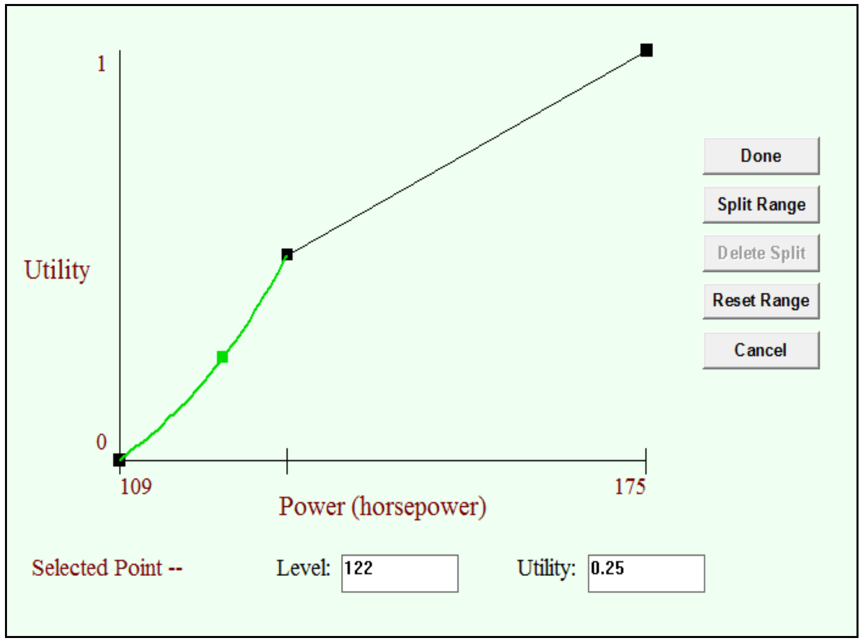


Figure 4- 6. Result of setting mid-preference level of 122 for range from 109 to 130 hp

Similarly, you can set the mid-preference level for the higher range. Assume that the mid-level splitting technique tells you that your mid-preference level is 140 for the range from 130 to 175 hp. You might get this result if you feel that there are decreasing returns for horsepowers over 130.

1. Press the left arrow key to "wrap around" and select the upper 130-175 range.
2. Set the mid-preference level for the range by typing "140" in the "Level" edit box. Don't forget to press **Enter** to update the graph.

You should get the SUF shown in Figure 4- 7. This completes the definition of the SUF for Power.

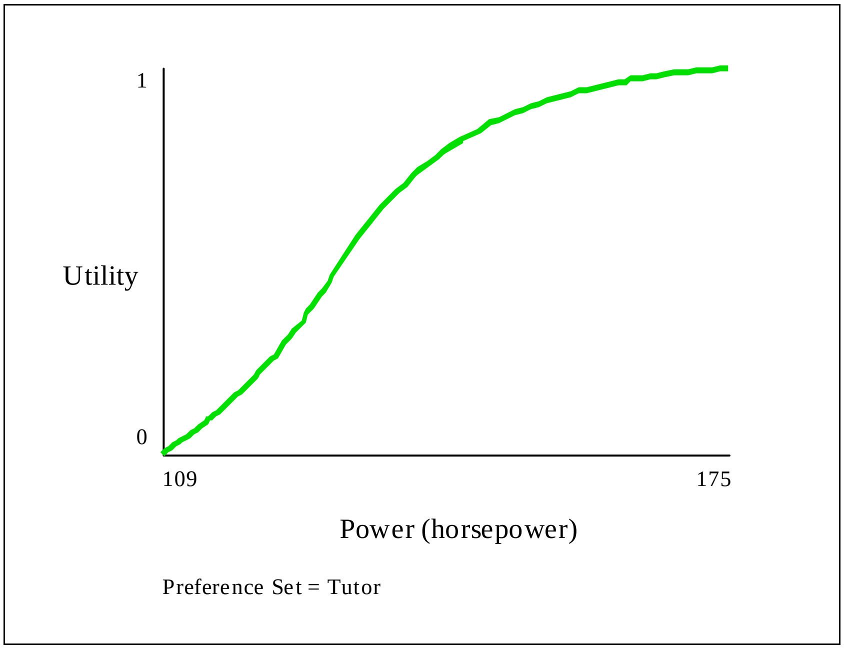


Figure 4- 7. Final SUF for Power

Assessing the SUF for a Measure With Labels. Since the "Styling" measure uses discrete labels rather than a continuous scale, we need to use a different method to convert its levels to common units. We will use the direct assessment method to directly assign a utility for each label. To do this:

1. Open the Assess::Common Units dialog box as described above
2. Select the "Styling" measure. Make sure the "direct Assessment" method has been selected
3. Click the "Assess" button.

You will see a bar graph like the one in **Figure 4-8**.

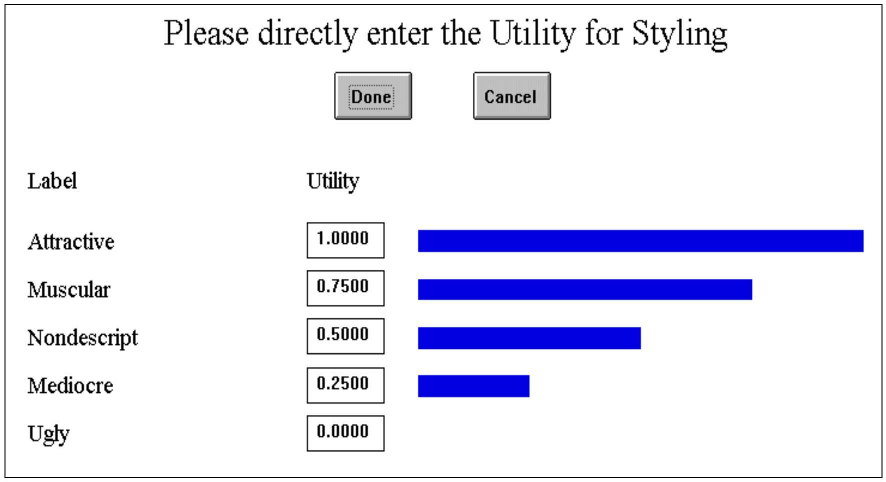


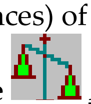
Figure 4- 8. Initial SUF assessment screen for Styling measure

In the figure, each label has a bar showing its utility. The "Attractive" label has the highest utility of 1.0, while the "Ugly" label has the lowest utility of 0.0 (no bar). The other labels have intermediate utilities. You can adjust the utility for a label by entering a new utility in its edit box or by dragging the end of a bar with your mouse. Let's change the utility of the "Mediocre" bar from 0.25 to 0.20. To do this:

1. Enter 0.2 in the edit box next to "Mediocre" and press **Enter**

We'll keep the other utilities the same. Click "Done" when you are finished.

Defining goal preferences (weights)

You have defined two goals, "Performance" and "Best Truck" in the example. Now you will define the weights (relative importances) of the members of these two goals. You will do this using the  Assess::Weights option or by clicking the Assess Weights line in the Facilitator.

You will see the weight assessment dialog box. You use this dialog box to set up the weight assessments for the goals.

We will assess weights for the "Performance" goal and then for the "Best Truck" goal.   To begin the “Performance” goal assessment:

1. In the Assess Weights dialog box, click the “Weights” tab to go to the weight assessment part of the dialog box.
2. Select "Performance" from the list of goals at the top of the dialog box.

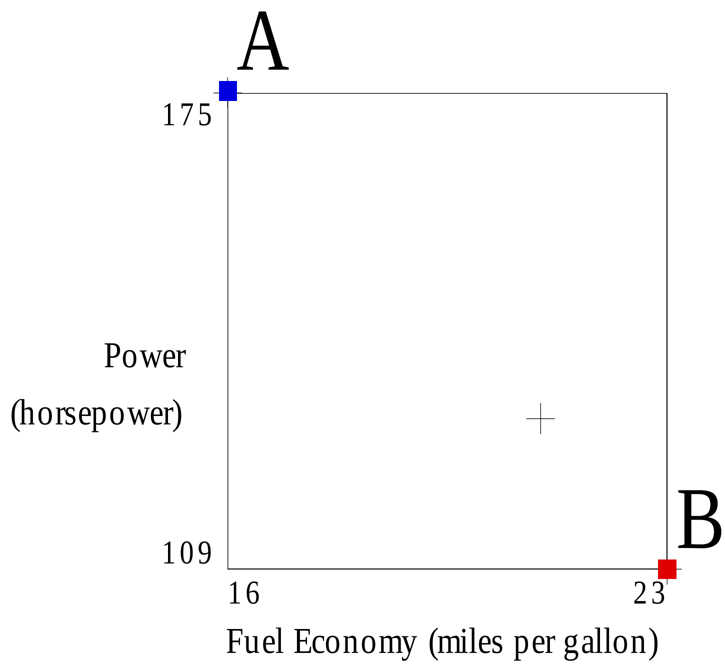
We will be using the "tradeoff" approach for weight assessments.

3.Select the ‘tradeoff” weight assessment method from the list. It should already be highlighted, but select it if it is not.
4.Click the "Assess" button to begin the tradeoff assessment
5.When you do this, you will see the tradeoff assessment dialog box.

The tradeoff assessment dialog box is where you will identify pairs of members under the "Performance" goal to use in tradeoffs.

To identify the two members for the next tradeoff, pick one from the "First Member:" list and one from the "Second Member:" list. Since the "Performance Goal" only has two members, one will always be highlighted in each list. Thus, we can go directly to the tradeoff assessment window by

1. Clicking the "Assess" button.   When you do this, the tradeoff graph shown in Figure 4- 9 appears.



	A	B	A-B
Fuel Economy (miles per gallon):	16	23	-7
Power (horsepower):	175	109	66

Figure 4- 9. Tradeoff assessment graph for Power vs. Fuel Economy

In Figure 4- 9, Logical Decisions asks you to compare two hypothetical alternatives, labeled **A** and **B**. Alternative **A** is a truck with 175 hp that gets 16 mpg. Alternative **B** has 109 hp and gets 23 mpg.

Always assume that all measures that aren't mentioned have the nominal utility defined in the goals dialog box. Specifically, you should assume that the Price measure has its most preferred level of $15,000 and the Styling measure has its most preferred level of "Attractive" for both alternatives **A** and **B**.

All you have to do is tell Logical Decisions whether you prefer **A** or **B**. Assume that you prefer **A** and **B** equally. This means that the decrease in Power for **B** compared with **A** is just compensated for by the increase in Fuel Economy.

This implies that the Power and Fuel Economy measures should have equal weights given their ranges in this example. Assume that you feel **A** and **B** are equally preferred. To let Logical Decisions know,

1. Click the "Equal" button at the right of the window.
2. Logical Decisions will connect **A** and **B** with a line of equally preferred possibilities and ask you if the proposed tradeoff is OK.
3. Click "OK" to accept the tradeoff.

This returns you to the tradeoff dialog box. You will see the tradeoff you just did listed in the "Previous Tradeoffs" box. You will also see that you don't need any new tradeoffs for the "Performance" goal.

Click the "Done" button and return to the assess weights dialog box. We are done with the weight assessments for the "Performance" goal.

Now we will do the assessments for the "Buy the Best Truck" goal:

1. Select the "Buy the Best Truck" goal from the goals list.
2. Click the "Assess" button to begin the assessment for the "Best Truck" goal.
3. Logical Decisions will again display the tradeoff assessment dialog box, but with a new list of measures and goals to select from.

The list should now contain the "Performance" goal, the "Styling" measure and the "Price" measure. The "Power" and "Fuel Economy" measures don't appear on the list because they are in the "Performance" goal. The list only contains the measures and goals that are members of the "Buy the Best Truck" goal.

First, we will assess a tradeoff between Performance and Price.

1. Select “Price” and "Performance" as the members for the first tradeoff
2. Click the "Assess" button to begin.

The next dialog box asks you to select a representative from the Performance goal for use in the tradeoff question. The representative can be *any* measure or goal under a goal in the goals hierarchy or the goal itself.

3. Select "Power" as the representative for the Performance goal.

A new tradeoff question should appear. This time alternative **B** is a hypothetical truck with a Price of $15,000 and 109 hp. Alternative **A** is a truck with 175 hp and a price of $23,000.

Here, you might feel that you prefer alternative **B**, which is $8,000 cheaper.

4. Click the "B" button to tell Logical Decisions.
5. Logical Decisions updates the screen and asks you to improve alternative **A** by reducing its price until it becomes equally preferred to alternative **B**.

You should be able to make **A** equally preferred because if you reduce **A**'s price to $15,000 it will equal the price of alternative **B**, and have 175 hp to **B**'s 109 hp. **Then you should definitely prefer A**.

You can use your mouse to move the square for **A** or you can type a new price for **A** in the edit box at the bottom of the screen. Suppose that, after looking at a few possible levels and comparing the alternatives, you decide that you would prefer **A** equally to **B** if its Price were $20,000.

6. Type **20000** and press **Enter** to select $20,000 as the price for alternative **A**.

7. Logical Decisions will draw the revised alternative **A** on the graph and will draw a line will be drawn to connect it with alternative **B**. The graph should look like Figure 4- 10.

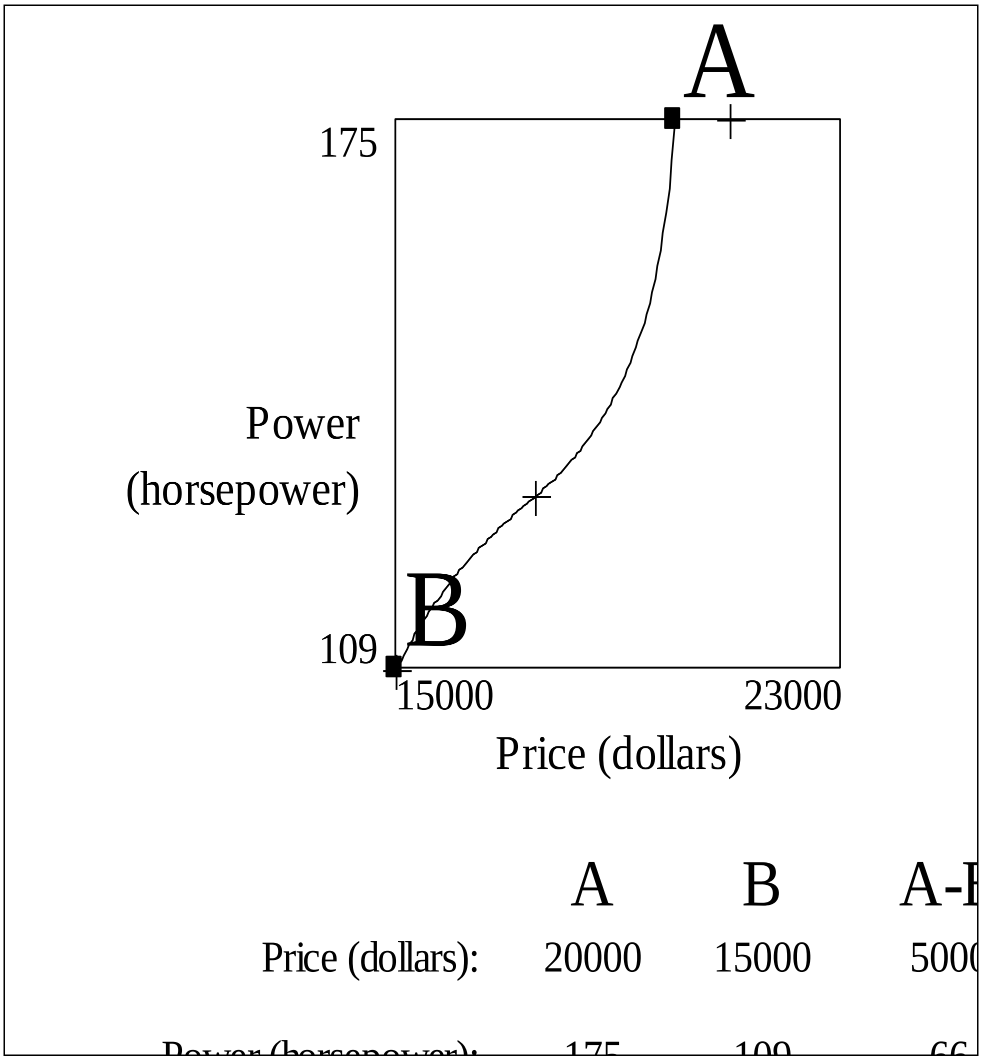


Figure 4- 10. Tradeoff between Price and Power

8. Click the "Equal" button to tell Logical Decisions that you now prefer **A** and **B** equally.

9. Logical Decisions will ask you to confirm that the tradeoff is OK
10. Click “OK” and you will return to the assess tradeoffs dialog box.

Next we will do a tradeoff between price and styling.

1. Select the "Price" and "Styling" measures in the tradeoff dialog box.
2. Click the "Assess" button.
3. Logical Decisions will generate and display a tradeoff comparing price and styling.

In the tradeoff, assume that we prefer the $15,000 "Ugly" truck (alternative **B**) to the $23,000 "Attractive" truck (alternative **A**).

4. Click the "B" button to tell Logical Decisions
5. Logical Decisions will redraw the tradeoff graph to let you lower the price on alternative **A** to make it more desirable.

Suppose that a price of $17,000 for the "Attractive" truck would make it equally preferable to the $15,000 "Ugly" truck.

6. Type **17000** in the edit box and press **Enter** to tell Logical Decisions.
7. Click the "Equal" button to tell Logical Decisions that **A** and **B** are now equal.
8. Logical Decisions will ask you to confirm that the tradeoff is OK.
9. Click “OK” and return to the assess tradeoffs dialog box.

You will see that there are no new assessments needed for the "Best Truck" goal, so

10. Click the "Done" button to return to the assess weights dialog box.

We can quickly review the weights that Logical Decisions has computed by

1. Select the Review::Tradeoff Summary Graph option.
2. Click "Price" as the "Starting Measure".
3. Select the "Color by goal" radio button.
4. Click "OK"

The display shown in Figure 4- 11 appears. In this display, each measure is shown by a circle whose size is proportional to the measure's weight. The lines connecting the circles show which pairs of measures were used in tradeoffs.

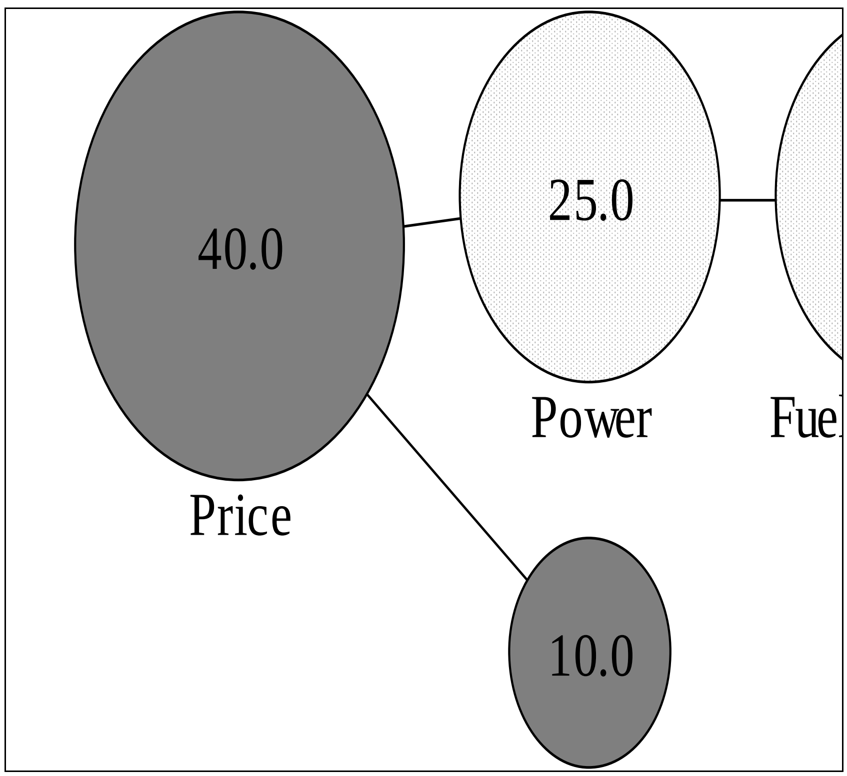


Figure 4- 11. Display generated by Review::Tradeoff Summary Graph option

You can also display the actual formulas for the goal MUFs.

1. Select the Review::Weights::MUF Formulas option.

When you select this option, Logical Decisions shows you a listing of the scaling constants for the goals and measures similar to **Figure 4- 12**. The scaling constants define how Logical Decisions will combine the utilities of the measures and goals to get an overall utility. **Figure 4- 12** shows that the overall utility is computed using a weighted average of the utilities for the "Performance" goal, the "Price" measure and the “Styling” measure, with most weight assigned to the "Performance" goal.

Scaling Constants for Preference Set Tutorial

Buy the Best Truck Goal has K = 0, defined by tradeoffs and

Performance Goal weight = 0.5000

Price Measure weight = 0.4000

Styling Measure weight = 0.1000

Performance Goal has K = 0, defined by tradeoffs and no inte

Fuel Economy Measure weight = 0.5000

Power Measure weight = 0.5000

Figure 4- 12. Table of scaling constants generated by <u>Review::Weights::Scaling Constants</u> display

Now you are ready to see the results of your analysis.

Displaying Results

The most important result of a Logical Decisions session is the ranking of the alternatives. Logical Decisions lets you rank on any measure or goal. The most important ranking is that for the “Buy the Best Truck” goal, which is the overall ranking of the alternatives.

To get an overall ranking of the alternatives:

1. Select the Results::Rank Alternatives option.
2. Select the "Buy the Best Truck" goal from the list.
3. Click “OK”

Logical Decisions computes the ranking formula and displays the ranking of the three alternatives shown in Figure 4- 13. As the figure shows, the "Coyote" ranks first followed by the "Mountain Lion" and the "Wolf".

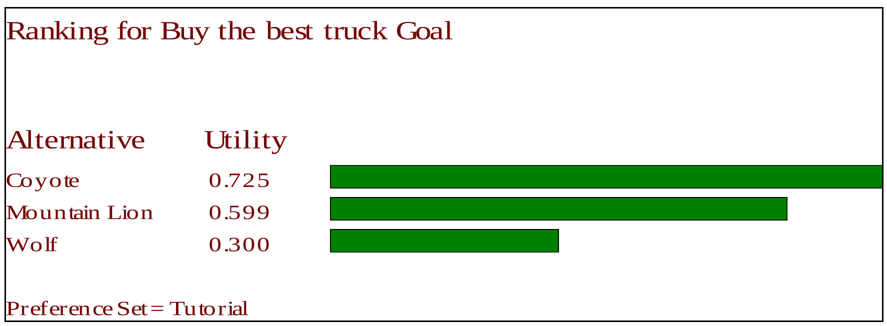


Figure 4- 13. Overall ranking for truck example

Based on this information alone, the Coyote seems to be the best choice. Logical Decisions lets you explore and understand the reasons why the Coyote ranks the highest. You can do this in a variety of ways using the different displays available from the Results Menu. Some of these options are described below.

Graph Alternatives

The Results::Graph an Alternative option lets you display a bar chart or “petal diagram” showing the utilities for an alternative on the measures and goals. You can display the graph for any goal. When you have picked the option, Logical Decisions shows you a dialog box with many options. You can display bars for the measures under the goal or for the members of the goal (which can be either measures or other goals). You also have a choice of displaying the bars in their nominal order or sorted by weight. Figure 4- 14. shows a graph for the Mountain Lion for the Best Truck goal with all measures in their nominal order. Try seeing what other bar graphs and petal diagrams look like.

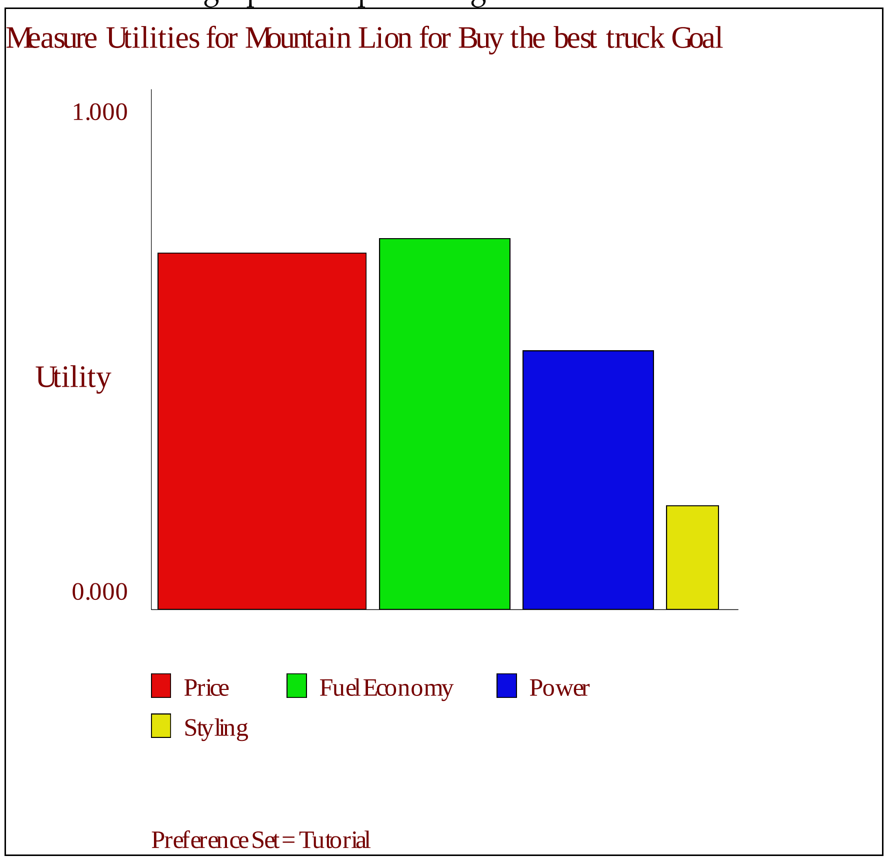


Figure 4- 14. Sample bar graph created with Results::Graph An Alternative option

A unique feature of Logical Decisions alternative graphs is that the width of the bars is proportional to the weight for the measure or goal being graphed. This makes the area of all of the bars equal to the utility of the alternative for goal you selected. Alternatives with tall wide bars are preferred.

Sensitivity Analysis

The Results::Sensitivity Graph option lets you see the effects of changing the weights for a single measure or goal

When you select the option you will first see a list of the measures and goals defined for the analysis (excluding Overall). Let's select the "Price" measure for our example. Logical Decisions will display graph like the one in Figure 4- 15.

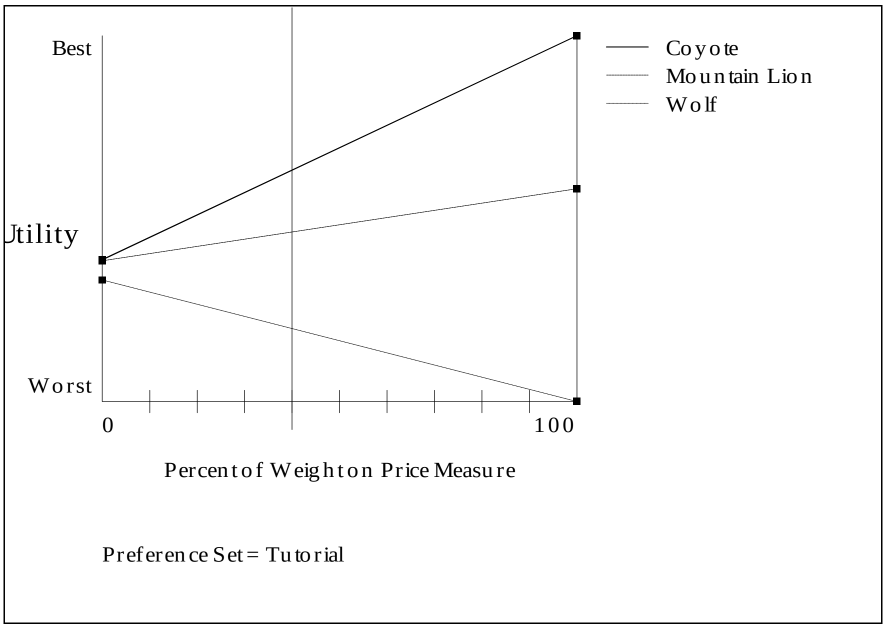


Figure 4- 15. Graph showing sensitivity to the weight for Price, created with Results:Sensitivity Graph option

The horizontal axis of this graph represents the weight on Price. This weight can range from zero to 100 percent, with zero meaning price is not considered at all and 100 percent meaning price is the only consideration. The thin vertical line is the current weight for Price. The vertical axis represents utility, and the lines represent the utilities for particular alternatives at each possible weight for price.

By examining this graph you see that if price is not considered, the three alternatives will rank very closely. This is shown by the closely spaced line ends on the left-hand side of the graph. However, as more weight is placed on price, the lowest price alternative (the Coyote) becomes more preferred. It appears that because Power and Fuel Economy tend to be inversely correlated that price becomes the primary consideration in the ranking.

Comparing Alternatives

The Results::Compare Alternatives option lets you directly compare two alternatives. You can use this option to increase your understanding of why the Mountain Lion ranked lower than the Coyote. When you select the option, Logical Decisions asks you to select from two lists of alternatives. Select the Mountain Lion and the Coyote. The graph shown in Figure 4- 16 lists the contribution of each measure to the difference in overall utility between the two alternatives.

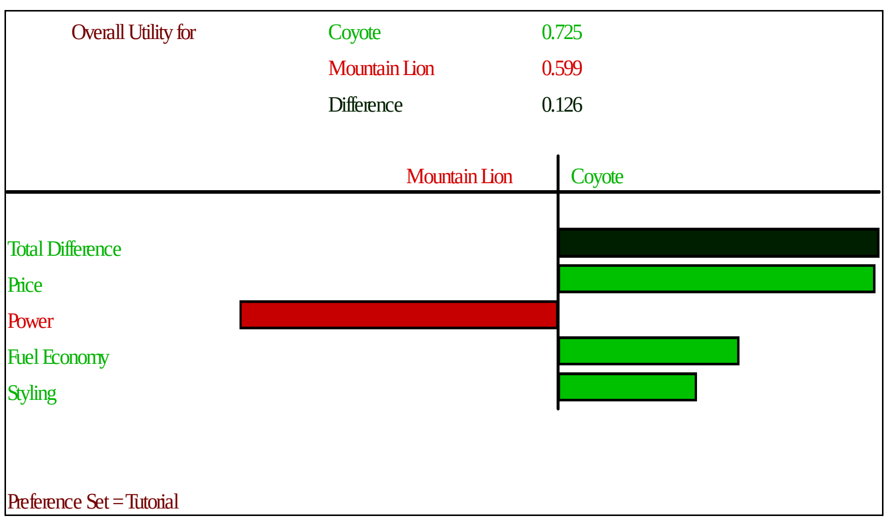


Figure 4- 16. Comparison between Coyote and Wolf generated with Results::Compare Alternatives option

The bar for each measure represents how much of the difference between the alternatives is caused by the measure. The bar lengths add up to the length of the "Total Difference" bar, which always goes to the right.

You can see the numbers that underlie this bar graph with the table option in the Results::Compare Alternatives dialog box.

Summary

This completes the introductory tutorial for Logical Decisions. You have learned how to

- define the alternatives you will rank,
- define the measures and goals that you will use to evaluate the alternatives,
- enter the data that describes the alternatives' performance on the measures,
- convert levels on the measures into common units,
- assess the weights for the measures and goals using the tradeoff method, and
- how to see the results of your analysis with the displays in the Results menu.

You can see the completed introductory tutorial in the file called TUTOR1.LDW.

Logical Decisions is a sophisticated program with many features and capabilities. You will want to experiment with the many display screens available in the Review and Results menus. You can experiment with these screens freely since none of them affects the underlying structure or preference assessments for your analysis. All of these screens are described in the "Using Logical Decisions" sections.

You will also want to experiment with the different methods for assessing preferences, including methods for converting to common units, assessing weights and assessing interactions. These are described in the "Using Logical Decisions" section and in the "In Depth" section. Interactions are also discussed in the

"Advanced Tutorial" section.

The advanced tutorial builds on the introductory tutorial with examples of using probabilities, defining measure categories, assessing interactions between measures, and importing and exporting data to other programs.

SECTION

Advanced Tutorial

5

Advanced Tutorial

This tutorial section covers some of Logical Decisions' more advanced features, including measure categories, probabilities, importing data from outside sources, and interactions.

We will work with the truck example from the Basic Tutorial. To retrieve this example, use the File::Open option to load in the file TUTOR1.LDW. To avoid overwriting this file, you should immediately use the File::Save As option to save it with the name TUTOR2.LDW.

Measure Categories

Measure categories are sub-measures you can use to combine related pieces of data into a single measure level. Measure categories are useful when you want a measure to be the weighted average or sum of several numbers. We will use categories in this tutorial to combine two fuel economy estimates into a single measure.

We will add two categories to the "Fuel Economy" measure. The categories will represent the EPA City and EPA Highway miles per gallon estimates for the truck alternatives.

When a measure has categories, its levels are computed as a weighted sum of its category levels. When you add a category for a measure, any previously defined levels for the measure will be overwritten.

Suppose we want the levels for the "Fuel Economy" measure to be the average of each truck's City and Highway mpg estimates, and suppose we have collected the following data:

Truck	Fuel Economy (mpg)	City (mpg)	Highway (mpg)
Coyote	23	19	27
Wolf	21.25	16.5	26
Mountain Lion	16.5	14	19

We will make the changes in the Matrix view:

1. Select the Matrix view or create a new one with the View::Matrix option.
2. In the Matrix view, click the cell labeled "Fuel Economy”.
3. Click the C Add a Category button.
4. Logical Decisions will create a new category for the "Fuel Economy" measure and display its properties dialog box.
5. In the dialog box, change the name for the category to "City”.
6. Change the units to "mpg".
7. Click “OK” when you are done.

You will see a column for the new "City" category to the right of the column for the "Fuel Economy" measure. The cells in a category column are shown in green. The cells in the "Fuel Economy" column will now be shown in red to indicate that you can’t change them directly.

To create the "Highway" category, click the Add a Category option again. Repeat the process you did for the "City" category, using the name "Highway" and the units "mpg". You should now see the columns for two categories to the left of the column for the "Fuel Economy" measure.

Now you will enter the levels for the new categories. Just click the cell you want and type in the number.

1. Now you should type in the City and Highway mileage numbers from the table above. As you do this, the numbers in the

Fuel Economy column will change.

There is a problem with the numbers in the Fuel Economy column. The numbers are the *sum* of the two category numbers, not the *average*.

To get the proper numbers you must change the **category multipliers**. They are the numbers at the top of the column for each category. (Did you notice that Logical Decisions added this row when you created the first category?). Logical Decisions computes the measure levels by multiplying each category level by the category's multiplier and then summing the adjusted levels.

Initially, Logical Decisions sets each new category multiplier to 1.0. To get the average of the two categories, we need to set each category's multiplier to ½ (0.5). To do this:

1. Type in 0.5 in the cell for each category multiplier.

You should now see the proper averages in the cells for the "Fuel Economy" measure.

The category multipliers are preference judgements. For example, a buyer that does 80% city driving might want to use multipliers of 0.8 for "City" and 0.2 for "Highway". For this reason, each preference set has its own set of multipliers. You could use this feature to see the effects on the overall ranking of different multipliers for the two mileage categories.

Probabilities

Logical Decisions lets you define levels as probability distributions. With this ability you can see how uncertainties in the levels might influence the desirability of the alternatives.

To see how Logical Decisions uses probabilities, we will add a new measure called “Resale Value” to the truck analysis. The units for "Resale Value" will be the percent of the original price we would be able to get if we resold the truck after five years.

Since we don't know what we will be able to get when we sell the car, we will use probability distributions as the levels for "Resale Value”.

Adding a Measure for Resale Value. First, let's add the "Resale Value" measure. Since this is a cost related measure we will associate it with the "Price" measure under a new "Cost" goal. First we will add the "Cost" goal:

1. Select the Goals Hierarchy window or create a new one with the View::Goals Hierarchy option.
2. Click the “Buy the Best Truck” box to select it.
3. Click the Add a Goal button.
4. Logical Decisions will display the Goal dialog box.
5. Change the name of the goal to "Cost”.
6. Click the “Position” tab.
7. Click the "Price" measure in the "Members" list to tell Logical Decisions to move the "Price" measure to under the "Cost" goal.
8. Click "OK" to close the goal dialog box.
9. Logical Decisions will ask you to confirm that the “Price” measure should be moved.
10. Click "OK" to confirm.

You should see the new "Cost" goal below the "Buy the Best Truck" goal in the Goals Hierarchy window.

Now we will add the "Resale Value" measure.

1. In the Goals Hierarchy view, click the "Cost" goal to select it.
2. Click the Add a Measure button and click "OK".
3. In the measure dialog box, change the name to “Resale Value”.
4. Click the “Scale” tab.

5. Change the units to "percent of original purchase price"
6. Change the Most Preferred Level to 75.
7. Change the Least Preferred Level to 45
8. Click "OK"

This information indicates that the range for "Resale Value" is from 45% to 75% percent of the original purchase price, with 75% being preferred.

Next we will assess the weight for the new measure. We'll prepare for this by adding a utility function for the "Cost" goal. We can do this in the Assess::Weights dialog box:

1. Select the  Assess::Weights option.
2. In the mini-hierarchy under the Organize/Review tab, click the "Cost" goal.
3. Click the "Has a MUF" radio button.
4. Logical Decisions will ask you to confirm that it should add a new MUF for the "Cost" goal.
5. Click "Yes".

Now you will assess the weights for the two members of the cost goal using the "Smart" method:

6. Click the "Weights" tab and make sure that the "Cost" goal is shown in the "Goal" combo box..
7. Select the "Smart method (Swing Weights)" from the "Weight Assessment Method" combo box
8. Click the "Assess" button.
9. Logical Decisions will display the Smart method assessment screen.

In the Smart assessment method, we assess **swing weights** that represent the relative importance of "swinging" a measure from its worst to its best level. For now we'll assume that the "Price" measure has a swing weight twice that of the "Resale Value" measure. To indicate this:

10. Enter 100 in the edit box for "Price”.
11. Enter 50 in the edit box for "Resale Value”. Remember to press **Enter** after you type each number.
12. Click "Done”.
13. Logical Decisions will compute weights that sum to 1.0 based on your swing weights.

You should see weights of 0.667 and 0.333 for "Price" and "Resale Value" respectively.

13. Click "OK" to return to the assess weights dialog box.
14. Click "Done" to return to the Goals Hierarchy view.

Now that we have added the "Resale Value" measure, we need to enter its levels. To do this select the Matrix view (or create a new one with the View::Matrix option). We will now add the levels for "Resale Value" as probability distributions.

Adding the Probability Distributions. First, we will add a uniform probability distribution for the “Wolf” alternative.

1. In the Matrix view, double-click the cell for the "Wolf" alternative and “Resale Value” measure.
2. Logical Decisions will display the "Define a Probabilistic Level" dialog box.

The “Define a Probabilistic Level” dialog box is where you can define probability distributions over the measure levels. There you will see radio buttons to select the type of probability distribution you will define. There are seven possibilities, one of which is the default point estimate (no uncertainty) option. We will define a uniform probability distribution for the "Wolf" truck.

3. Click the "Uniform Distribution" radio button.
4. Logical Decisions will display a dialog box where you can enter

the parameters for the uniform distribution.

A uniform distribution is defined by an upper and lower limit. Any level between the two limits is equally likely to occur. Assume that we feel that the "Resale Value" for the "Wolf" truck is equally likely to be anywhere between 60 and 70 percent.

5. Enter 70 as the "Upper Bound”.
6. Enter 60 as the "Lower Bound”.
7. Click "OK” twice to return to the Matrix view.

The cell for "Resale Value" for the "Wolf" truck should now be highlighted in red. This indicates that you can't directly modify this cell. You must make any new changes in the probability dialog box.

Next we will enter the level for the "Mountain Lion" truck. Assume we think that the resale value for this truck has a Normal distribution (bell shaped curve) with a mean of 60 percent and a standard deviation of 5 percent. To enter this distribution:

1. In the Matrix view, double-click the "Resale Value" cell for the "Mountain Lion" truck.
2. Logical Decisions will display the probability dialog box.
3. Click the "Normal Distribution" radio button.
4. Logical Decisions will display a dialog box where you enter the parameters for the Normal distribution.
5.Enter a Mean of 60.
6. Enter a Standard Deviation of 5.
7. Click "OK" twice to return to the Matrix view.

Finally, we'll define the probability distribution for the "Coyote" truck as a discrete distribution with three possible outcomes. The possibilities are:

Probability	% Resale Value
0.25	50
0.50	60
0.25	65

To enter this distribution:

1. In the Matrix view, double-click the "Resale Value" cell for the "Coyote" truck.
2. Click the "Discrete Distribution" radio button.
3. Logical Decisions will display a data entry dialog box for the discrete distribution.
4. Enter 3 in the "Number of Levels" edit box to tell Logical Decisions there will be three possible discrete levels. Don't Press **Enter**.
5. Enter the levels and their probabilities. Enter 0.25 in the "Prob 1" edit box and 50 in the "Level 1" to define the first level-probability combination.
6. Enter 0.5 in the "Prob. 2" edit box, 60 in the "Level 2" edit box.
7. Enter 0.25 in the "Prob 3" edit box, and 65 in the "Level 3" edit box to complete the definition of the distribution.
8. Click "OK" twice to return to the Matrix view.

Probabilities for Measures with Labels. You can also define probability distributions for measures that use labels. However, since continuous distributions are inappropriate, you are restricted to a discrete distribution over the different labels. To see how this works, let's define a probability distribution over "Styling" for the "Mountain Lion" truck:

1. In the Matrix view, click the "Styling" cell for the "Mountain Lion" truck.
2. Select the  Matrix::Define Probability option.
3. Logical Decisions will display the "Define Label Probabilities" dialog box.

On the left is a list of the possible labels. On the right are edit boxes and sliders showing the probability of the labels. To define the probability distribution:

4. Move through the list and enter the following probability for each label:

Label	Probability
Attractive	0.0
Muscular	0.0
Nondescript	0.25
Mediocre	0.50
Ugly	0.25

5. Click "OK" to return to the Matrix view.

The cell will be highlighted in red to show it has a probability distribution. The label with the highest probability is shown in the cell. If you want to convert from a probability distribution back to a single label, enter a probability of 1.0 for one of the labels and 0.0 for the others.

Now might be a good time to save your analysis. Use the  File::Save option.

Results Displays for Probabilities

Several results displays are available to see how probabilities affect your results. The results are computed using **Monte Carlo Simulation**. Monte Carlo simulation uses random numbers to estimate possible outcomes for the probabilistic levels. The utilities of these possible outcomes are computed and saved. After this has been done many times, Logical Decisions can use the saved results as an estimate of the cumulative probability over the utility or level of interest.

The default number of simulation trials is 100. You can change this with the Preferences::Simulation Options option.

You can see the simulation results in the  Results::Rank Alternatives option:

1. Select the option.
2. Choose the "Best Truck Goal" from the list.
3. Click the "Show Uncertainties" check box.
4. Un-click the “Show Stacked Bars” check box.
5. Click “OK”.

You will see a display like the one in Figure 5- 1.

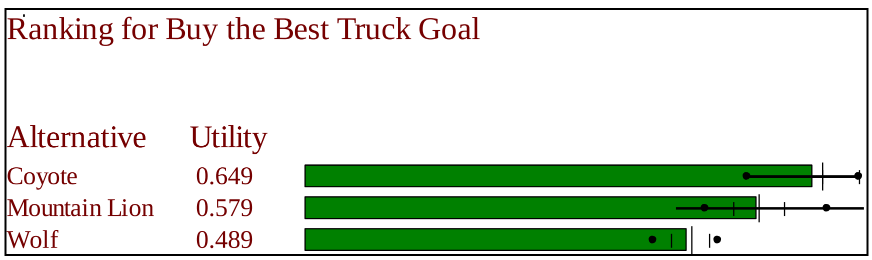


Figure 5- 1. Results::Rank Alternatives display showing uncertainty ranges

In the figure, the horizontal bars represent the range of uncertainty for each alternative, based on the Monte Carlo simulation. The dots are the 5% and 95% levels, the short vertical bars are the 25% and 75% levels and the long vertical bar is the 50% level. From this you can see that for certain outcomes the "Mountain Lion" could rank higher than the "Coyote", but that the "Wolf" ranks lower under all scenarios.

To see more details about the uncertainties, use the Results::Uncertainty Summary option.

1. Select the option.
2. Choose the "Best Truck Goal" from the list.

3. Click “OK”.

You will see a table like the one in Figure 5- 2.

Utility uncertainty summary for Buy the best truck Goal

Alternative	Mean	Std. Dev.	Median	Min.	5%P	95%P	Max.
Coyote	0.650	0.033	0.654	0.593	0.593	0.685	0.685
Mountain Lion	0.562	0.034	0.565	0.493	0.508	0.619	0.641
Wolf	0.311	0.018	0.313	0.279	0.281	0.335	0.340

Figure 5- 2. Example of Results::Uncertainty Summary display

The figure presents statistics summarizing the probability over the selected member for each alternative.

The Results::Alternative Uncertainty Graph option provides a graphical summary of the uncertainty for a single alternative over a selected member.

1. Select the option.
2. Choose the "Mountain Lion" alternative.
3. Choose the "Buy the Best Truck" goal to evaluate.
4. Select the defaults for the other choices by clicking "OK".

When you do this, Logical Decisions will display a graph like the one in **Figure 5-3**.

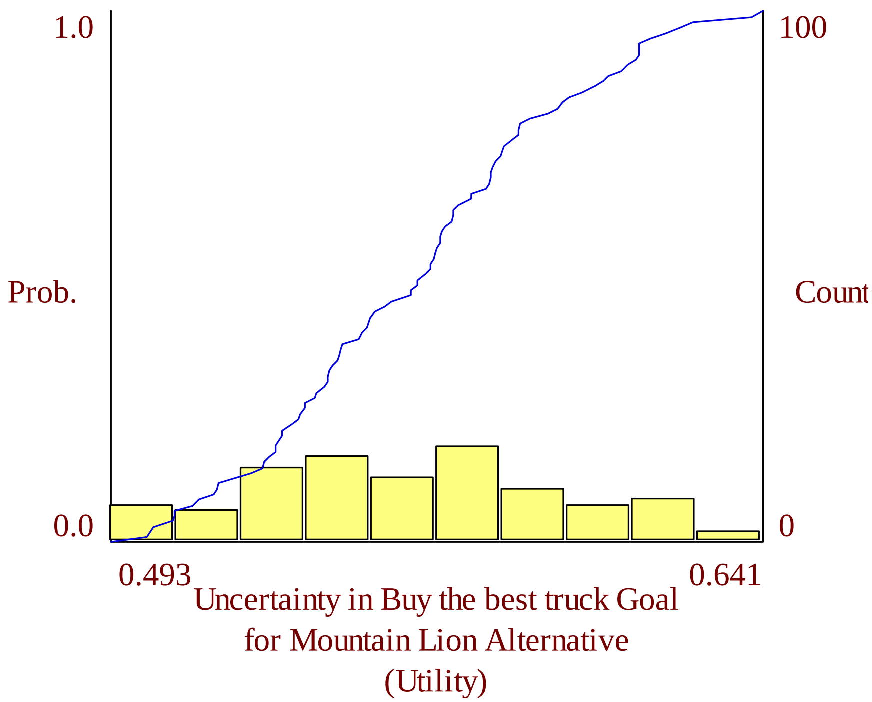


Figure 5- 3. Example of <u>Results::Alternative Uncertainty Graph</u> option

In the figure, the bars represent the number of simulation trials that fell within the bar's range. The bars use the scale at the right of the graph.

The line in the figure represents the cumulative probability distribution, as estimated by the simulation results. Each point on the line represents the probability (the scale at the left of the graph) that the utility will be less than the utility on the x-axis of the graph.

Note that this graph combines the effects of the uncertainties for the "Mountain Lion" truck on both the "Resale Value" and "Styling" measures on the "Mountain Lion's" overall utility.

Importing and Exporting Data

Logical Decisions provides powerful features for importing and exporting data from external databases. These features can let you quickly screen a large database for the alternatives that are most likely to meet your needs.

We will show how you could use a data file to update the truck example we have been developing. If you have skipped any steps in the tutorial, you should use the File::Open option to load in the file TUTOR2.LDW now.

We will update the analysis from the file TUTOR.TAB. The contents of this file are shown in Figure 5- 4.

```
ALTERNATIVES
NAME          NUMBER NUMBER NUMBER       NUMBER NUMBER NUMBER       LABEL
NAME          Price  Power  Fuel Economy City  Highway Resale Value Styling
Crocodile      21000  140   16.5         15     18      45            Laughable
Mountain Lion 19000   109   21.25        16.5   26      65            Mediocre
Tiger         18000  125    21           18     24      75            Mediocre
Falcon        27000  160    17.5         16     19      66.3          Attractive
Coyote        22000  109    23           19     27      55            Muscular
Wolf          17500  175    15.5         14     17      65           Nondescript
```

Figure 5- 4. The tutor.tab file

The tab delimited file in the figure has some special clues that help Logical Decisions interpret it. The word "ALTERNATIVES" in the upper left tells Logical Decisions that this is a file it knows how to interpret. The next line (with NAME, NUMBER, etc.) tells Logical Decisions the type of data to expect in each column. The next row has the names of the data columns. Notice that the names can correspond to either measures or measure categories. The names of the alternatives are on the left of the matrix.

The easiest way to create a file that Logical Decisions can read is to first use the File::Export option to create a file of the type you want, and then modify it to include the data you want to import.

Setting Cutoffs. Notice also in the figure that the current alternatives ("Coyote", "Mountain Lion" and "Wolf") have their current levels (but with no uncertainties). Note also that the "Falcon" has a price ($27,000) that is above the least preferred level, and that the "Crocodile" has a label for "Styling" -- "Laughable" -- that is not on the list. Let's assume that these alternatives are unacceptable and we don't want to add them to the analysis.

For measures with labels, Logical Decisions assumes that any label not on the list fails the cutoff for the measure. For other measures, we must explicitly assign an upper and lower cutoff. To set a cutoff for "Price:"

1. Double click the cell for "Price" in the Matrix or Goals Hierarchy view to view its dialog box.
2. Click the "Scale" tab.
3. Enter 25000 in the "Upper Cutoff Level" edit box to set the cutoff for "Price" at $25,000.
4. Click "OK".

Importing the Data. Now we will import the data from the text file:

1. Select the File::Import option.
2. Logical Decisions will display a dialog box called "Import Options".
3. In the dialog box, select the "Tab Delimited" Import File Format and click the "Add new alternatives" radio button. Click "Next" when you are done.
4. Logical Decisions will display the standard "Open File" dialog box.
5. Select TUTOR.TAB and click "Next".
6. Logical Decisions will display a screen called "Select Measures to Update". This is where you match database fields to measures and categories.
7. Scroll through each line in the "Measures" list to make sure each measure and category has an asterisk next to it. This indicates that it will be updated. If a measure or category does not have an

asterisk, select it by clicking it and then click the field with the same name in the "Database Fields" list. An asterisk should appear beside the name in each list.
8. When each item has an asterisk, click “Next" to go on. Note that you only have to do this once. Logical Decisions will remember the fields you used to do the updating for the next time.
9. Logical Decisions will show you the update and append options.
10. We don’t want to append new alternatives whose names match the existing alternatives, so uncheck that box.
11. We do want to "Apply Cutoffs", so check that box. Logical Decisions will not add an alternative that fails any of the cutoffs.
12. We want to append all the acceptable alternatives in the file, so keep the big number in the “Maximum number of alternatives to append” edit box. If you enter a number less than the number of records in the file (say 10), Logical Decisions will rank each alternative as it reads it and will only append the top 10 ranking alternatives.

When you click "OK", Logical Decisions will scan the database and append any records that pass all the cutoffs.

If you next look at the Matrix view, you will see that only one new alternative has been appended -- the "Tiger". The "Coyote", "Mountain Lion" and "Wolf" records were not appended because their names matched existing alternatives.

The "Falcon" alternative was not appended because its price of $27,000 was above the upper cutoff of $25,000. The "Crocodile" alternative was not appended because its styling label -- "Laughable" -- was not on the list of acceptable labels.

Defining Interactions Between Goal Members

The final (optional) step in the preference assessment process is to define the interactions between the members of the goals. This is probably the most unfamiliar part of the process and the most difficult to explain. Fortunately, in most situations interactions are not needed and the default weighted average is the appropriate way to combine an alternative's utilities on the measures. See page 336.

Suppose you have a feeling that there is some interaction between the members of the Performance goal. Specifically, you want it all -- both high power and good fuel economy. In other words, if a truck does poorly on “Power” or “Fuel Economy”, you feel it should have a low “Performance” utility no matter how well the truck does on the other measure.

In addition, you prefer a truck that does moderately well on both measures to a truck that does very well on one measure and poorly on the other. This is called "destructive interaction”.

To quantify this idea you must answer another preference assessment question. We need to define the utility we should assign to the extreme points where an alternative has the best level on Horsepower and the worst level on Fuel Economy and vice versa.

To do this we can draw the following matrix:

		Fuel Economy (mpg)	
		16 (worst: U = 0)	23 (best: U = 1)
Power (hp)	175 (best: U = 1)	**?**	1.0
	109 (worst: U = 0)	0.0	**?**

In the matrix there are four potential alternatives – both Power and Fuel Economy at their worst levels (lower left cell), both at their best levels (upper right cell) and two alternatives with one measure at its worst and the other at its best. We want to define a two measure utility function for the Performance goal that gives an appropriate result for each possibility.

By definition, we want the lower left alternative to have a utility of 0.0, since it is the worst on both measures. Similarly, we want the upper right alternative to have a utility of 1.0. The question is what level is correct for the other possibilities, where an alternative is best on one measure and worst on the other. There is no objectively correct answer to this question, so we must use our best judgment.

Suppose we feel that an alternative that has the best Fuel Economy and the worst Power should get have a Performance utility of 0.3 and that an alternative that has the best Power and the worst Fuel Economy should have a Performance utility of 0.4. We can update the matrix above as follows:

		Fuel Economy (mpg)	
		16 (worst: U = 0)	23 (best: U = 1)
Power (hp)	175 (best: U = 1)	**0.4**	1.0
	109 (worst: U = 0)	0.0	**0.3**

There is no weighted average formula that can result in the utilities in the cells. However, there is an alternate function, called a multiplicative utility function, we can use:

$$U(a) = w_1 U_1(a_1) + w_2 U_2(a_2) + K w_1 w_2 U_1(a_1) U_2(a_2)$$

Where U(a) is the Performance utility of alternative a, w_i are weights, K is an additional scaling constant and $U_i(a_i)$ are the individual measure value functions. We will talk more about the multiplicative value function in Section 9,but for now notice that if we substitute 1 for $U_1(a_1)$ and 0 for $U_2(a_2)$ and 0.4 for U(a) -- the values from the upper left cell -- that the equation gives us 0.4 = w_1. Similarly, substituting from the lower right cell gives us 0.3 = w_2.

This means that in the multiplicative utility function, the weights are equal to the values in the upper left and lower right cells of the matrix. Logical Decisions can solve for the scaling constant K, which equals 2.5 in this case.

To enter this information into Logical Decisions, we can use the Set All Weights multiplicative MUF assessment method. We do this as follows:

1. Select the Assess::Weights option.
2. Logical Decisions will display the assess weights dialog box.
3. Click the "Interactions" tab.
4. Select the "Performance" goal from the "Goal" combo box.

The several ways to define interactions are listed in the "Interactions Assessment Method" combo box. We want the Set All Weights option.

5. Select the Set All Weights method for defining interactions from the combo box.
6. Click the "Assess" button to begin the assessment process.

You will see the same data entry window as for the "Directly Enter Weights" weight assessment option, except that in this case the weights will not be adjusted.

7. Enter the weights from the matrix – 0.4 for Power and 0.3 for Fuel Economy.
8. Click "Done"

You can see the new scaling constants for performance by selecting the Review::Weights::MUF Formulas option. In the table, you will see that the big K for performance is 2.5. Since the scaling constant big K is greater than zero, destructive interaction is indicated. This is also shown by the fact that the individual weights (small **k**s) for the members of the Performance goal (the Power and Fuel Economy measures) do not sum to one as they do for the members of the Best Truck goal, which has neutral interaction.

If we now use the Results::Rank Alternatives option to see the ranking of the alternatives on the "Buy the Best Truck" goal, we see that the rankings for all the alternatives have gone down slightly.

The "Coyote's" ranking goes from 0.649 to 0.609, the "Mountain Lion's" ranking goes from 0.579 to 0.548, and the "Wolf's" ranking goes from 0.489 to 0.457. Thus the addition of interactions seems to have had a somewhat larger negative effect on the "Coyote" alternative than on the others.

This ends the Advanced Tutorial.

SECTION

Using Logical Decisions 1: Structuring

6

Using Logical Decisions 1: Structuring

Introduction

The next three sections describe how to use Logical Decisions (Logical Decisions) by providing detailed instructions on the three main steps in a Logical Decisions analysis:

- Structuring the analysis,
- Assessing preferences, and
- Reviewing results.

This section describes the Logical Decisions options related to structuring the analysis. The next sections describe options for assessing preferences and reviewing results. You should read the Quick Start section before these sections.

Structuring a Logical Decisions Analysis

You structure a Logical Decisions analysis by defining the alternatives you will rank, the measures you will use to describe the alternatives, and the goals you will use to group the measures. Its best to finish structuring your analysis before you begin the preference assessment step. However, since this is not always possible, Logical Decisions lets you make structural changes any time with only a minimum loss of preference data
.
This section includes descriptions of the editing options available for structuring your analysis and of the views where the structuring takes place. Then there is a discussion of the

information you need and how you structure each of the objects that make up a Logical Decisions analysis.

Editing Options for Structuring Your Analysis

The Edit menu options are the tools you will need to structure your analysis. They let you add, delete, or modify the various objects that make up a Logical Decisions analysis. These options are briefly discussed here and are discussed in more detail in the sections for the different views below.

The Edit::Insert option. The Insert option adds a new Logical Decisions object with the default settings.

If you use the Insert option in the Goals Hierarchy view Logical Decisions will ask you if it should insert a new goal or a new measure, since this is not clear from the context. In the Matrix view, Logical Decisions asks if you would like to insert a measure or a measure category. Logical Decisions always shows you the new object's dialog box so you can make changes after inserting.

The Edit::Add option. The Add option lets you add a new object to your analysis no matter which window, if any, is active. When you select the option, you will see a dialog box with a list of the different types of items you can add. You can add a new measure, goal, alternative, preference set or measure category. Just click the radio button for the object you want and click "OK”.

Logical Decisions will usually ask you if you want to copy the new object from an existing object. If you say "Yes”, you will pick the object to copy from a list. Otherwise, a new object with the default settings will be added.

The Add a... buttons. The Logical Decisions toolbar contains buttons that add specific objects. You can add alternatives, goals, measures and measure categories using these buttons. These buttons are all available in the View::Brainstorming view. The add a measure and goal buttons are available in the View::Goals Hierarchy view. The add a measure, measure category and alternative buttons are available in the View::Matrix view.

The Edit::Cut option. The Cut option lets you delete the object you have selected but save it for later pasting into the analysis.

If you cut a goal, Logical Decisions also cuts all of the goals and measures below it and saves them for pasting.

The Edit::Copy option. The Copy option lets you save the object you have selected for later pasting into the analysis without deleting it.

If you copy a goal, Logical Decisions also copies all of the goals and measures below it and saves them for pasting.

The Edit::Paste option. The Paste option lets you retrieve an object you've saved using the Cut or Copy option.

If you paste a goal, Logical Decisions also pastes all of the goals and measures below it.

The Edit::Delete option. You can use the Delete option to delete an object you have selected in a view window. Logical Decisions will not save the object you delete for later pasting, and will ask you to confirm before the deletion takes place.

Logical Decisions does not delete the members of a goal you delete, but makes them members of the next higher goal in the hierarchy.

If the active window is not a view window, the Delete option becomes the opposite of the Add option. Then you can delete any of the objects in your analysis. When you select the option, you will see a dialog box with a list of the different types of items you can delete. You can delete a measure, goal, alternative, preference set or measure category. Just click the radio button for the object you want and click OK. You will pick the object to delete from a list.

The Edit::Modify option. The Modify option lets you view the dialog box for any existing object in your analysis no matter which window, if any, is active. When you select the option, you will see a dialog box with a list of the different types of items you can modify. You can modify a measure, goal, alternative, preference set or measure category. Just click the radio button for the object you want and click OK. You will pick the object to modify from a list.

The Edit::Undo option. The Undo option lets you undo many actions you have taken in Logical Decisions.

Views for structuring your analysis

You develop the structure for a Logical Decisions analysis in the windows you can create in the View menu. Logical Decisions automatically displays the two most important windows -- the Goals Hierarchy view and the Matrix view when you start it or when you load in a new Logical Decisions file. You can create as many copies of these windows as you want. This can be useful for viewing several different parts of a complicated analysis all at once. The following options are available in the View menu:

- **Facilitator** – A window that guides you through the Logical Decisions process and provides help at each step.

- **Summary** -- view a dialog box that summarizes your entire analysis.

- **Goals Hierarchy** -- create a window showing the hierarchy of goals and objectives for your analysis.

● **Matrix** -- create a window showing the alternatives, measures and measure levels for your analysis.

● **Brainstorming** -- create a window showing the alternatives, goals, measures and measure categories for your analysis in a tree structure for quick modifications.

● **Select/Change Preference Sets** -- view a dialog box where you can select the active preference set. You can also add and delete preference sets and view their properties in this dialog box.

Next we will discuss these options in more detail.

The Facilitator View

The Facilitator view guides you through the entire Logical Decisions analysis process, while providing help along the way. The Facilitator view is active when you start Logical Decisions, but you can toggle it off and on using the View::Facilitator option. The Facilitator view has two primary areas – the outline tree at the top and the help window at the bottom. You navigate the Facilitator view by clicking an entry in the outline. When you click an entry, Logical Decisions opens the summary help screen for that entry in the help window and also opens the Logical Decisions views and/or dialog boxes that are associated with that entry, while closing any other open windows. Thus the Facilitator provides a quick way to navigate through Logical Decisions' many views and options. Here is a summary of the Facilitators outline tree and the windows it opens:

Structure – opens the Brainstorming, Goals Hierarchy and Matrix views

Name the analysis – opens the summary dialog box
Brainstorming – opens the Brainstorming view
Define goals – opens the Brainstorming and Goals Hierarchy views

Define measures – opens the Brainstorming, Matrix and Goals Hierarchy views

Define alternatives – opens the Brainstorming and Matrix views

Assess – opens the Goals Hierarchy view with the "Show Assessment Status" option enabled

Assess Common Units – opens the Assess Common Units dialog box

Assess Weights – opens the Assess Weights dialog box

Preference Sets – opens the View/Select Preference Sets dialog box

Results – does not open any windows

Rank Alternatives – opens the Results::Rank Alternatives window

Compare Alternatives – opens the Results::Compare Alternatives window

Sensitivity – opens the Results::Dynamuc Sensitivity window

Logical Decisions for Groups – describes options available in the Logical Decisions for Groups version

Logical Decisions Portfolio – Describes options available in the Logical Decisions Portfolio version.

The next sub-sections describe Logical Decisions' structuring windows in more detail.

The Summary View

When you select the View::Summary option Logical Decisions will display the dialog box shown in Figure 6- 1.

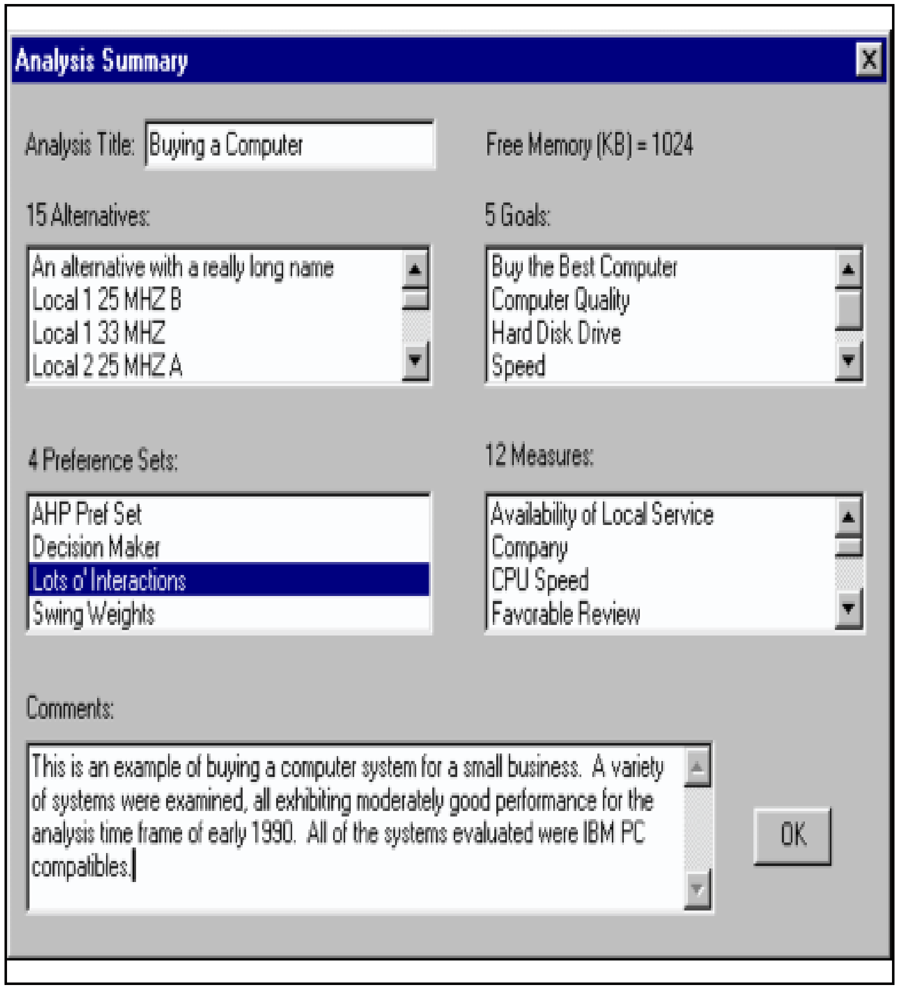


Figure 6- 1. Dialog box for <u>View::Summary</u> option

This dialog box summarizes the objects in your analysis and lets you add a title and comments to your analysis.

The four list boxes in the summary dialog box display the four object types that make up a Logical Decisions analysis -- alternatives, measures, goals, and preference sets. You can view the properties of any of these objects by double clicking its name. You can also select the active preference set by clicking its name in the list of preference sets.

You can also view the summary dialog box by clicking the upper-left corner cell in the Matrix view.

The Brainstorming View

The Brainstorming view is designed to let you quickly structure your analysis without worrying about details such as measure scales and levels. The Brainstorming view has two parts. The left side is a tree structure like those seen in the Windows Explorer Folders option. The right side is an unstructured area where you can freely enter ideas. You select the Brainstorming view with the View::Brainstorming option. Logical Decisions displays a window like the one shown in Figure 6- 2**.**

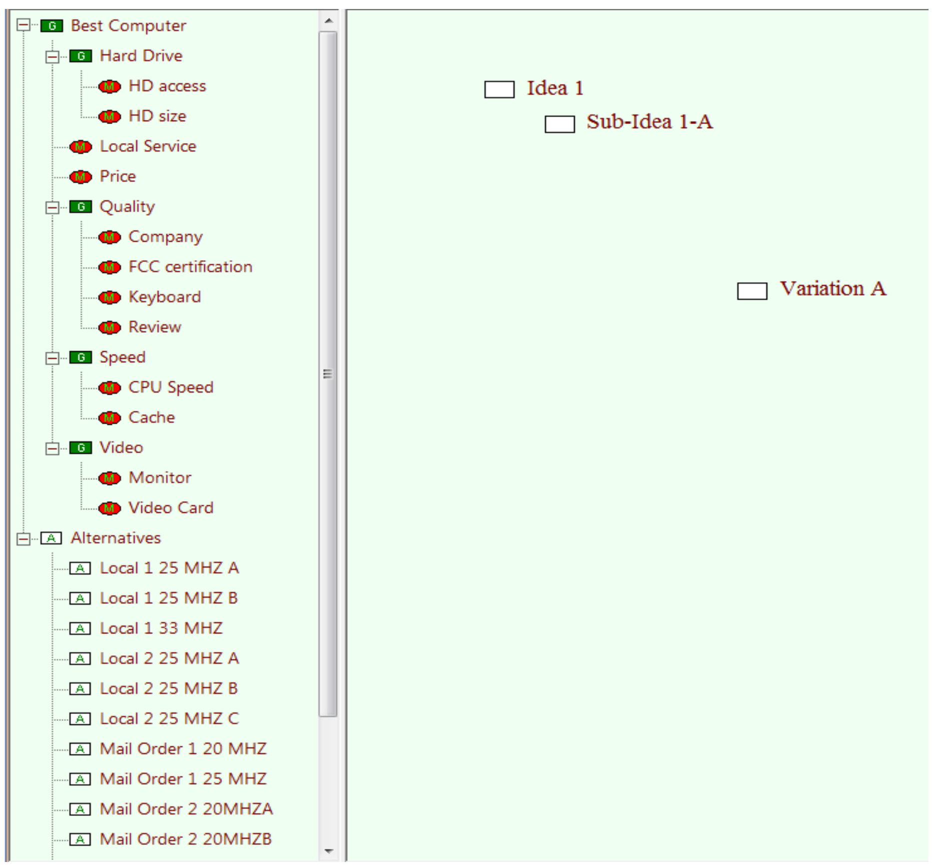


Figure 6- 2. Example of Brainstorming view

The left side of the Brainstorming view shows the alternatives, goals, measures and measure categories as leafs in a tree. The right side of the view shows unclassified ideas called "Items".

You select an object by clicking it. If you click again you can edit the object's name, ID number or both, depending on the setting of the Preferences::Name Preferences option.

If you double click a leaf of the left hand tree you can see the object's properties dialog box.

Moving and converting objects. You can move goal, measure and measure category leafs by dragging and dropping them where you want them to go. That can be another spot on the tree or on the freeform right hand side of the view. If you move an object from the left to the right hand side, the object will lose its previous identity and any associated information and will become a simple text tag.

You can also drag items from the right to left hand side of the view. The item will be promoted measure if it is dragged to the goals hierarchy part of the tree and will be converted to an alternative if it is dragged to the alternatives list part of the tree.

Adding or deleting objects. On the left hand side of the view you can use the Edit::Cut, Edit::Copy and Edit::Paste and the options as usual. The Add a Goal, Add an Alternative, Add a Measure and Add a Measure Category options are all available. You can delete the active object with the Edit::Delete option.

The confirmations that are required in other views are not activated in the Brainstorming view.

On the right hand side of the view, the only option is to Add an Item. Items are undifferentiated ideas that you can place anywhere on the right hand side of the Brainstorming view. The idea is that you will enter items quickly and then organize and consolidate them and drag them to the more structured left hand side when you know how they will fit in your analysis.

The Goals Hierarchy View

The Goals Hierarchy view is where you can organize the goals, measures and measure categories for your analysis into a structure like an organization chart. The goals hierarchy lets you see how the measures and goals relate to one another and to the overall objectives of your decision.

There is only one goals hierarchy for an analysis, but Logical Decisions provides many options for customizing how you display it.

The Goals Hierarchy view is structured like an organization chart, with goals shown as rectangles, measures shown as ellipses and measure categories shown as rounded rectangles.

You can create a new goals hierarchy window by selecting the View::Goals Hierarchy option. When you do this you will see the dialog box shown in Figure 6- 3. This dialog box lets you customize the appearance and functions of the goals hierarchy window.

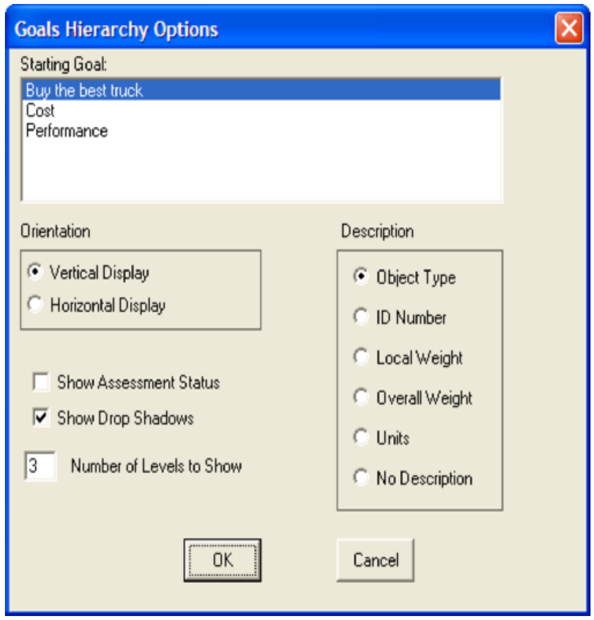


Figure 6- 3. Dialog box for View::Goals Hierarchy option

The list at the left of the dialog box controls the highest level goal shown in the display. Normally you will want to have the "Overall" goal at the top, since this lets you view your entire goals hierarchy. If you select another goal, Logical Decisions will show only the part of the hierarchy underneath that goal.

The radio buttons below the goals list control how the goals hierarchy is drawn. The default is a **Vertical Display**. Logical Decisions shows the highest level goal at the upper left and shows the members of each goal in a column to the right of it. Figure 6- 4 shows a goals hierarchy displayed vertically. The other option is a **Horizontal Display**. Logical Decisions puts the highest level goal at the top center of the hierarchy and puts the members of each goal in a horizontal line below it. Figure 6- 5 shows a goals hierarchy displayed horizontally.

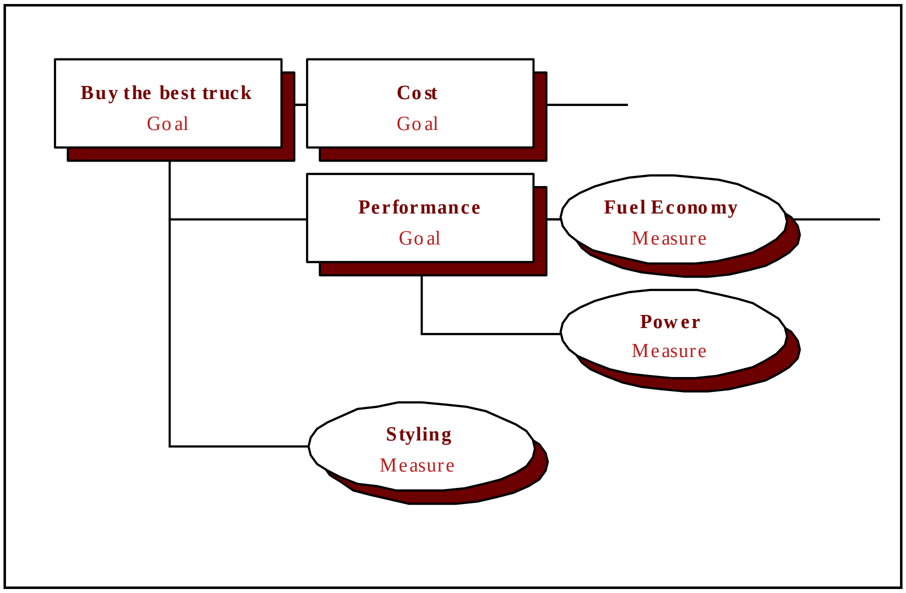


Figure 6- 4. Goals hierarchy view with vertical orientation

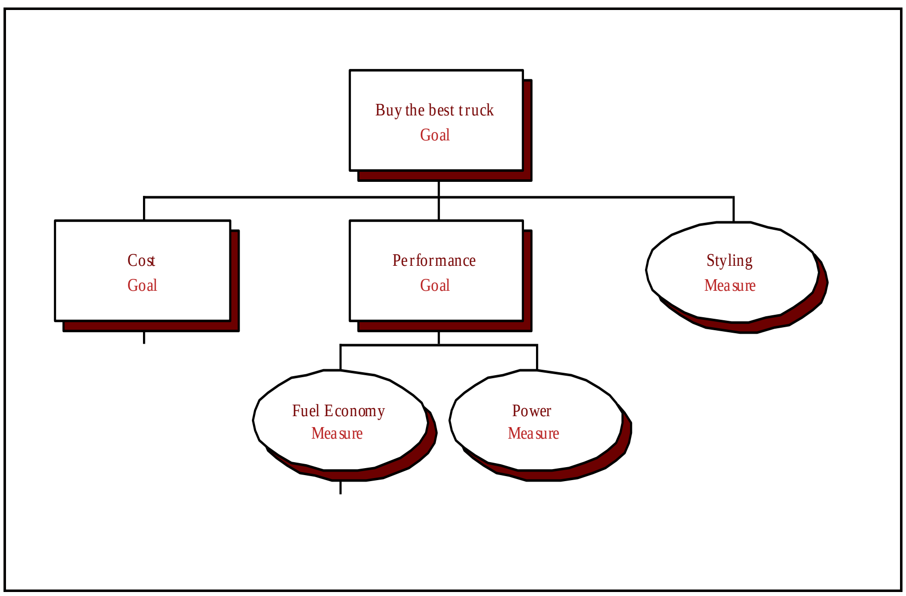


Figure 6- 5. Goals hierarchy view with vertical orientation

If you check the **Show Assessment Status** box, Logical Decisions will color the goals hierarchy to indicate whether you have completed the preference assessment process for each goal and measure. Measures and goals with completed assessments are shown in blue. Those with uncompleted assessments are shown in red. Goals that don't have their own utility function are shown in gray.

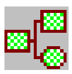
If you check the **Show Drop Shadows** box, Logical Decisions will draw the goals hierarchy with the black rectangles that highlight each goal and measure, otherwise Logical Decisions will not draw the rectangles.

The **Number of levels to show** edit box lets you specify how deep to draw the hierarchy. The default is to show the whole hierarchy. The figures above were drawn showing three levels.

The buttons in the lower right of the dialog box determine the description for each goal and measure.

● The default **Object Type** button causes Logical Decisions to show the type of each object (goal, measure, measure category) below its name.
● The **Local Weight** button causes Logical Decisions to display each member's weight in the utility function it belongs to. If there are interactions between a goal's members the multiplicative utility function scaling constants are shown. These may not sum to 1.0.
● The **Global Weight** button causes Logical Decisions to display each member's weight as a fraction of the total weight. The multiplier for each measure category is displayed instead of a weight. For goals with multiplicative value functions, the multiplicative scaling constants are adjusted to sum to 1.0.
● The **Units** button causes Logical Decisions to display the units for each member.
● The **No Description** button causes Logical Decisions to display the member names with no further description.

The Hierarchy Menu. The Hierarchy menu item appears in the main menu bar when you select the Goals Hierarchy view as the active window. The Hierarchy menu has the following options (many of which correspond to options in the Goals Hierarchy dialog box):

● Horizontal Display -- redraw the hierarchy in horizontal orientation,
● Vertical Display -- redraw the hierarchy in vertical orientation,
● Show Shadows -- toggle the display of drop shadows in the hierarchy,
● Show Assessment Status -- redraw the hierarchy and color it to show the status of the preference assessments -- blue for completed, red for not completed and gray for no assessment necessary.
●  Expand -- Toggle whether goals, measures and measure categories below the active object are shown,
● Description — this sub-menu determines what to display beneath the name for each member.

    Type of Object -- show the type of each object
    Local Weights -- show the weight for each object in the MUF it belongs to
    Global Weights -- show the weight for each object as a fraction of the overall weight
    Units — show the units for each object
    No Description — show nothing below each object

● Promote/Demote — Promote or demote the currently selected object. Goals can be demoted to measures, measures can be promoted to goals and measure categories can be promoted to measures
● Has a MUF -- Toggles whether the selected goal has a utility function. The utility function will include any goals and measures not already in a lower level utility function.

Right click menus. When you right click an object in the goals hierarchy, Logical Decisions will display a menu with options appropriate to that object.

Active member. When you click an object in the goals hierarchy, it becomes active and is highlighted in green. Actions you perform subsequently will apply to the active object.

You can delete the active measure or goal with the Edit::Cut or Edit::Delete option. The cut option deletes the active member but saves it for later pasting. When you cut a goal, Logical Decisions also cuts all of the members below it in the hierarchy.

The Edit::Delete option deletes the member without saving a copy. When you delete a goal with the Edit::Delete option its members are not deleted. Instead, they become members of the next higher goal in the hierarchy.

The Edit::Copy option lets you copy the active member for later pasting without deleting it.

The active goal or measure also determines where Logical Decisions positions new members in the goals hierarchy. Logical Decisions puts new members below the active goal (that is, they become members of the active goal). Logical Decisions puts new members next to the active measure (they become members of the same goal as the active measure).

You can add a new measure or goal with the Add a Goal and Add a Measure options.

The Matrix View

The Matrix view is where you can add and delete alternatives, measures, and measure categories and where you can define the levels for the alternatives on the measures and categories. When you select the View::Matrix option, Logical Decisions will create a display like the one from the tutorial in Figure 6- 6.

	Fuel Economy	City Mileage	Highway Mileage	Power	Price	Resale Value	Styling
Category Multipliers		0.5	0.5				
Coyote	23	19	27	109	9000	58.75	Muscular
Mountain Lion	21.25	16.5	26	130	11000	65	Mediocre
Tiger	21	18	24	125	15000	75	Mediocre
Wolf	16.5	14	19	175	15000	60	Nondescript

Figure 6- 6. Example of View::Matrix display

The matrix has four different types of cells -- measure/category cells (along the top of the matrix), alternative cells (on the left side of the matrix), level cells (in the center of the matrix), and the upper left corner cell. Double clicking the upper left corner cell displays the View::Summary dialog box.

Measure, measure category and alternative cells.

Clicking a cell at the top or left of the matrix prepares you to modify, delete or cut the object. The Edit::Delete option deletes the active object without saving it. Logical Decisions asks you to confirm before the deletion takes place. The Edit::Cut option also deletes the active object, but Logical Decisions saves a copy for later pasting. The Edit::Copy option saves a copy of the object without deleting it.

You can insert a new object into the matrix with the Add a Measure, Add a Category, or Add an Alternative option. When you select one of these options, Logical Decisions adds the object and shows its properties dialog box. If you add a new measure or measure category, Logical Decisions sets its levels for the alternatives to its least preferred level. If you add an alternative, Logical Decisions sets its levels on the measures to their least preferred levels.

You can view an object's properties dialog box by double clicking its cell.

Level cells. Since each alternative must have a level on each measure, Logical Decisions does not allow you to insert or delete levels. However, you can use the Edit::Copy and Edit::Paste options to copy levels from one cell to another. If you double click a level cell, you will see the probability dialog box, where you can define probabilistic measure levels and add comments. See the discussion starting on page 113 for complete information on how to define measure levels.

Logical Decisions also marks certain level cells to show special situations. Cells with probabilistic levels or levels defined by measure categories have a red background. You can't modify these levels by just typing in a number. You must make all modifications using the probability dialog box or by modifying the levels of the measure's categories. Level cells for measure categories have a green background.

Category Multiplier cells. When Logical Decisions shows measure categories, it adds one more row to the matrix. The additional row shows the category multipliers. These multipliers are the basis of the weighted sum of the categories that makes up the measure levels for the alternatives. For example, in the tutorial, Logical Decisions computes the level of 23 for the "Coyote" alternative as 0.5*(19) + 0.5*(27), the sum of the multipliers times the category levels.

You can modify a category multiplier by clicking it and typing in the number you want. There is no requirement that the multipliers sum to one.

You can create a new Matrix view by selecting the View::Matrix option. When you select this option, you are shown the dialog box in **Figure 6-6**.

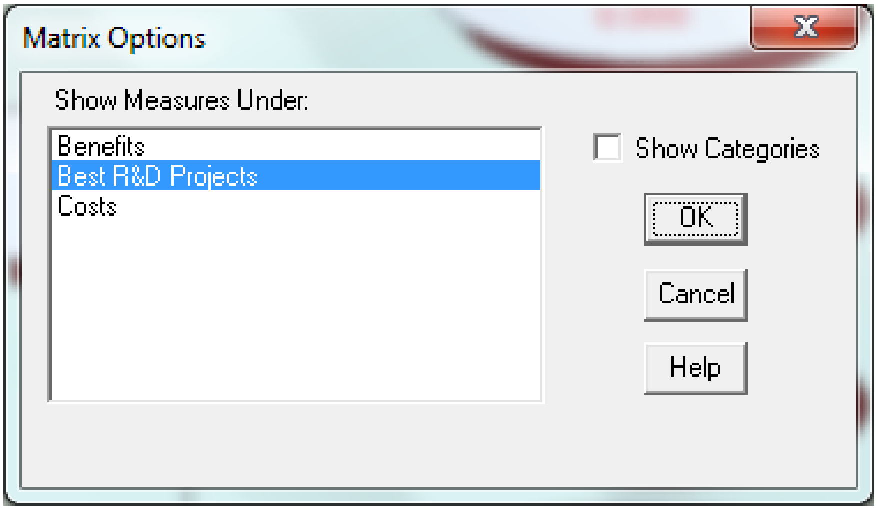
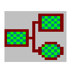
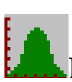


Figure 6- 7. View::Matrix option dialog box

The goal you select from the list at the left of the dialog box determines which measures will be shown in the matrix. Only those measures below the selected goal in the goals hierarchy will be shown. When you check the box labeled "Show Categories", Logical Decisions will display the columns for the measure categories associated with the measures in the matrix. If you don't check the box, the measure category columns will be hidden. You will be able to view them later by selecting the Matrix::Show Measure Categories option.

The Matrix Menu. When you have selected the matrix view as the active window, Logical Decisions will display the Matrix menu item in the menu bar. It has the following options:

-  **Show/Hide Measure Categories** -- this option is only available when you have selected a measure that has one or more measure categories When the option is on, Logical Decisions displays the columns for the measure's categories in the matrix.

- **Define Probability** -- this option is only available when you have selected a level cell in the matrix view. When you select it, Logical Decisions will display the "Define a Probabilistic Level" dialog box, where you can define a probability distribution for the active level. You can also get to this dialog box by double clicking a level cell.

Structuring Alternatives

The alternatives in a Logical Decisions analysis are the choices that you are evaluating. You describe the alternatives in terms of their levels on the evaluation measures, but you also must name each alternative. You can also add comments and an ID number if you want.

You enter the measure levels that describe an alternative in the Matrix view. See the discussion on the Matrix view on page 111 and the discussion on measure levels on page 113 for the details on how to do this.

You can view or modify the other information about an alternative in its properties dialog box.   You can view an alternative's properties dialog box by double clicking its box in the Brainstorming view, its cell in the Matrix view, its line in the Summary dialog box, or by selecting Properties from the right click menu. Figure 6- 8 is an example of an alternative properties dialog box.

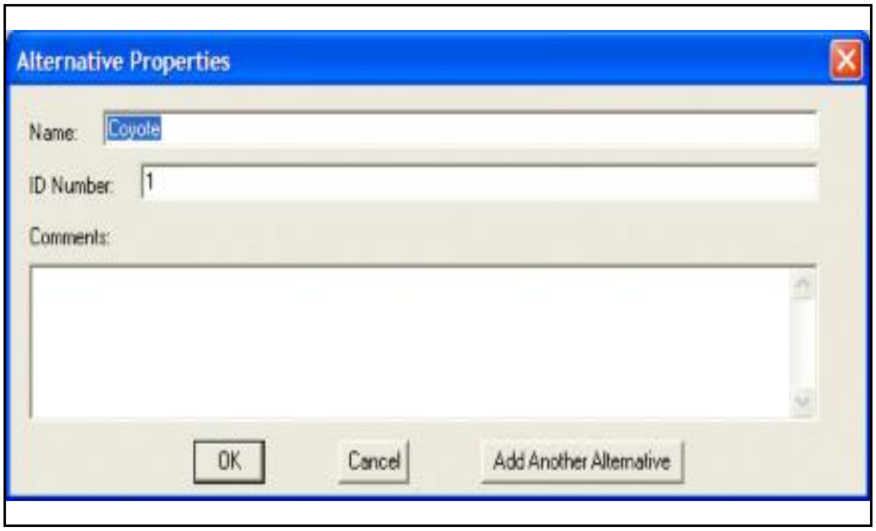


Figure 6- 8. Example alternative properties dialog box

In the dialog box, the "Name" field in the upper left corner defines how to describe the alternative in various lists and tables. The "ID Number" field allows an alternate description or code for the alternative. You can use the Preferences::Names option to control how Logical Decisions uses these two fields to describe the alternatives. The comments field at the bottom of the dialog box lets you provide a more detailed description of your alternative.

Adding an Alternative. You can add an alternative at any time using the Edit::Add option. Just select the "Alternative" button and click OK. Logical Decisions will give you the option of copying an existing alternative or adding a new default alternative. You can also add alternatives in the Matrix or Brainstorming view with the Add an Alternative option. If you have previously saved an alternative using the Edit::Cut or Edit::Copy option you can retrieve it with the Edit::Paste option. Finally, you can click the "Add Another Alternative".

Deleting an Alternative. You can delete an alternative at any time by selecting it and using the Edit::Delete option. Logical Decisions will ask you to confirm before it deletes the alternative in the Matrix view.

Structuring Goals

The goals in a Logical Decisions analysis are the concerns or objectives that are affected by selecting an alternative. You describe the goals in terms of the measures and sub-goals that are their members, but you also must name each goal. You can also add comments and an ID number.

You define a goal's members in the Goals Hierarchy or Brainstorming view. The members of a goal are those measures and other goals that are directly under the goal in the hierarchy. You can use the options in the Edit menu to add, delete or modify the members of a goal. Each measure and goal is a member of exactly one goal, except the "Overall" goal, which defines the top of the goals hierarchy.

You can view or modify the other information about a goal in its goal properties dialog box. You can view a goal's properties box by double clicking its box in the Goals Hierarchy or Brainstorming view, double clicking its line in the Summary dialog box, or with the Edit::Modify option.

In the dialog box, the "Name" field defines how Logical Decisions refers to the goal in various lists and tables. The "ID Number" field allows an alternate description or code for the goal. You can use the Preferences::Change Names option to control how Logical Decisions uses these two fields to describe each goal. The comments field at the bottom of the dialog box lets you provide a more detailed description of your goal.

Logical Decisions needs the "Nominal Utility" field when using representatives for the goal in assessing weights. It is the utility that Logical Decisions assigns to the other members (besides the representative) when computing the goal's weight from the weight of the representative. You should leave the nominal utility at one unless you are a very advanced Logical Decisions user.

The options under the "Position" tab control where the goal is located in the goals hierarchy. The "Goal Above" combo box identifies the goal directly above the active goal in the goals hierarchy. You can change the selection in this box to move the active goal beneath any other goal in the hierarchy. If you do this, Logical Decisions also moves all of the members of the selected goal. Logical Decisions asks you to confirm this change when you close the dialog box.

The "Members" list is a list of all the measures and goals in the analysis. The measures and goals highlighted in the list are the members of the selected goal. You can add a member to the goal by clicking an un-highlighted measure or goal to make it a member. You can delete a member from the goal by clicking it to unhighlight it. Logical Decisions asks you to confirm all changes in the goal's member list when you close the dialog box. Some changes create loops in the hierarchy and aren't allowed.

Adding a Goal. You can add a goal at any time using the Edit::Add option. Just select the "Goal" button and click OK. You can also use the 

Add a Goal option in the Goals Hierarchy or Brainstorming view. To do this you must first select an existing goal or measure to tell Logical Decisions where to add the new goal. If you have previously saved a goal using the Edit::Cut or Edit::Copy option you can retrieve it with the Edit::Paste option. New goals are added below the active goal or below the goal the active measure belongs to in the hierarchy.

Deleting a Goal. You can delete a goal at any time using the  Edit::Delete option. The deleted goal's members will become members of the next higher goal in the hierarchy. You can also delete a goal by clicking it and then selecting the Edit::Cut option. The Cut option saves a copy of the goal and its members for later pasting.

Structuring Evaluation Measures

The measures in a Logical Decisions analysis are the variables that describe an alternative and are also the lowest level objectives of the analysis. You describe the alternatives to Logical Decisions by their levels on the measures. You define a measure by its scale, units and range, but you also must name each measure. You can also add comments and an ID number if you want.

You can view or modify the information about a measure in its properties dialog box. You can view a measure's properties dialog box by double clicking its box in the Goals Hierarchy view, Matrix view, or Brainstorming view, double clicking its line in the Summary dialog box, or with the Edit::Modify option.

In the dialog box, the "Name" field defines how Logical Decisions describes the measure in various lists and tables. The "ID Number" field allows an alternate description or code for the measure. You can use the Preferences::Change Names option to control how Logical Decisions uses these two fields to describe each measure. The comments field at the bottom of the dialog box lets you provide a more detailed description of your measure.

The "Goal Above" combo box identifies the goal directly above the active measure in the goals hierarchy. You can change the selection in this box to move the active measure beneath any other goal in the hierarchy. Logical Decisions asks you to confirm this change when you close the dialog box.

Defining a measure's scale. The items under the “Scale” tab describe the scale associated with the measure.

The "Units" box is a text description of the scale of your measure. Logical Decisions shows the units in many assessment and results displays.

The "Most Preferred Level" and "Least Preferred Level" boxes are where you tell Logical Decisions the range for the measure. Logical Decisions uses the range in converting the measure's levels to common units and in some methods for computing the measure's weight.

A measure's scale is "increasing" if the most preferred level in the range is higher than the least preferred level and is "decreasing" otherwise. If levels in the middle of the range are more preferred (or less preferred) than the levels at the ends of the range, you will describe this to Logical Decisions in the Assess::Common Units option and you can define either end of the range as the most preferred level in the measure dialog box.

To help you define the measure's range, Logical Decisions displays the current levels for the most and least preferred alternative for the measure.

The item labeled "Number of Categories", just tells you how many measure categories are associated with this measure.

Cutoffs. The "Upper Cutoff Level" box lets you define a level above which an alternative is unacceptable. Similarly, the "Lower Cutoff Level" box lets you define a level below which an alternative is unacceptable. These cutoffs do not affect any of Logical Decisions' calculations. Logical Decisions simply marks measures failing one or more cutoffs in the Results::Rank Alternatives and other options. You can also get a summary of the alternatives failing cutoffs by selecting the Results::Cutoff Summary option.

Labels. The items under the "Labels" tab let you define a scale based on text descriptions rather than numbers.

When you check the "Use Labels" box, Logical Decisions first asks you to confirm and then defines a default set of text labels ("High", "Medium", and "Low") for the measure. It is also necessary for Logical Decisions to delete any measure categories associated with the measure and to delete any probabilistic levels. Logical

Decisions sets the level for all alternatives to "High".

If you uncheck the "Use Labels" box, Logical Decisions will delete the labels and assign numeric levels for the measure. The initial level will be 1.0 for all alternatives. The “Use Labels” check box appears under both the “Scale” and “Labels” tabs.

The list box under the “Labels” tab lets you define the labels for your measure. Figure 6- 9 shows this part of the measure dialog box.

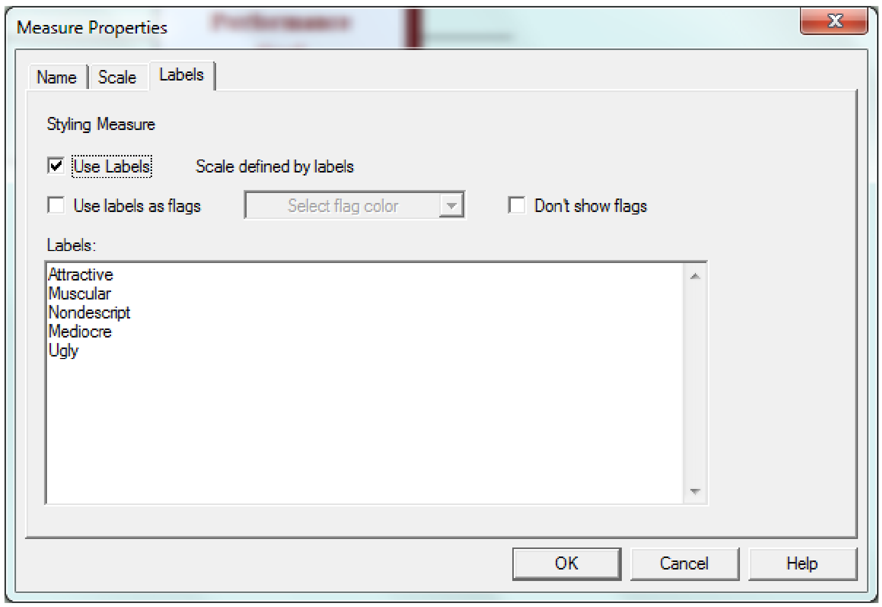


Figure 6- 9. Define labels tab of measure properties dialog box

At the bottom is the current list of labels. To modify the list, just edit it, making sure that each label is on a separate line.

Using labels as flags

Logical Decisions lets you highlight alternatives based on their label for a measure. These highlights are called Flags. You define flags in the Labels tab of the measure properties dialog box and then can view them using the Results::Rank Alternatives display. See page 225.

To use labels as flags, you first check the “Use labels as flags” box. You can then associate colors with different labels by first clicking the label and then using the “Select flag color” color picker. Only those labels that you select a color for will be flagged in the Rank Alternatives display.

You can keep your color definitions, but temporarily disable displaying the flags for the measure by checking the “Don’t show flags” box.
Figure 6- 10 shows how flags appear in the Results::Rank Alternatives display. Each measure with flags has a column labeled F1, F2, etc. A key at the bottom of the display identified the measure and label associated with each flag. You control whether to show flags with the “Show flags” check box in the Results::Rank Alternatives dialog box.

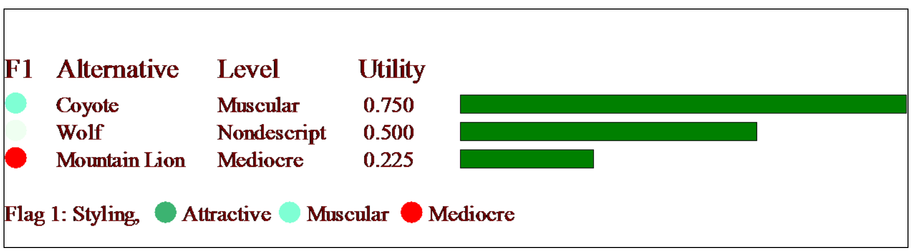


Figure 6- 10. Example of flags in Results::Rank Alternatives display

Adding and Deleting Measures

Adding a Measure. You can add a measure at any time using the Edit::Add option. Just select the "Measure" button and click OK. You can also add measures in the Goals Hierarchy, Brainstorming or Matrix view with the Add a Measure option. If you have previously saved a measure using the Edit::Cut or Edit::Copy option you can retrieve it with the Edit::Paste option. In the Goals Hierarchy and Brainstorming views, new measures are added below the active goal or below the goal the active measure belongs to in the hierarchy. In the Matrix view, new measures are added to the left of the selected measure as members of the "Overall" goal.

Deleting a Measure. You can delete the active measure in a view window using the  Edit::Delete or Edit::Cut option. The Cut option saves a copy of the measure. The Delete option does not save a copy and requires confirmation before it deletes the measure.

Structuring Measure Levels

A measure level describes an alternative's performance on a measure. Each alternative has one level for each measure or measure category. Thus, Logical Decisions does not let you add or delete measure levels, only change them. You set measure levels in the Matrix view. Each cell in the matrix defines the level for the measure at the top of the column and the alternative at the start of the row for the cell.

Types of Measure Levels. Most measure levels are "point estimates". That is, they are single numbers with no uncertainty. However, Logical Decisions lets you define several other types of levels. "Probabilistic levels" are levels with uncertainty. You describe the uncertainty by defining a probability distribution for the level.

Measures that have measure categories have their levels defined by a weighted sum of the category levels.

Measures that use labels describe levels with brief textual descriptions (such as "High", Medium" or "Low").

You can define all types of levels in the Matrix view.

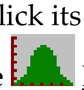
Levels and AHP or Balance Beam. If you are planning to use the Analytic Hierarchy Process or the Balance beam method to convert a measure to common units, you don't need to worry about levels, since Logical Decisions does not use the levels for the measure when doing the conversion. In AHP and Balance Beam you directly compare the alternatives. The Balance Beam common units assessment method has an option to convert the assessed scores to measure levels.

Defining "Point Estimate" Levels. Point estimate levels are easy to define. Just select the level you want to define and type in the number. Remember to confirm that you have finished by pressing the **Enter** key or the **Up-Arrow** or **Down-Arrow** key. There are no restrictions on the numbers you can enter as measure levels.

In particular, *the levels you enter do not need to be within the measure's range as defined in its properties dialog box*. Just be aware that Logical Decisions will convert levels outside a measure's range to common units (utilities) greater than one or less than zero.

There are many options available for defining probabilistic measure levels, so they are discussed in the next section.

Probabilistic Measure Levels

You define probabilistic measure levels from the Matrix view. To start the process, select the level you want to make probabilistic and double-click its cell. Or, you can select the cell by clicking it and select the  Matrix::Define Probability option. In either case you will see the probability dialog box shown in Figure 6- 11.

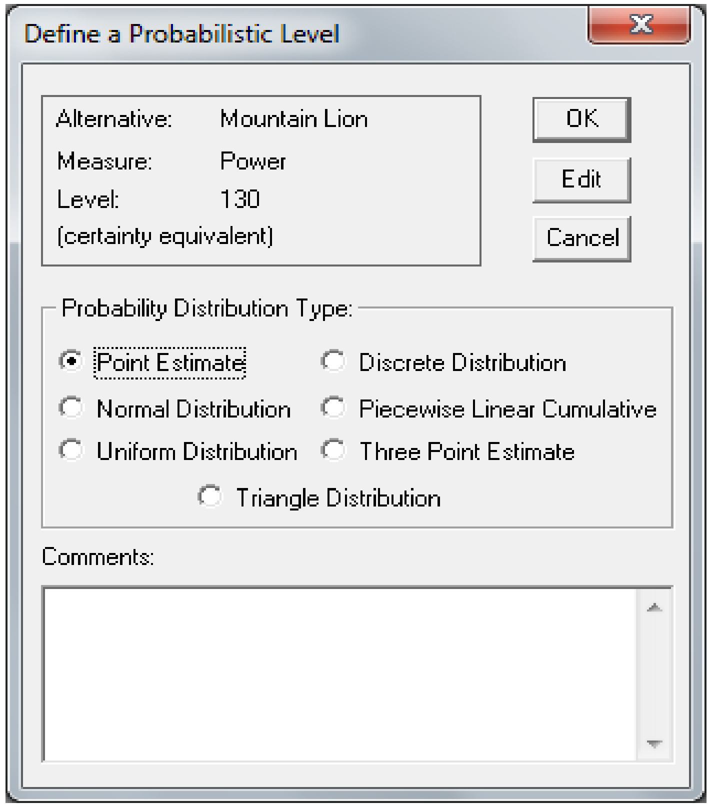


Figure 6- 11. Define probability dialog box

The probability dialog box shows the level being modified and its current probability distribution. The following types are available:

● **Point Estimate** -- use a single number as the level. This is the default.

● **Uniform Distribution** -- define the level with a uniform probability distribution defined by an upper and lower limit.

● **Discrete Distribution** -- define the level as several different levels, each of which with its own probability.

● **Piecewise Linear Cumulative Distribution** -- define the level with several levels that define a cumulative probability distribution.

● **Normal Distribution** -- define the level with a Normal (bell shaped curve) probability distribution.

● **Three Point Estimate** -- define the level with three points of the probability distribution: the 0.05 level, the 0.50 level and the 0.95 percent level.

● **Triangle Distribution** -- define the level with a triangle distribution defined by the minimum, most likely and maximum levels.

You select a distribution type by clicking the radio button for that type. Then Logical Decisions asks you to enter the parameters for that distribution.

After you enter the data, Logical Decisions displays the resulting **certainty equivalent**. The certainty equivalent is the point estimate level that has the same utility as the **expected utility** of the probabilistic level. Logical Decisions computes expected utility by combining the level's probability distribution with the associated measure’s utility function.

The sections below describe the parameters that define the different probability distributions.

Point Estimate. The Point Estimate option lets you define a single number as the level of the active measure and alternative. Point estimates are the default, and the measure levels entered elsewhere are point estimates.

When you select this option, Logical Decisions replaces the probability distribution with its certainty equivalent. Any previously entered probability information is lost.

Uniform Distribution. The Uniform Distribution option lets you describe the level for a measure and alternative as a uniform probability distribution. A uniform distribution is one where all levels between two endpoints are equally likely and there is no probability of being outside the endpoints. See Figure 6- 12.

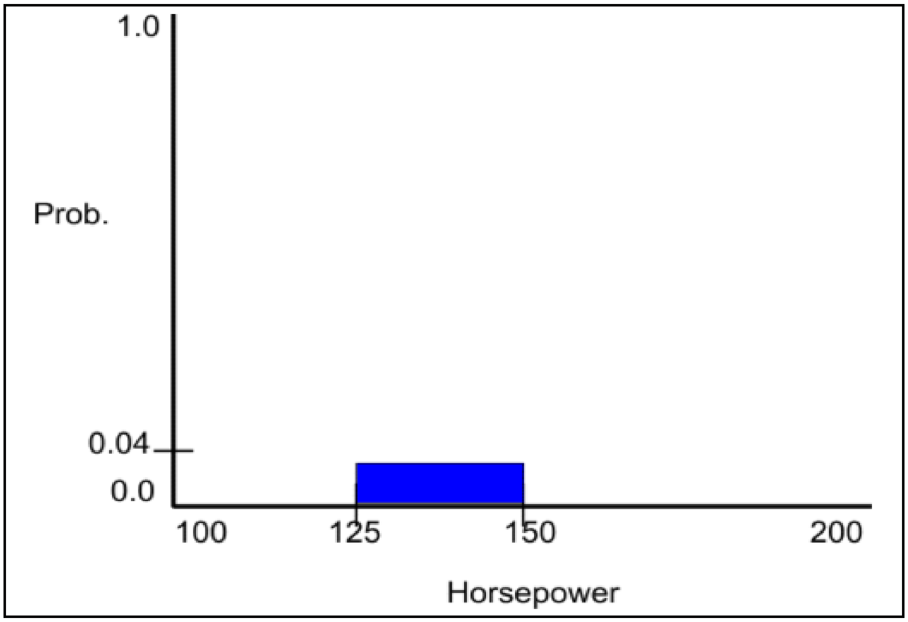


Figure 6- 12. Example of a level with a uniform probability distribution

When you select this option, Logical Decisions asks you to enter the minimum and maximum levels for the range.

Discrete Distribution. The Discrete Distribution option lets you to enter a discrete probability distribution as the level for a measure and alternative. A discrete distribution has probabilities defined for several different levels such that the probabilities sum to 1.0. Thus, the level will be one of several possibilities, with the likelihood of each possibility defined by its probability and the probability of any other level being zero. See Figure 6- 13.

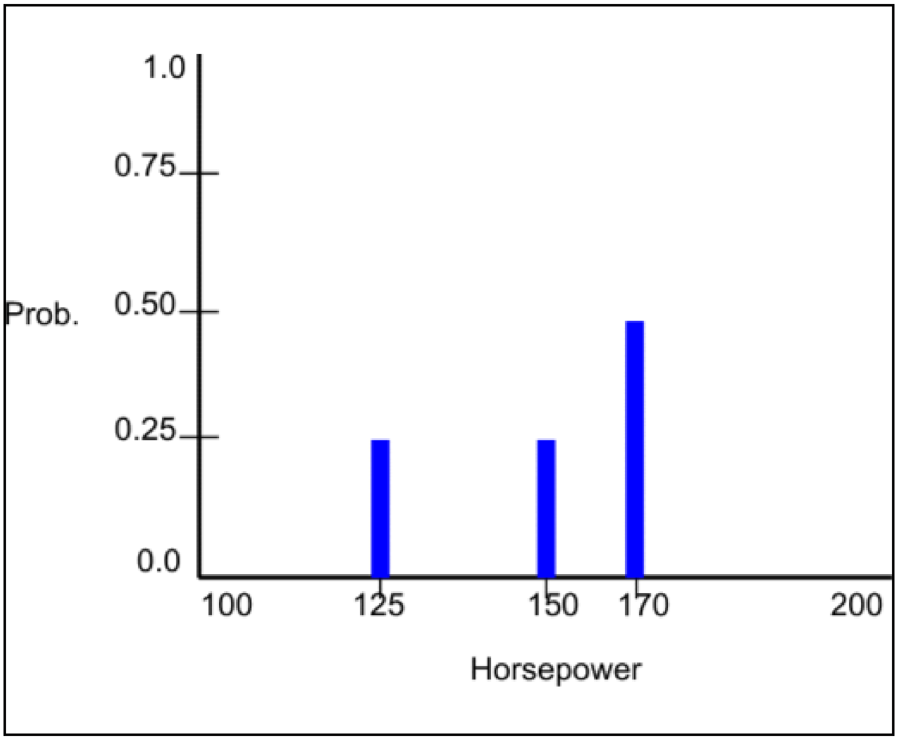


Figure 6- 13. Example of a level with a discrete probability distribution

When you select this option, Logical Decisions asks you to enter the number of points (up to 10) that you will define. You then enter a level and a probability for each point. If your probabilities do not sum to 1.0, Logical Decisions will proportionally adjust them so that they do. The levels do not have to be in increasing order, although this will make it easier to see what's going on.

Piecewise Linear Cumulative. The Piecewise Linear Cumulative option lets you describe the level of a measure for an alternative as a Piecewise Linear Cumulative probability distribution. A Piecewise Linear Cumulative distribution is described by several levels where the probability of being less than or equal to that level is defined. These points are connected by straight lines to form a complete cumulative probability distribution function. See Figure 6- 14.

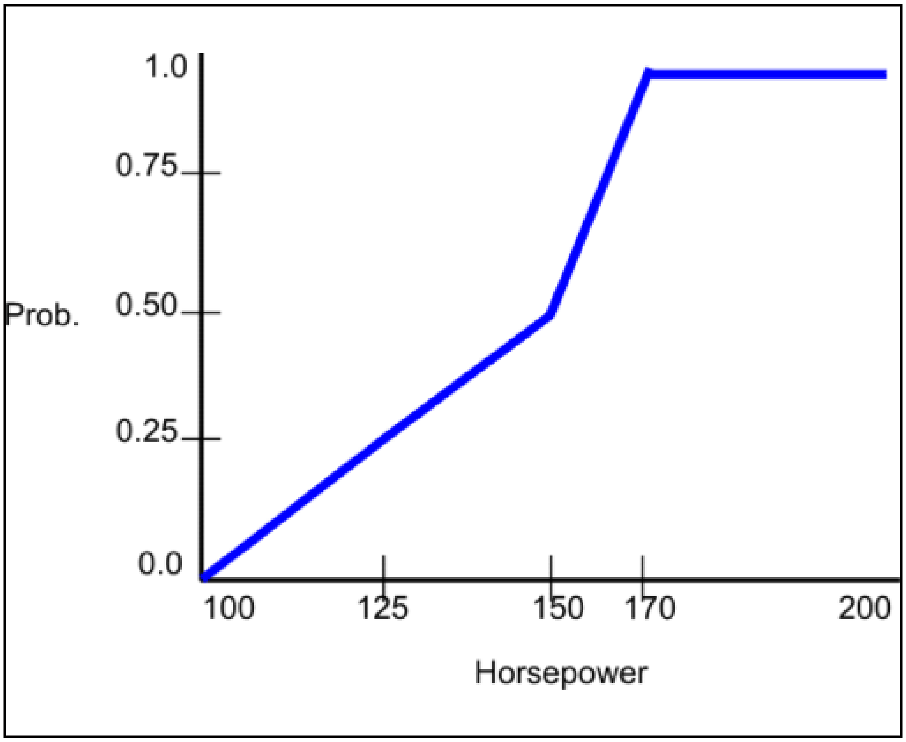


Figure 6- 14. Example of a level with a Piecewise Linear Cumulative probability distribution

When you select this option, Logical Decisions asks you to enter the number of points you will define. Next, you enter pairs of probabilities and levels. The probabilities represent the chance that the actual level is less than or equal to the level for that point. The first probability must be 0.0, the last 1.0, and the probabilities must be increasing.

Normal Distribution. The Normal Distribution option lets you describe the level of a measure for an alternative with a Normal probability distribution. A Normal (Gaussian) distribution is the familiar bell shaped curve and is defined by a mean and a standard deviation. See Figure 6- 15.

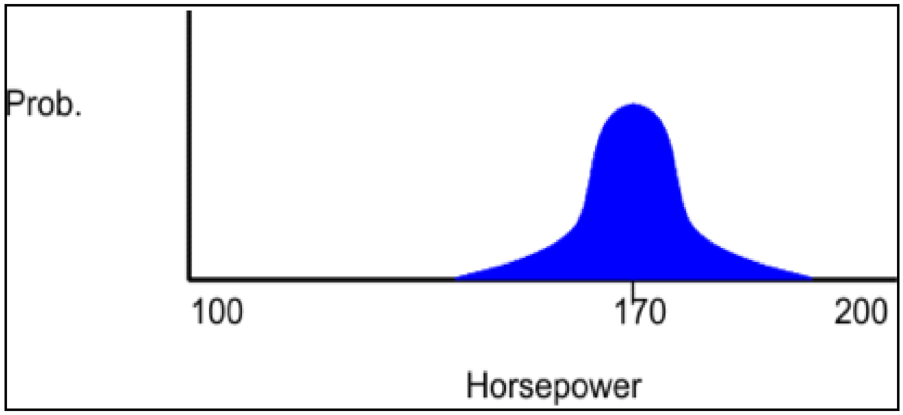


Figure 6- 15. Example of a level with a Normal distribution

When you select this option, Logical Decisions asks you to enter the mean and standard deviation for the selected measure and alternative.

Triangle distribution. The Triangle Distribution option lets you describe the level for a measure and alternative with a triangle distribution defined by the minimum, most likely and maximum levels. See Figure 6- 16.

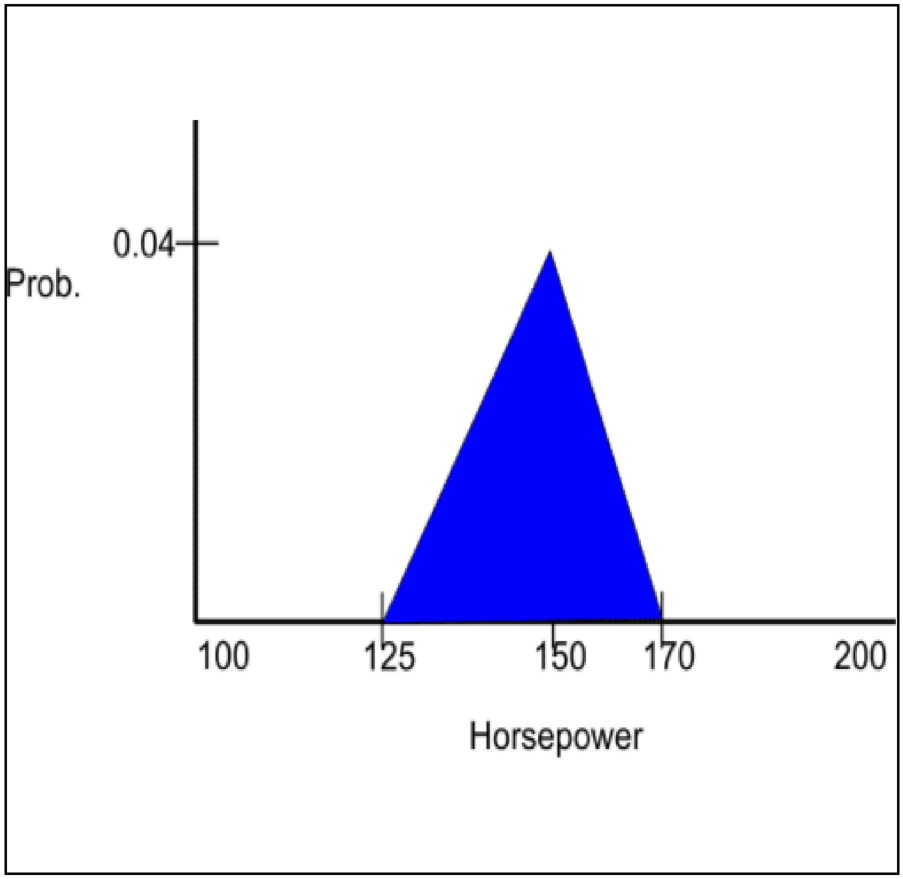


Figure 6- 16. Example of a level with a triangle distribution

When you select this option, Logical Decisions asks you to enter the three levels.

Three Point Estimate. The Three Point Estimate option lets you describe the level for a measure and alternative by defining the 5 percent, 95 percent, and 50 percent levels of its cumulative probability distribution function. See **Figure 6-16**.

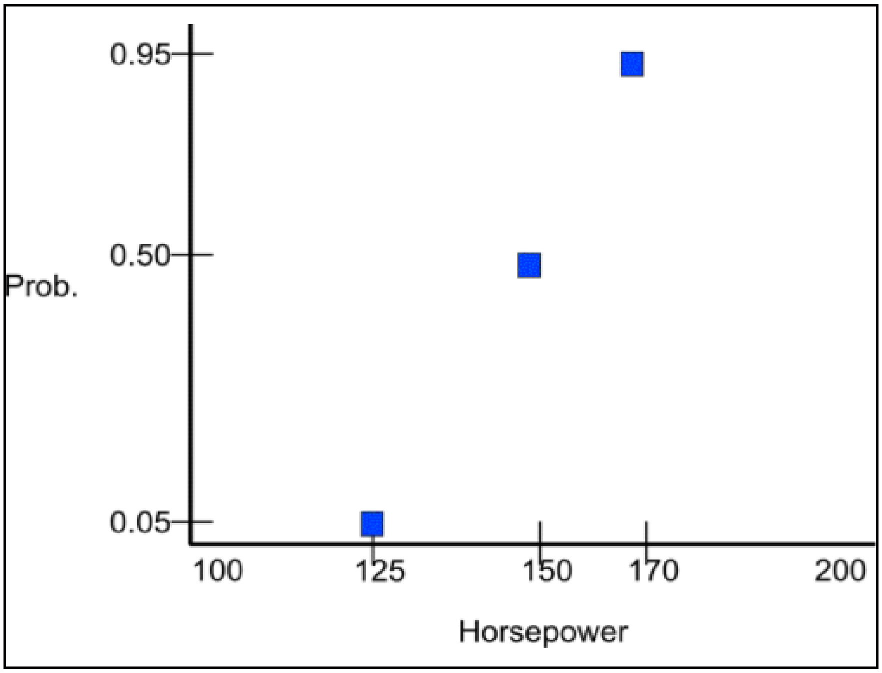


Figure 6- 17. . Example of a level with a three point estimate

When you select this option, Logical Decisions asks you to enter the three levels. You can use this option when you are unsure of the actual form of the distribution, and still get reasonably accurate results.

How Logical Decisions uses Probabilities. Logical Decisions generally treats probabilities as certainty equivalents -- single numbers that are equal in terms of preference to the entire probability distribution. The theory of decision science tells us that this certainty equivalent alone should be sufficient for decision making.

Logical Decisions also provides options that let you see how the uncertainties in measure levels result in uncertainties in the overall results. Logical Decisions does this by using **Monte Carlo Simulation.**

In Monte Carlo simulation, a number of passes are made to compute an alternative's utility on a measure or goal. For each pass, Logical Decisions replaces each probabilistic level with a single number that is **sampled** from the probability distribution for the level. A sample is a number that is randomly drawn from a probability distribution with a likelihood that is based on the probability distribution.

For example, if a level with units of horsepower has a discrete distribution of p(150hp) = 0.5, p(160hp) = 0.3, and p(170hp = 0.2), then about 50% of the samples will have a level of 150hp, about 30% of them will have a level of 160hp and about 20% of them will have a level of 170hp.

Because the samples are based on random numbers, the proportions won't exactly match the fractions in the probability distribution. However after a large number of samples have been taken the proportions should be very close.

After each probabilistic level has been sampled, Logical Decisions computes the alternative’s utility and saves it. After many passes, you will get an idea of the probability distribution of the alternative’s utility.

The following Logical Decisions options use Monte Carlo simulations:

● the Preferences::Simulation Options option lets you define the number of samples to use when doing a Monte Carlo simulation.

● the Results::Alternative Uncertainty Graph option lets you see a histogram and cumulative probability distribution for any alternative and measure or goal.

● the Results::Uncertainty Summary option lets you generate a table comparing the uncertainties for all the alternatives for any measure or goal.

● the Results::Rank Alternatives option has a feature that lets you show the uncertainty range for each alternative along with its expected utility.

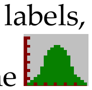
Adding Comments to Levels. The probability dialog box shown in Figure 6- 11 includes an edit box for entering comments. You can use this comment field for any level, regardless of whether the level is probabilistic. This comment field lets you add a comment to any particular measure level. A similar comment field is provided in the probability dialog box for labeled levels.

Levels with labels

Measure labels let you describe the level on a measure with a brief text description rather than a number. You define the allowable labels in the measure's properties dialog as described on page 111.

To select a particular label for an alternative you first select the level's cell in the matrix view. When you click a cell for a measure that has labels, it turns into a combo-box showing the current label with a drop down list of the possible levels. To select a new level just click one of the labels in the list. The combo-box will disappear when you select another cell.

Defining probabilities with labels. Since labels provide only a discrete set of possible levels for a measure, Logical Decisions only allows a discrete distribution that specifies the probability of each label on the list.

To define a probability distribution over the labels, select the cell for the level you want to define and select the  Matrix::Define Probability. When you select the option, Logical Decisions displays the dialog box shown in Figure 6- 18.

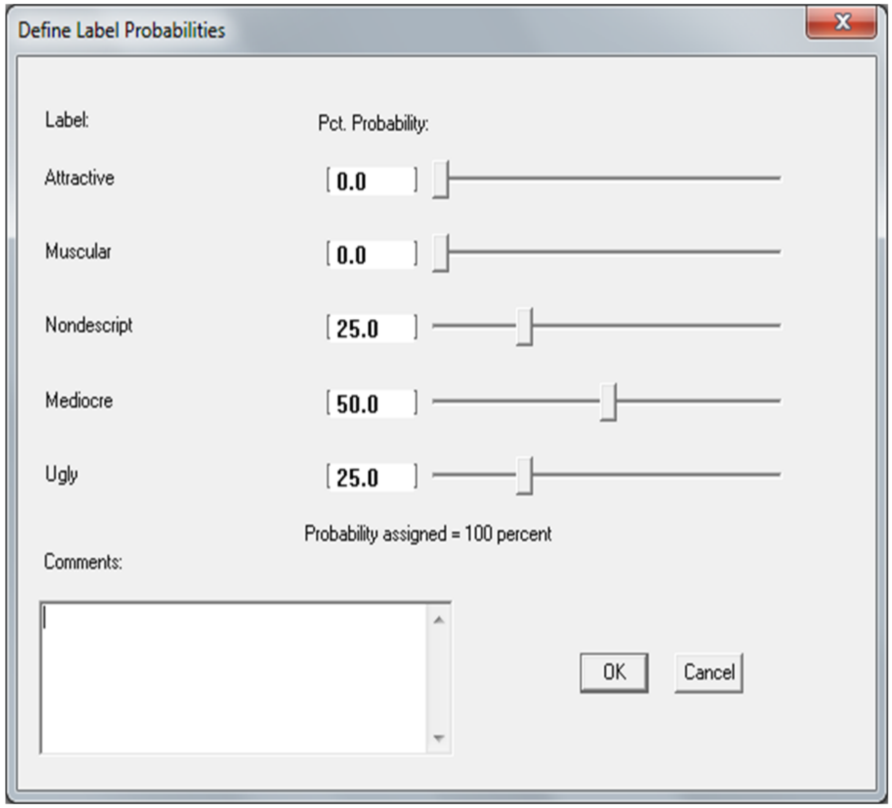


Figure 6- 18. Label probabilities dialog box

The left side of this dialog box has a list of the labels for the active measure. You can enter the percent probability for each label using the edit box or the slider to the right of the label. Each slider goes from 0 to 100. The total probability assigned to the labels can't exceed 100 percent, so if you move a slider to a position that would cause the total probability to exceed 100 percent Logical Decisions will "steal" probability from the other labels to make the total probability assigned equal 100 percent. You should assign the proper probability for each label and then click "OK".

Logical Decisions will adjust your probabilities if they don't sum to 100 percent. If only one label has a positive probability, Logical Decisions will convert the probabilistic level to a point estimate level.

Logical Decisions displays the label with the highest probability in the Matrix view.

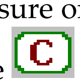
Measure Categories

Measure categories are sub-measures that define an alternative's level as a weighted average of its category levels. A measure category is defined by a multiplier for the category and a category level for each alternative.

Different preference sets can have different multipliers for the categories.

You define category levels in the Matrix view in the same way as you define measure levels. You can define probabilistic category levels but you can't define category levels using labels.

If you have defined categories for a measure, Logical Decisions will compute the levels for that measure from the category levels. Logical Decisions will override any levels you have previously defined in the Matrix view and will lock the measure's level cells when you define the first category for the measure.

Adding a Measure Category. You can add a measure category at any time using the Edit::Add option. Just select the "Measure Category" button and click OK. You can also add measure categories in the Matrix or Brainstorming view. To do this you first select an existing measure or measure category and then add the new category with the  Add a Category option. If you have previously saved a measure category using the Edit::Cut or Edit::Copy option you can retrieve it with the Edit::Paste option. The category will belong to the active measure, which can be different from the measure the category was copied from. You can view measure categories in the Goals Hierarchy view, and you can also cut and paste them, but you can't insert them.

Deleting a Measure Category. You can delete measure categories in the Matrix, Goals Hierarchy or Brainstorming view. To do this you first select the category you want to delete and then delete it with the  Edit::Delete option or the Edit::Cut option. The Cut option saves a copy of the measure category. The Delete option does not.

Modifying a Measure Category. Generally you will modify a measure category by changing its levels on the alternatives. You can also modify the name and other information about a measure category by reviewing the properties dialog box shown in Figure 6- 19. You can view this dialog box by double clicking a category's cell in the Matrix, Goals Hierarchy or Brainstorming view or by selecting the Edit::Modify option.

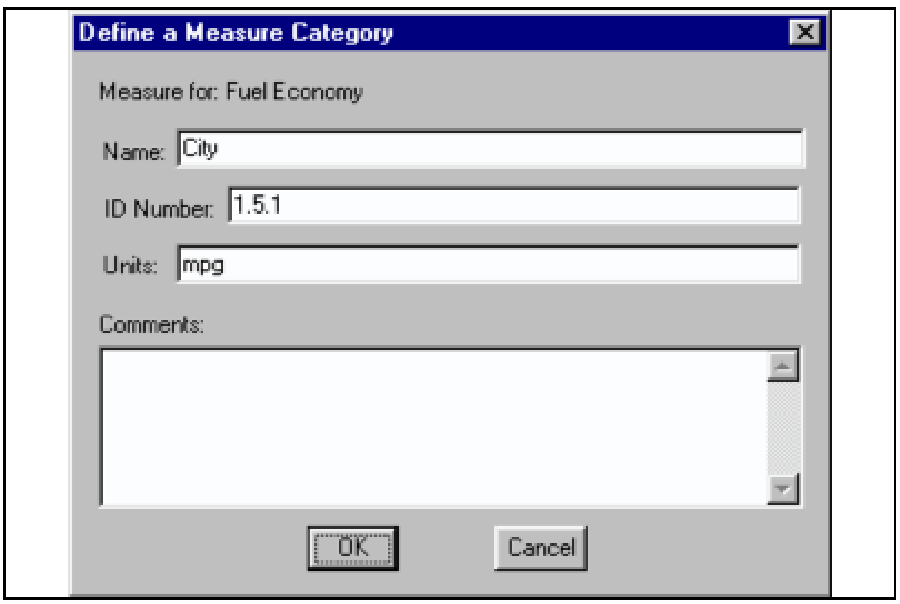


Figure 6- 19. Measure category dialog box

Printing Evaluation Forms

The Assess::Evaluation Form option lets you generate a form that you can use to evaluate alternatives. When you select the option, Logical Decisions generates a form similar to that shown in Figure 6- 20.

Evaluation form for Buying a Truck decision

Prepared By _______
Date
Alternative____________________

Buy the best truck Goal

Styling: _____ (labels)
1) Attractive
2) Muscular
3) Nondescript
4) Mediocre
5) Ugly

Cost Goal

Price: (dollars)
range: 23000 (least preferred) to 15000 (most preferred)

Resale Value: (Pct. of original purchase price)
range: 45 (least preferred) to 75 (most preferred)

Performance Goal

Fuel Economy Measure

City: ___________ (miles per gallon)
Highway: (miles per gallon)
Power: (horsepower)
range: 109 (least preferred) to 175 (most preferred)

Figure 6- 20. Example evaluation form

You can print the form out directly from logical decisions or save it as a .doc or other text format file and then use it to collect data for your alternatives.

SECTION

Using Logical Decisions 2: Assessing

7

Using Logical Decisions 2: Assessing

Introduction

The second major step of a Logical Decisions analysis is to assess preferences. Logical Decisions needs your preference judgments to define how to convert the measures to common units and how to compute the weights of the measures and goals. Logical Decisions uses this information to compute an overall utility for each alternative.

The information you enter in the "Structuring the Problem" step is often relatively objective. Different experts can often agree on the structure of the goals hierarchy and the levels for the alternatives.

The information collected in the preference assessment step is different. There are generally no objectively right answers to the preference questions and reasonable people can disagree.

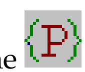
There is no way to avoid the preference assessment step in decisions with more than one evaluation measure. Some approaches claim to avoid it, but usually they just hide it by combining it with the more objective parts of the analysis. This makes it very difficult to see what's going on and severely limits the usefulness of the analysis.

Logical Decisions takes a better approach. It clearly separates the objective parts of the analysis (structuring the problem) from the more subjective parts (the preference assessments). Logical Decisions then provides tools to identify the effects of different preferences and to identify those preference judgments that are crucial to the results of the analysis. This can help focus the discussion about the decision to those aspects that are most critical.

Preference Sets

Preference sets are where Logical Decisions stores the preference judgments for a single individual or homogeneous group. A preference set contains all the information Logical Decisions needs to rank the alternatives on the "Overall" goal. This information includes category multipliers, single-measure utility functions, and the weight assessment information that lets Logical Decisions compute the multi-measure utility functions for the goals. The information Logical Decisions stores varies based on the preference assessment methods selected.

The active preference set. Logical Decisions always has an active preference set. It is the basis for any results displays. In addition, any preference judgments collected with the options in the Assess menu are part of the active preference set.

You select the active preference set with the  View::Select/Change Preference Sets option. When you select this option, Logical Decisions displays the dialog box shown in Figure 7- 1.

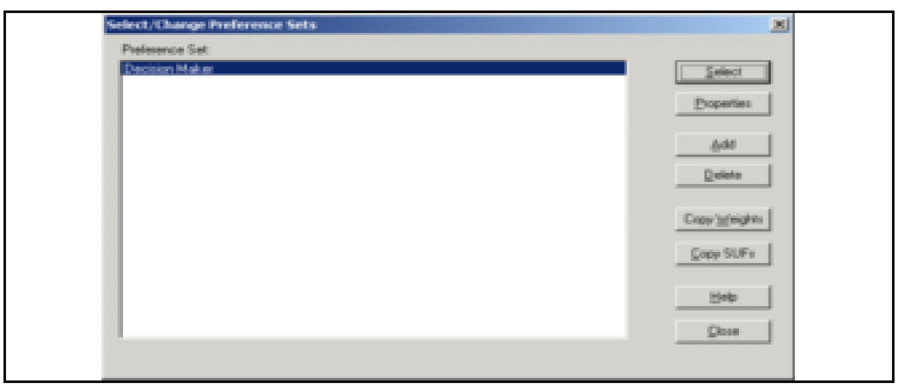


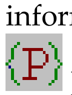
Figure 7- 1. Select/Change preference sets dialog box

At the left of this dialog box is a list of the preference sets in the analysis. Double clicking one of these will select it as the new active preference set. You can also use the "Select" button to select the highlighted preference set. You can use the "Add" button to add a new preference set to the analysis or the "Delete" button to delete the highlighted preference set from the analysis. Logical Decisions will ask you to confirm before deleting a preference set. You can use the “Copy Weights” button to copy the MUFs from the highlighted preference set to another preference set or to all of the other preference sets. Similarly, you can use the “Copy SUFs” button to copy the single measure utility functions from the highlighted preference set to another preference set or to all of the other preference sets.

Finally, you can click “Properties” to view the properties dialog box for the highlighted preference set.

You can also change the active preference set by clicking on a preference set name in the Summary dialog box.

Logical Decisions displays the active preference set in the lower right-hand corner of the Logical Decisions main window.

Adding a Preference Set. You can add a new preference set to your analysis using the Edit::Add option. Just select the "Preference Set" radio button and click OK. Logical Decisions will give you the option of copying an existing preference set or adding a new default preference set. If you copy an existing preference set, Logical Decisions also copies all of the preference information associated with the preference set. Logical Decisions assigns new preference sets the defaults for all needed preference information. You can also add a new preference by selecting the  View::Select/Change Preference Sets option as described above.

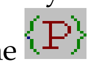
Deleting a Preference Set. You can delete a preference set using the Edit::Delete option. Just select the "Preference Set" radio button and click OK. Logical Decisions will ask you to select a preference set from a list and then to confirm before it deletes the preference set. You can also delete a preference set by selecting the View::Select/Change Preference Sets option as described above.

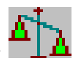
If you just want to initialize all or part of your preference information to the default values, don't delete the preference set. Instead, use the initialization options in the preference set properties dialog box discussed in the next section.

Modifying a Preference Set. You can change the name and other information about a preference set by using its properties dialog box. You can view the preference set properties dialog box by double clicking on the name of a preference set in the View::Summary dialog box or by clicking the “Properties” button in the View::Select/Change Preference Sets option.

In the preference set properties dialog box, the "Name" edit box in the upper left corner defines how Logical Decisions describes the preference set. The "ID Number" field is an alternate description or code for the measure. You can use the Preferences::Change Names option to control how Logical Decisions uses these two fields to describe each preference set. The comments field at the bottom of the dialog box lets you provide a more detailed description of your preference set.

Under the “Structure” tab in the preference set dialog box, the "Goals with a MUF" list box identifies which of the goals in the analysis will have their own utility function. You can select a goal to have a utility function by clicking on an un-highlighted goal. You can delete the utility function for a goal by clicking on its name to un-highlight it. Logical Decisions saves as much preference information as possible when you change the "Goals With a MUF" list.

The "Common Units Default" combo box lets you identify the default method to use for converting measures to common units. When you select a method from the list, Logical Decisions converts all measures currently having default SUFs to the defaults for the new method. Logical Decisions does not make changes to measures for which you have already entered preferences. In addition, when you select the  Assess::Common Units option, Logical Decisions will pre-select the default method for you.

The "Weight Assessment Default" has a similar function for the assessment methods for the  Assess::Weights option.

Under the “Status” tab in the preference set properties dialog box, the "Reset" check boxes let you initialize parts of the preference information for the active preference set. The initialized parts are set to their default values.

Checking the "All SUFs" box initializes the SUF curves for all measures to straight lines.

Checking the "All MUFs" box initializes all weights to equality. Any tradeoffs or other weight information assessed is deleted.

Checking the "All Category Multipliers" box initializes all category multipliers to one. You must confirm any initializations when you close the properties dialog box.

Finally, the "Status" line informs you of how far you have progressed in your preference assessments. The possibilities are

- **Defaults Used** -- no assessments have been done and Logical Decisions uses the defaults for all needed preference information.

- **Partial Assessment** -- some assessments have been done, but some defaults are still being used.

● **Assessments Complete** -- all needed preference assessments have been completed.

Overview of Preference Assessments

The purpose of the preference assessments is to collect the judgments needed to combine the measure levels for an alternative into an overall utility for that alternative. Three types of preference judgments may be needed:

● **Category Multipliers** -- to allow measure category levels to be combined into measure levels,

● **Common Units Conversions** -- to allow the measure levels to be converted from their original units to standardized units called utility, and

● **Weight Assessments** -- to allow the utilities for individual measures and goals to be combined into utilities for the higher level goals.

Logical Decisions gives you lots of freedom in the order and methods you use for these assessments. In addition, Logical Decisions provides defaults so you can skip steps and still do a ranking of your alternatives. Logical Decisions lets you compute results based on your preference assessments at any time.

Just before Logical Decisions displays the results, it computes the needed ranking functions based on your preference assessments so far. This computation is quite fast, so you probably won't even notice when it is happening.

You should generally do the preference assessments in the order of the options in the Facilitator outline. This will allow the most detailed information to be aggregated first and will make the results displayed in the weight assessment process more accurate.

Thus, we recommend that you assign the multipliers for any measure categories first. Next, you should do the assessments for the single measure utility functions that convert the measures to common units. Finally, you should do the weight assessments.

Defining Category Multipliers

Logical Decisions computes the levels for measures that have categories as the weighted sum of the alternatives' category levels. Thus, measures with categories require multipliers to define how to weight each category in the weighted sum.

Since Logical Decisions lets you have different multipliers for different preference sets, you should make sure you define multipliers in each preference set in your analysis.

Logical Decisions provides two places to define category multipliers. The "Category Multipliers" row in the Measure Categories view (accessible with the View::Matrix option) shows the multipliers for the active preference set.

The Category Multipliers row is only shown if you have elected to show the categories for at least one measure. Once the multipliers are visible, you can click on the multiplier you want and type in the multiplier.

You can also set the multipliers with the Assess::Category Multipliers option. When you select this option, Logical Decisions asks you to select a measure from a list and then lets you type in a multiplier for each category for that measure.

Logical Decisions assigns a default value of one (1.0) for each category multiplier. See the discussion on page 305 for suggestions on how to assess category multipliers.

Note that you should generally use a straight line (linear) conversion to common units for measures that use categories.

Converting Measure Levels to Common Units

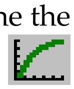
Logical Decisions converts measure levels to common units using what are called single measure utility functions (SUFs). Since that conversion is always needed, each preference set has a SUF for each measure.

SUFs are defined so that the least preferred level of the measure (as defined in the measure's properties dialog box) is assigned the least preferred utility level – 0.0. The most preferred measure level is assigned the most preferred utility level - 1.0. (You can change the most and least preferred utility levels in the Preferences::Utility Options option.)

The default SUF for any measure is a straight line (linear) conversion from the measure's original scale to utility. This means that each additional unit on the measure's scale represents a constant change in utility. Linear SUFs are often used in decision analysis. If a linear SUF is appropriate for a measure then you don't need to do anything to define the measure's SUF. Just use the default.

Logical Decisions provides five methods for converting a measure's levels to common units -- SUFs, Balance beam, AHP SUFs, Analytic Hierarchy Process, Adjusted AHP and Direct Assessment.

SUFs are the most traditional method, where you define a curve to convert measure levels to utility. SUFs and the other conversion methods are discussed in more detail below.

You define the parameters for any of the assessment methods using the  Assess::Common Units option. When you select this option you will see the dialog box in Figure 7- 2.

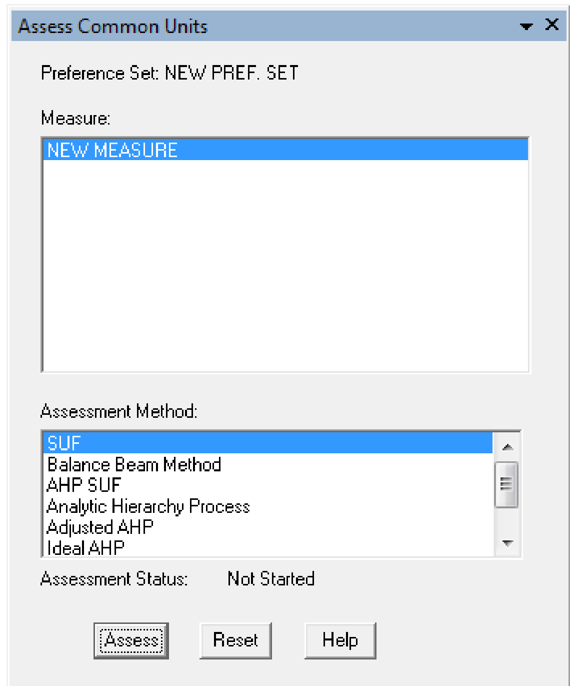


Figure 7- 2. Assess::Common Units dialog box

In this dialog box, the "Measure:" list box identifies the active measure. The status line tells you how much of the assessment you have completed for the active measure. There are three possibilities -- "Not Started", "Partial Assessment", and "Assessment Complete".

The "Assessment Method" list box shows the method selected for the active measure. Initially this will be the method selected in the "Common Units Default" combo box in the properties dialog box for the active preference set.

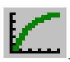
The "Reset" button deletes any assessment information for the active measure and returns its status to "Not Started". Logical Decisions will ask you to confirm before this is done.

Finally, the "Assess" button begins the assessment process for the selected method.

Note that the Assess Common Units dialog box is a “modeless” dialog box that can stay open as long as you want. It is generally docked on the right hand side of the Logical decisions window. You don’t need to keep it open when you are assessing the SUF for a measure. To avoid confusion, it is probably best to only have only one SUF assessment window open at once.

The following sections describe the assessment process for the various methods for converting measure levels to common units.

Common Units Using SUFs

When you select the "SUF" assessment method in the  Assess::Common Units dialog box and click on the "Assess" button, you will see a graphical SUF assessment screen like the one shown in Figure 7- 3.

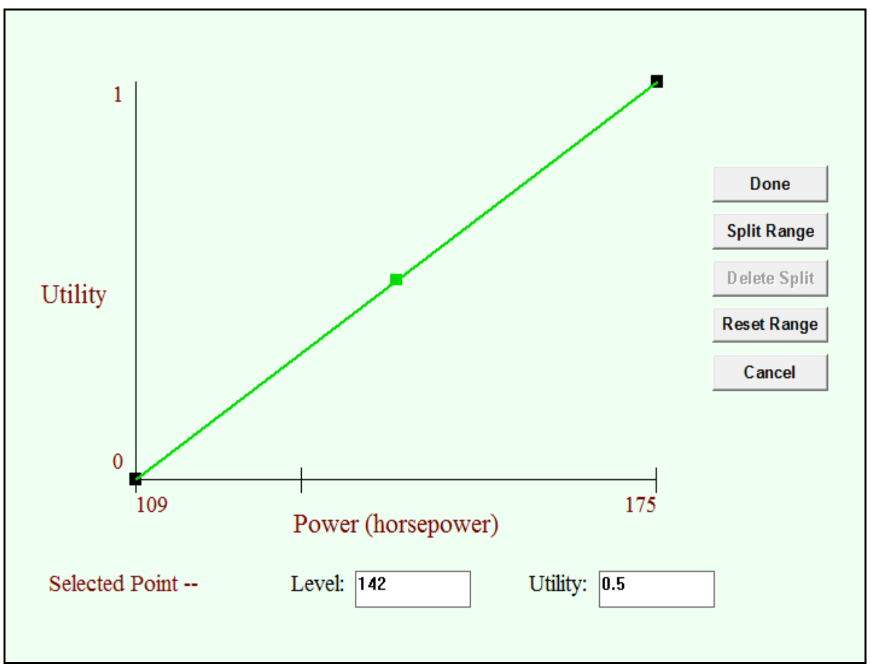


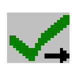
Figure 7- 3. Initial screen display for assessing horsepower SUF.

The screen shows a graph with the range of the measure on the horizontal axis. The vertical utility axis has a range from zero to one (assuming you haven't changed the utility range with the Preferences::Utility Options option). Logical Decisions displays the current SUF as a line or curve going from zero to one in utility and from the least preferred to most preferred level in the active measure's units. The SUF shows the utility associated with any level of the active measure.

The options associated with the assess SUFs window will let you change the shape of the SUF curve by breaking it into pieces (called sub-ranges) and by changing any sub-range from a straight line to a curve. Initially there is only one sub-range -- the whole curve.

Logical Decisions highlights the active sub-range on the graph in green. The shape of the curve for the sub-range is defined by three points -- the lowest and highest levels for the sub-range and the active point marked by a green square near the middle of the sub-range. Logical Decisions shows the location of the active point in the two edit boxes at the bottom of the SUF assessment window.

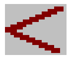
When you begin a SUF assessment, Logical Decisions adds the SUF menu to the main menu. The SUF menu has the following options:

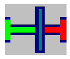
-  Done -- save the current SUF and close the assessment window.

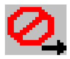
- Reset Range -- return the current SUF range to its default (straight line) value.

- Split Range -- split the active range into two parts at the active point.

- Delete Split Point -- combine the two sub-ranges separated by the active point.

-  Assess Utility -- assess the utility of the active point by asking a probability question.

-  Assess Value -- assess the utility of the active point using the "mid-level splitting" method.

-  Cancel – Close the assessment window without saving.

The Done, Cancel, Split Range, Delete Split and Reset Range options have corresponding buttons in the SUF assessment window.

The discussion starting on page 311describes the assess utility (probability) and assess value (mid-level splitting) methods for assessing the shape of the SUF curve for a measure. How these methods are implemented in Logical Decisions is discussed below.

Changing the Shape of the Active Sub-Range. The SUF curve for the active sub-range always passes through the active point. You can change the shape of the curve by moving the active point.

You can move the active point in two ways. First, you can drag the active point with your mouse. You can drag the active point anywhere in the rectangle defined by the two endpoints of the active sub-range.

Logical Decisions will attempt to fit a smooth (exponential) curve through the endpoints of the sub-range and the new active point. It is not always possible to do this if you move the active point near an endpoint. Logical Decisions will move the point if necessary to fit smooth curve. Logical Decisions shows the new location of the point in the edit boxes at the bottom of the window.

You can also move the active point by changing the values in the two edit boxes. The box on the left contains the level for the active point and the box on the right contains its utility. If you enter a new value for either of these numbers, Logical Decisions will update the location of the active point in the graph and will draw a new SUF curve through it. You must press **Enter** to let Logical Decisions know when you have finished changing a number in one of these boxes.

Splitting a Sub-Range. You can split a sub-range into two parts using the "Split Range" button or the SUF::Split Range option. When you select this option, Logical Decisions will split the active sub-range into two sub-ranges at the active point. The active point will become the highest level of one sub-range and the lowest level of the other. Logical Decisions will set the SUF curves for the two new sub-ranges to straight lines.

Changing the Active Point. Two types of points can be the active point -- points that define the midpoint of a sub-range and points that define an endpoint of a sub-range. When you select the midpoint of a sub-range for the active point, Logical Decisions highlights the entire sub-range in green. When you select an endpoint for the active point, Logical Decisions highlights just that point in green.

You can make a point active by clicking on it with your mouse. Or, you can use the **Left** and **Right-Arrow** keys to move the active point between adjacent midpoints and endpoints.

Combining Two Sub Ranges. You can combine two sub-ranges using the "Delete Split" button or the SUF::Delete Split Point option. Before you can select this option you must make the endpoint that joins the two sub-ranges the active point.

When you click the button, Logical Decisions combines the two ranges and adjusts the SUF curve for the new (combined) sub-range to pass through the active point. The active point becomes the midpoint for the combined sub-range.

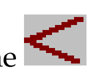
Moving an Endpoint. You can move an active endpoint of a sub-range in the same ways you can move a sub-range's midpoint.

You can move the point by dragging it with your mouse. You can also enter new values for the point's level and utility in the edit boxes at the bottom of the SUF assessment window. You can move an endpoint anywhere in the rectangle defined by the two closest endpoints on the horizontal axis and the zero and one utility points on the vertical axis. You can raise or lower the endpoints of the entire measure range but you can't move them horizontally. This ability to move the endpoints of a measure's range lets you define SUF curves with their most preferred or least preferred levels in the middle of a measure's range instead of at the ends.

When you move an endpoint, Logical Decisions initializes the SUF curves for the adjacent sub-ranges to straight lines.

Initializing a Sub-Range. You can reset the SUF curve for the active sub-range by selecting the “Reset Range” button or the SUF::Reset Range option. When you click the button, Logical Decisions resets the SUF curve for the sub-range to a straight line.

Formal Methods of Setting a Point’s Utility. Up till now, there has been no discussion of how to assign a utility to a particular level. Logical Decisions provides two methods for doing this by posing preference questions to the decision maker. The “Utility” method asks the decision maker to compare hypothetical certain and uncertain outcomes. The “Value” method asks the decision maker to identify the point that is preferentially halfway between two endpoints.

Assessing Utility. You can use the  SUF::Assess Utility option to assess the utility of the active point with a probability question. When you select this option, Logical Decisions displays the screen shown in Figure 7- 4. This screen compares a guaranteed outcome (labeled **A**) with a lottery (or uncertain outcome, labeled **B**). **A** and **B** represent simplified hypothetical alternatives that differ only on a single measure.

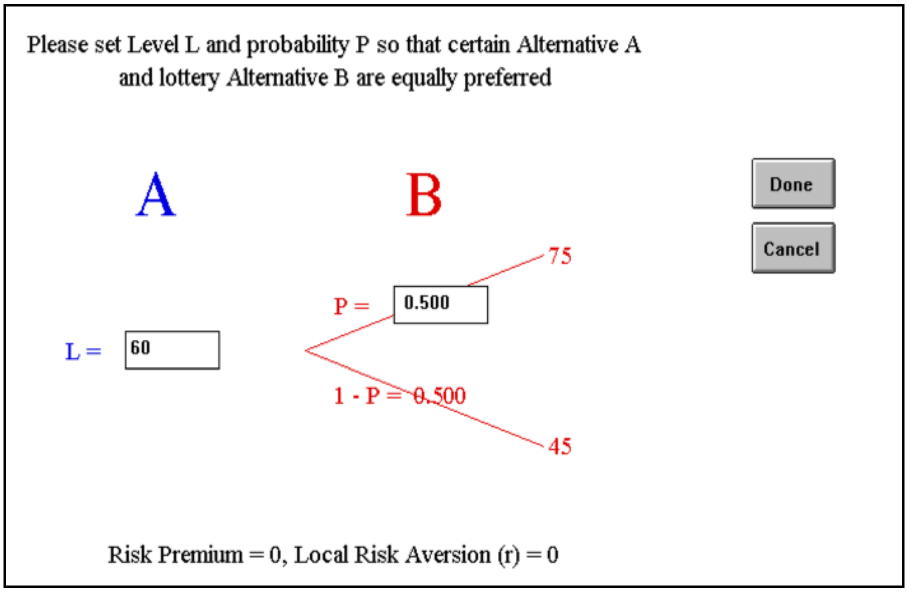


Figure 7- 4. Utility Assessment Screen

The screen in the figure shows a comparison based on truck resale values. In the figure, alternative **A** has a resale value of 60 percent of purchase price with no uncertainty.

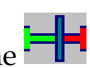
The < lines for alternative **B** represent an alternative with uncertainty in the resale value measure. Specifically, **B** has a probability of P = .5 of having a resale value of 75 percent of purchase price and a probability 1 - P = .5 of having a resale value of 45 percent of purchase price.

The goal of the assessment is to identify values for the certain level (L) for alternative **A** and for the probability P in alternative **B** that make alternatives **A** and **B** equally preferred. Logical Decisions will then use this information to set the level and utility for the active point in the main preference assessment screen. You can modify L and P by entering numbers in the associated edit boxes. Click on the "Done" button to indicate that you have finished and that you now prefer **A** and **B** equally.

The numbers at the bottom of the utility assessment screen are two parameters that are useful in understanding the utility assessment results. The first number, the **risk premium** indicates how much you would pay to avoid the uncertainty in the lottery. It is the difference in the expected value of the lottery **B** and the certain level L.

If the risk premium is positive and higher levels of the measure are preferred, then you would be willing to accept less of the measure (in terms of expected value) in order to avoid uncertainty. This type of preference is called **risk-averse**. The converse is when the risk premium is negative and you would have to have a higher expected value in the certain alternative before it is equally preferred to the lottery. This type of preference is called **risk-seeking**.

The **local risk aversion** (r) is a somewhat less intuitive number. It is defined as the ratio $r = -u''(x)/u'(x)$, where $u'(x)$ is the first derivative and $u'(x)$ is the second derivative of the utility function. In the case of the exponential utility functions used in Logical Decisions this complicated function has a simple result. It is equal to the constant c in the exponential formula $u(x) = a + be^{-cx}$. If r is positive you are locally risk-averse (for measures where higher levels are preferred). If r is negative, you are locally risk-seeking.

Assessing Value. You can use the  SUF::Assess Value option to assess the utility of the active point with the mid-level splitting method. When you select this option, Logical Decisions displays the screen shown in **Figure 7-5**. This screen has two static outcomes (labeled **A** and **C**) with a variable outcome (labeled **B**). **A, B** and **C** all represent simplified hypothetical alternatives that differ only on a single measure.

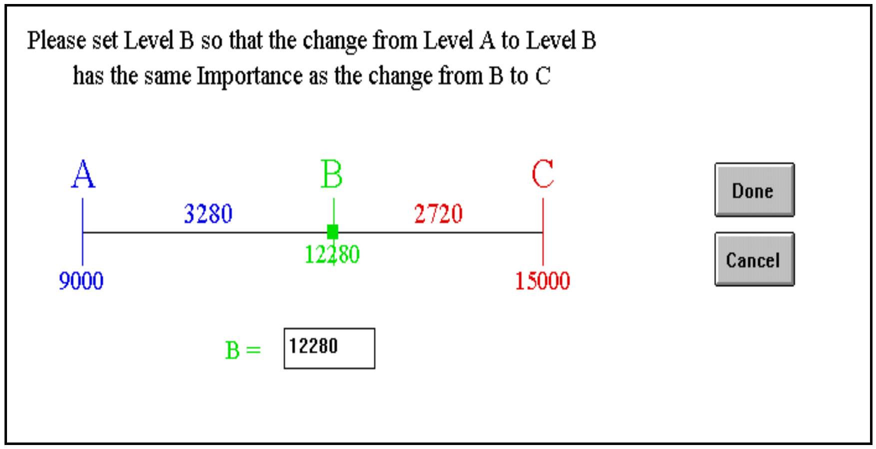
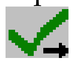
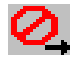


Figure 7- 5. Screen for Value Assessment using Mid-Level Splitting Method.

The screen in the figure shows a comparison based on truck prices. In the figure, alternative **A** has a price of $9,000 dollars and alternative **C** has a price of $15,000 dollars. The object of the mid-level splitting method is to identify a price for alternative **B** so that the change in desirability of improving from **C** to **B** is the same as the change in desirability of improving from **B** to **A**. In other words, we want to find a price for **B** that is halfway in terms of desirability between the prices for **A** and **C**. This price could be very different from the average of the two prices of $12,000 dollars. You locate the mid-preference level by using the mouse to drag **B** to the left or right along the line connecting alternatives **A** and **C**. You can also enter the mid-preference level directly in the edit box at the bottom of the screen. Logical Decisions will use the mid preference level as the level for the active point and will set the active point's utility as the average of the utilities for **A** and **C** in the main preference assessment screen. Click on the "Done" button to indicate that you have finished.

Completing the SUF Assessment. When your SUF curve looks the way you want it, you can save it and return to the common units dialog box by clicking on the "Done" button at the left of the SUF assessment window.

If you want to discard the changes you have made, click on the "Cancel" button. Logical Decisions will restore the SUF curve to its original shape and you will return to the common units dialog box. The  SUF::Done and  SUF::Cancel options echo the functions of these buttons.

Before Logical Decisions saves a SUF, it checks to see that at least one level receives the most preferred utility (usually one) and that at least one level receives the least preferred utility (usually zero). If these conditions are not met, Logical Decisions adjusts the vertical range of the SUF curve until they are.

When you are finished, Logical Decisions updates the active measure's SUF assessment status to "Assessment Complete".

Creating a non-monotonic SUF.. Occasionally it is useful to have a utility function that has its most or least preferred level in the middle rather than at an endpoint. An example might be body temperature in a medical application. It's better to be at 98.6º F than above or below that ideal number. You can do this as follows:

1. If you have made any changes to your SUF, reset the SUF to a straight line using the "Reset" option in the SUF assess dialog box.
2. Click the "Assess" button.
3. Split the SUF into two pieces with the SUF::Split Range option.
4. Click and drag the split point between the two ranges up until it has a utility of 1.0.
5. Click and drag the endpoint that has a utility of 1.0 down until it has the desired utility.

You should now have a SUF that looks like a triangle. You can modify either side of the triangle using the SUF assessment options until your SUF has the shape you want.

Common units using the Balance Beam Method

The balance beam method is an approach to common units that is suitable for measures where the levels for different alternatives can be meaningfully combined. It works by comparing the level of a single (more preferred) alternative with the combined levels of several (less preferred) other alternatives. If you prefer the single alternative equally to the bundle of alternatives, the balance beam method sets the utility of the more preferred alternative equal to the sum of the utilities of the alternatives in the bundle.

When you use the Balance Beam method, any levels you have entered for the measure will be ignored. At the end of the Balance Beam process, Logical Decisions will give you the option of converting the balance beam scores to levels. Otherwise the scores are adjusted so that the highest score equals 1.0 and are retained as utilities.

To start the Balance Beam process, select the Balance Beam method from the list in the Assess Common Units dialog box and click “Assess”. You will see an assessment window similar to the one in Figure 7- 6.

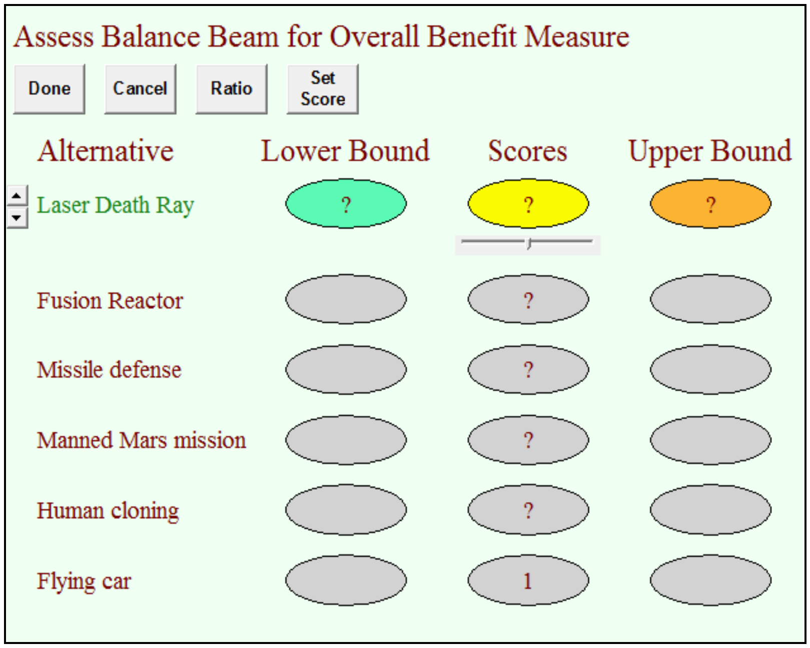


Figure 7- 6. Starting screen for Balance Beam example

The example in the figure is prioritizing a set of broad research initiatives by their overall benefit. The first thing we want to do is order the alternatives.

Ordering the Alternatives. When you click an alternative, it is highlighted as shown above. An up-down arrow control also appears to the left of the alternative. You can move the alternative in the list by clicking the up or down arrow or with the up or down arrow keys. Figure 7- 7 shows a possible order for the alternatives.

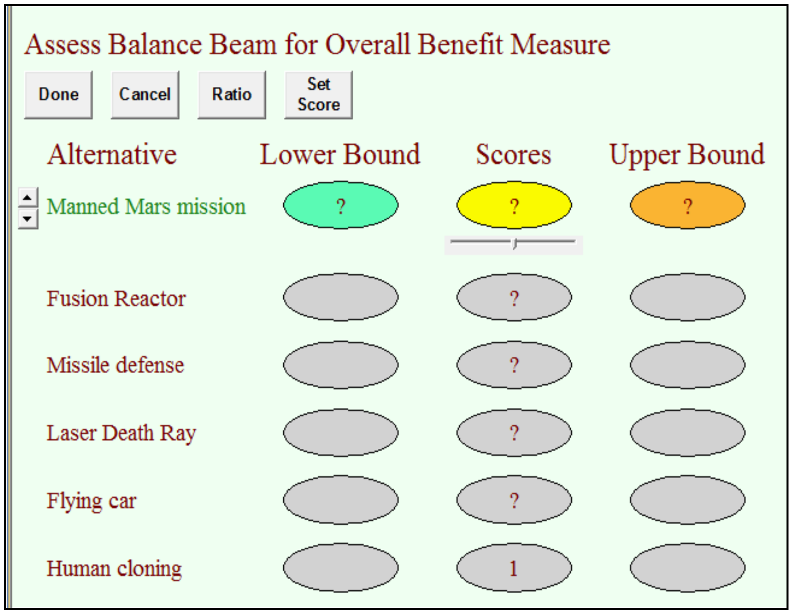


Figure 7- 7. Balance Beam screen after sorting alternatives

Setting a lower bound. Now we select the highest ranking alternative and try to establish upper and lower bounds for its score. Suppose we feel that having the Mars Mission is preferred to having both the Fusion Reactor and Missile Defense. To show this, we make sure that the Mars Mission is highlighted as above and click the ovals for Fusion Reactor and Missile Defense as shown in Figure 7- 8. This indicates that the score for the Mars Mission should be higher than the sum of the scores for Fusion Reactor and Missile Defense.

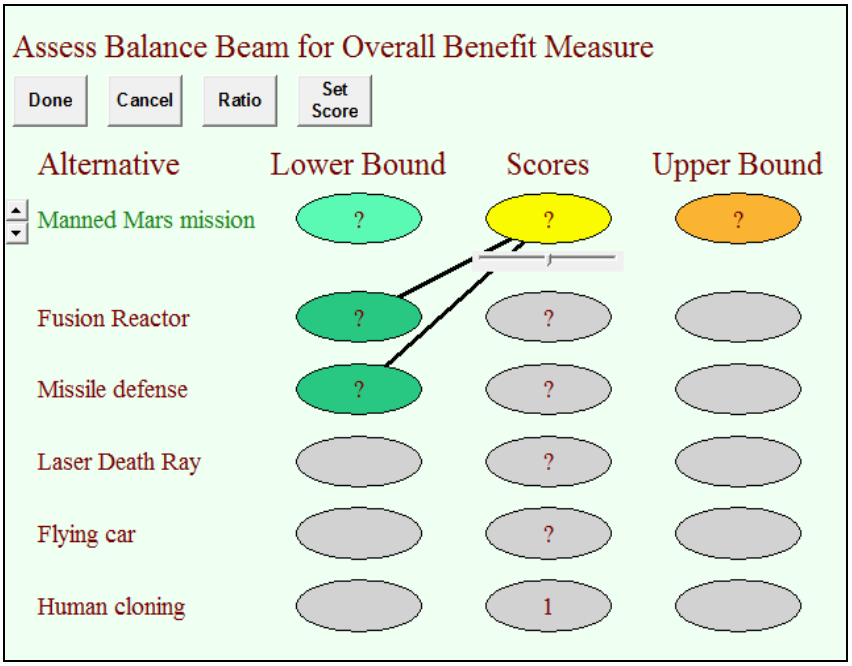


Figure 7- 8. Setting a lower bound for Mars Mission alternative score

In the figure, most of the ovals have question marks, indicating that Logical Decisions can't yet compute scores for the alternatives. As we add more bounds, that will become possible and Logical Decisions will replace the question marks with scores.

Adding an upper bound. Suppose we feel that the combination of Fusion Reactor, Missile Defense and Laser Death Ray is preferred to the Mars Mission alone. We indicate that by clicking ovals in the Upper Bound column as shown in .

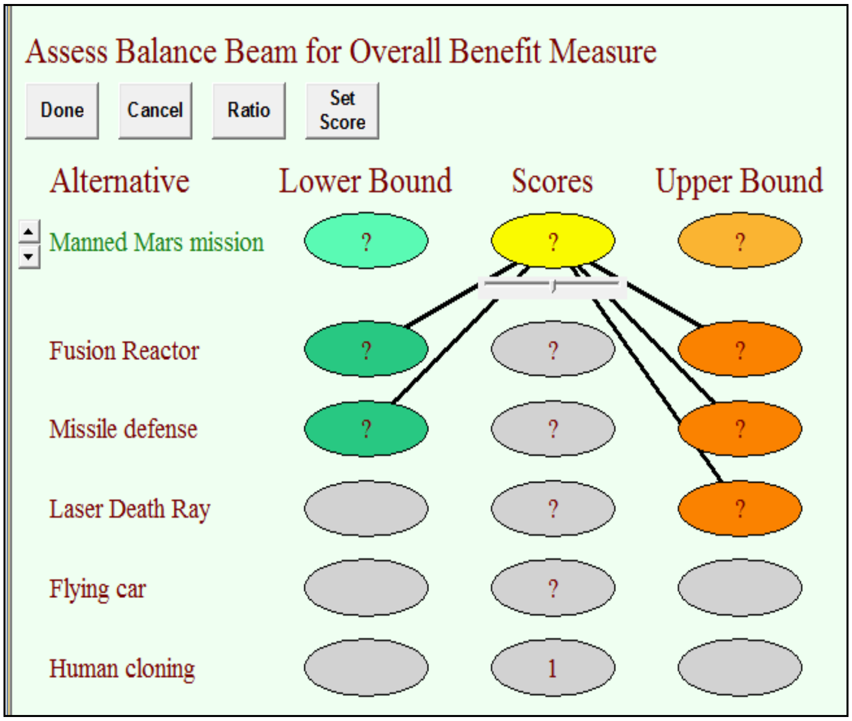


Figure 7- 9. Setting an upper bound for Mars Mission alternative score

Setting the score between the bounds. Logical Decisions needs to know where in the range between the upper and lower bounds it should set the score for the Mars Mission alternative. You indicate this with the slider that appears below the yellow score circle for the Mars Mission. Logical Decisions uses a default of 50% of the way between the bounds, but you can set to percentage to any number you want between 0 and 100%. When Logical Decisions is able to compute the exact scores for the upper and lower bounds, it replaces the percentages in the slides with the actual numbers in the range between the bounds.

Note that you can set an equality bound by selecting the same set of alternatives for both the upper and lower bound.

You continue the Balance Beam process by working your way down the list of alternatives and setting upper and lower bounds. Figure 7- 10 shows the Balance Beam window with upper and lower bounds marked for the Fusion Reactor, Missile Defense and Laser Death Ray alternatives. The thin black lines indicate the upper and lower bounds for the alternatives above the selected alternative in the priority list.

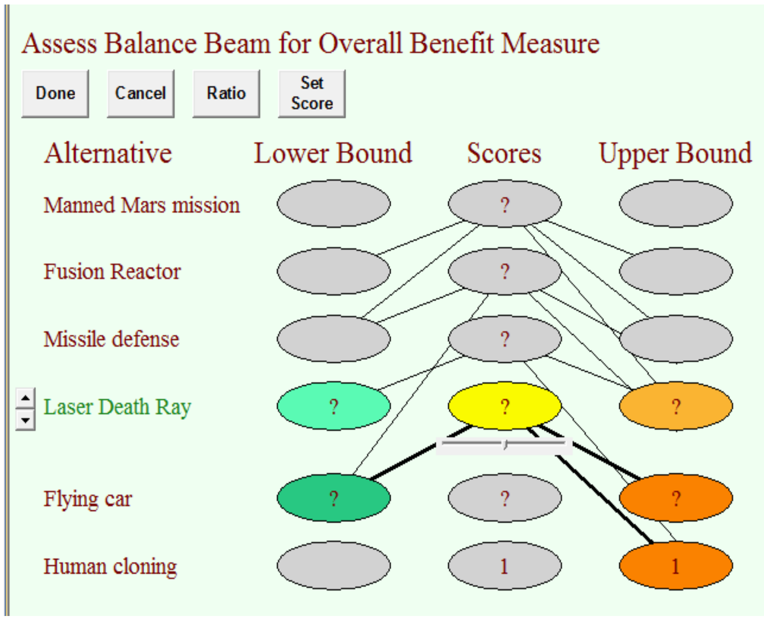


Figure 7- 10. Balance Beam with additional bounds entered

At the bottom of the priority list there are few alternatives to use to create bounds. For this reason, it is common to set the score for the next to last alternative as a ratio to the score of the last alternative. Suppose we think that the Flying Car provides twice as much benefit as Human Cloning. We enter this ratio by first selecting the Flying Car alternative, then selecting Human Cloning as a lower bound and finally clicking the "Ratio" button. After you enter "2" in the dialog box Logical Decisions will update the display as shown in Figure 7- 11.

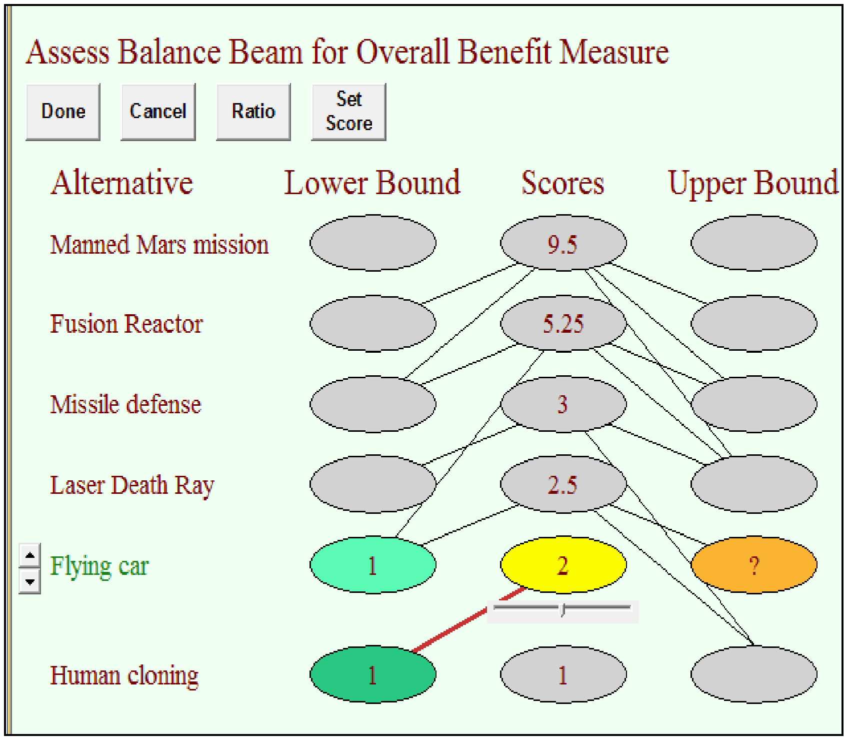


Figure 7- 11. Completed Balance Beam process

In the figure, the ratio bound is shown as a red line. You can assign a ratio to a lower bound that includes more than one alternative if you like.

Computing the scores. Logical Decisions can now compute the scores for the alternatives, since it assigned a score of 1.0 to the lowest ranked alternative as a default. Logical Decisions computes the other scores as follows:

> Flying Car's score must be 2.0 times Human Cloning's score. Laser Death Ray's score is halfway between Flying Car's score (2) and the sum of Flying Car's and Human Cloning's scores (3). The other scores are computed similarly.

Assigning a score to an alternative. Logical Decisions gives you the option to assign any score greater than zero to a selected alternative by clicking the "Set Score" button. Logical

Decisions will adjust the current scores to make the chosen alternative’s score come out to the amount you desire. For example if you set the score of the Mars Mission to 1000 in the above example, Logical Decisions would multiply all the scores by 1000/9.5, resulting in a score for Human Cloning of 105. The assigned score is highlighted in red in the Balance Beam display.

If you don’t choose to convert the Balance Beam scores to measure levels, Logical Decisions will adjust the scores so that the highest is 1.0. In the example, the Manned Mars Mission would be assigned a utility of 1.0 and Human Cloning would be assigned a utility of 1/9.5 = 0.105.

When you click the “Done” button, Logical Decisions will offer you an opportunity to convert the Balance Beam scores to levels for the associated measure. Logical Decisions will adjust the range of the measure so that the most preferred level equals the highest score and the most preferred level equals 0.

Common Units Using the Analytic Hierarchy Process

The Analytic Hierarchy Process approach to converting measure levels to common units does not require you to define explicit levels for your measures. Instead, you make comparisons between pairs of alternatives as to their relative performance on the active measure. The preference information you enter is the ratio of the alternatives’ performances on the measure.

Logical Decisions uses the ratios you enter to compute a score for each alternative on the measure. We'll call these scores utilities although they are not really the same as the utilities resulting from the "SUF" method. One property of the Analytic Hierarchy Process approach is that the sum of the utilities of all the alternatives is one (1.0). This differs from the SUF approach, where the utilities range from 0.0 to 1.0.

When you select the "Analytic Hierarchy Process" method in the common units dialog box and click "Assess", you will see a matrix like the one in Figure 7- 12.

l-max = 3.247 C.I. = 0.123 C.R. = 0.237	House C	House B	House A
House C	0.712487	8	5
House B	0.125	0.0544537	0.142857
House A	0.2	7	0.233059

Figure 7- 12. Assessment window for Analytic Hierarchy Process

Figure 7- 13

In this matrix, the rows and columns both represent alternatives. The cells in the matrix represent the performance ratio of the row alternative to the column alternative.

Since the ratio of an alternative to itself must be one, Logical Decisions does not need to show the ratios on the diagonal of the matrix. Instead, Logical Decisions uses the diagonal cells to show the current utility for each alternative based on the assessment so far.

Initially, Logical Decisions assumes that all of the alternatives have equal performance, so that all the ratios off the diagonal equal one.

To complete the assessment for the Analytic Hierarchy Process method, you need to enter the ratio for each possible pair of alternatives. This means you need to enter a ratio in each non-diagonal cell in the matrix.

Since each pair appears twice in the matrix (once above the diagonal and once below it), you only need to enter ratios for the cells above the diagonal. Logical Decisions automatically enters the proper ratio in the corresponding cell below the diagonal.

You enter the ratios between alternatives by highlighting the cell you want to enter and typing in the appropriate ratio.

You can get help with this by double clicking the cell. When you do this, you will see a dialog box like the one in Figure 7- 14.

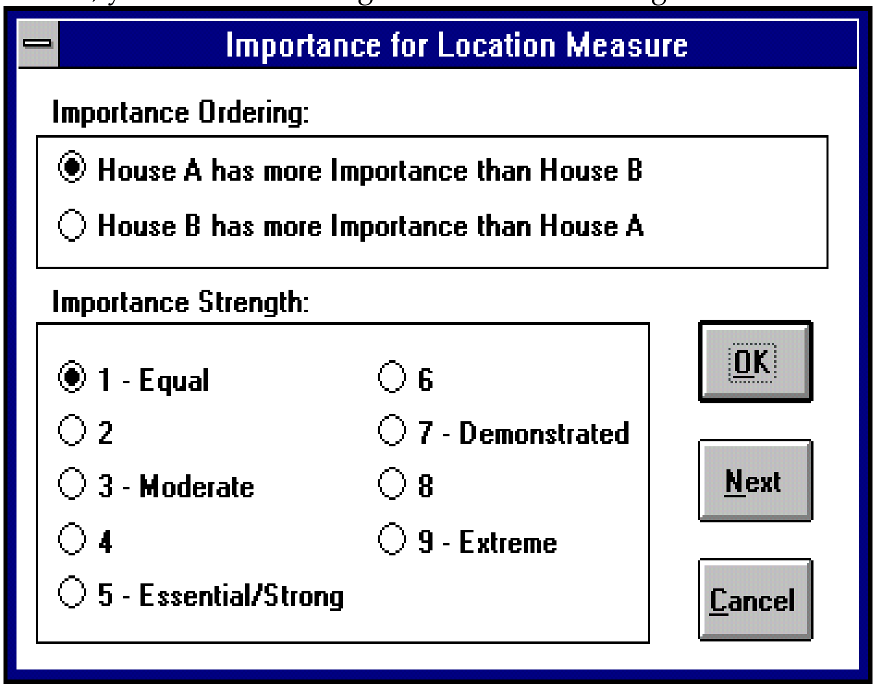


Figure 7- 14. Dialog box for Analytic Hierarchy Process comparison

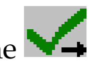
This dialog box helps you define the relative performance (or importance) of the two alternatives using terms created by the developers of the AHP approach.

To set a ratio in the dialog box, first click on the radio button at the top of the dialog box that best describes the order of the alternatives. Next click on the performance ratio ("importance strength") that best describes the ratio of performance of the better performing alternative to the other alternative. You may find the descriptions associated with the odd numbered ratios helpful in doing this.

Once you have selected an ordering and a performance ratio, click OK and Logical Decisions will enter the proper ratio in the active cell.

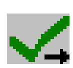
After you have entered a ratio, Logical Decisions uses the AHP computation process to compute a new set of utilities for the alternatives. Logical Decisions shows the computed utilities in the diagonal cells.

Logical Decisions marks cells where you have entered performance ratios in blue. Your assessment will be complete when all the non-diagonal cells in the matrix are marked in blue.

You can, however, leave the assessment process at any time. The utilities for the alternatives will be computed based on the ratios you have entered to that point. Just click the  "Done" button when you have completed your assessments.

The AHP process collects more preference judgments than are required to compute a set of utilities. Consequently, some judgments are likely to be inconsistent. Logical Decisions represents the degree of inconsistency by the numbers in the upper left corner of the matrix. The number labeled "C.I". is the "Consistency Index" for the matrix. It is an absolute measure of how consistent the ratios in the matrix are. The number labeled "C.R". is the consistency ratio and is a relative measure of consistency. The developers of the AHP approach suggest that C.R.s above 0.10 indicate that you should adjust the matrix to make it more consistent.

The AHP Menu. When doing an AHP assessment, the AHP menu appears in the main menu bar. It has the following options:

-  Done -- Save the current AHP matrix and return to the Common Units Dialog Box.

-  Cancel -- Return to the Common Units Dialog Box without saving the AHP matrix.

● Hide Weights -- Don't show the computed AHP levels or weights along the matrix diagonal. Selecting this option again will restore the levels/weights.

● Show C.R. Only -- Show only the consistency ratio statistic in the upper left-hand corner of the matrix. Selecting this option again will restore the lambda-max and consistency index statistics.

● Hide All Statistics -- Don't show any of the three statistics in the upper left-hand corner of the matrix. Selecting this option again will restore all three statistics.

● Estimate Ratios -- When checked, Logical Decisions computes a performance ratio for each pair of alternatives based on the ratios entered so far. When unchecked, Logical Decisions does not compute these ratios.

● Identify Outliers — Highlights those ratios that differ most from the ratios computed by Logical Decisions based on the utilities displayed on the diagonal of the AHP matrix. When you select this option, Logical Decisions will ask you how many outliers to highlight and will redraw the matrix with that number of cells highlighted in red.

Common Units Using Adjusted AHP

The Analytic Hierarchy Process method for converting to common units has the property that the computed utilities for the alternatives sum to 1.0. This may pose a problem when combining the Analytic Hierarchy Process with other methods which range from 0.0 (worst) to 1.0 (best). To remedy this problem, Logical Decisions provides an alternate assessment method -- called Adjusted AHP -- which adjusts the computed AHP utilities so that they range from 0.0 (worst) to 1.0 (best). This adjustment is the only difference between the two approaches. The adjusted utilities appear on the assessment matrix diagonal during the assessment process, which is otherwise exactly the same as for the Analytic

Hierarchy Process method.

Common Units Using AHP SUFs

The Analytic Hierarchy Process and Adjusted AHP approaches described above require that you include every alternative in the matrix. This makes the assessment requirements excessive for problems with more than a few alternatives. In addition, there is no link between the ratios assessed and the levels for the alternatives on the measure. For these reasons, Logical Decisions provides an alternate approach called "AHP SUFs". The AHP SUFs method lets you develop an AHP matrix for just some alternatives. Logical Decisions uses the utilities computed from the matrix as the basis for a single measure utility function. Logical Decisions can then use this SUF to rank all of the alternatives. Note that -- unlike the traditional Analytic Hierarchy Process method -- the AHP SUFs method requires you to define a level for each alternative on the active measure.

When you select the "AHP SUF" method in the common units dialog box and click "Assess", Logical Decisions first asks you to select a set of alternatives to use in the matrix. Just click on the alternative names to select and highlight them. Only alternatives whose levels are within the range defined in the active measure's properties dialog box can be selected. Then you will see an AHP matrix like the one in Figure 7- 15. Logical Decisions will include only the alternatives you selected in the matrix. Complete the matrix assessments as described in the section above on Analytic Hierarchy Process.

l-max = 4.036 C.I. = 0.012 C.R. = 0.013	Local 1 25 MHZ A	Local 1 33 MHZ	Mail Order 1 20 MHZ	Regional 1 25 MHZ
Local 1 25 MHZ A	0.213324	0.6	1.5	0.75
Local 1 33 MHZ	1.66667	0.364716	3	1.11111
Mail Order 1 20 MHZ	0.666667	0.333333	0.149685	0.7
Regional 1 25 MHZ	1.33333	0.9	1.42857	0.272275

Figure 7- 15. . AHP matrix for AHP SUF example

When you have completed the assessment, click the "Done" button and Logical Decisions will compute a SUF curve based on the matrix.

If the alternatives selected do not cover the entire range for the measure, Logical Decisions will assign zero to the least preferred level, and one to the most preferred level. Then Logical Decisions will assign the utilities computed from the AHP matrix to the levels associated with the alternatives. Logical Decisions will connect these points with straight lines.

If the alternatives in the matrix cover the entire range for the active measure, Logical Decisions will expand the range for the utilities in the matrix so that the highest utility is one and the lowest is zero. Logical Decisions will modify the other utilities accordingly. Logical Decisions will then use these adjusted utilities to define points on a SUF curve. Logical Decisions will connect the points with straight lines.

As an example, assume that the range for the HD size measure in Figure 7- 15 is 60 to 120 mb (measuring the hard disk size in a computer buying decision). Also assume that the alternatives have the following levels on the HD size measure:

Alternative	HD size
Mail Order 1 20 MHZ	65 mb
Local 1 25 MHZ	80 mb
Regional 1 25 MHZ	100 mb
Local 1 33 MHZ	110 mb

The utilities on the diagonal of the matrix will be assigned to measure levels as follows:

Alternative	HD size	Utility
Mail Order 1 20 MHZ	65 mb	0.149
Local 1 25 MHZ	80 mb	0.215
Regional 1 25 MHZ	100 mb	0.272
Local 1 33 MHZ	100 mb	0.364

In addition the endpoints for the range of the measure will be assigned the following utilities:

Least preferred level	60 mb	0.0
Most preferred level	120 mb	1.0

These assignments result in the SUF curve shown in **Figure 7- 16**.

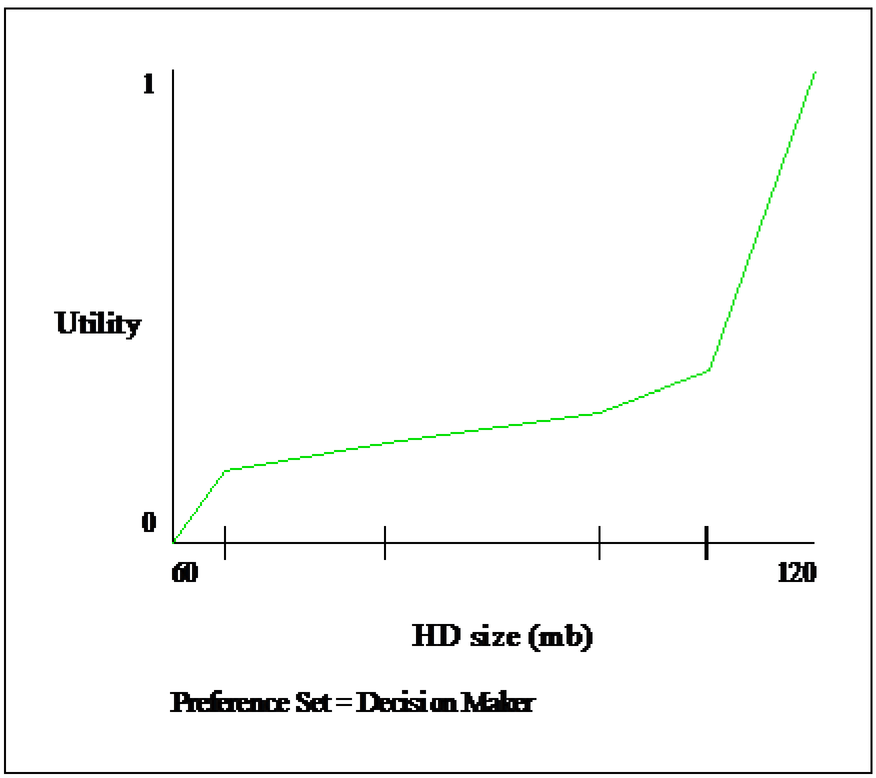


Figure 7- 16. Suf resulting from AHP SUF assessment example.

Common Units Using Direct Entry

The final method for converting to common units provided by Logical Decisions is direct entry. In this method, you directly specify the utility for each alternative. There is not necessarily any connection between the levels of the alternatives and their utility. For instance, you can assign different utilities to alternatives with the same level. Logical Decisions provides a graphical method for directly entering the utilities. When you select this method, Logical Decisions displays a screen like the one in Figure 7- 17.

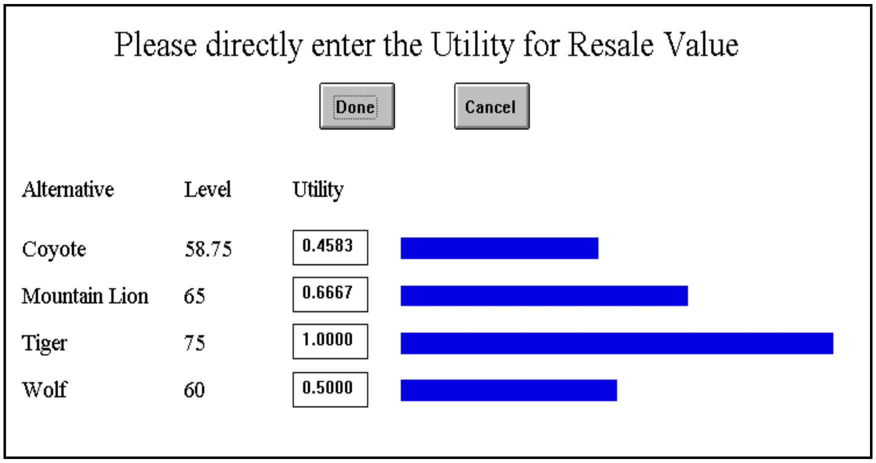


Figure 7- 17. . Direct Entry assessment screen.

In this screen, each alternative is represented by its name, its level, an edit box and a bar. The length of the bar is proportional to the utility in the edit box.

To change the utility, you can either enter a utility directly in the edit box or use the mouse to adjust the length of the alternative's bar. To adjust the bar length with the mouse, drag the end of the bar.

Click on the "Done" button when the utilities are correct to save them.

Common Units for Measures With Labels

Because labels provide a discrete rather than continuous scale for measure levels, some of the assessment methods described above are inappropriate. In particular, the SUF and AHP SUF assessment methods are not available for measures with labels. The three remaining methods are Direct Entry, the Analytic Hierarchy Process, and Adjusted AHP. Each of these methods is performed in the way described above except that the assessments are done on the list of labels rather than on the alternatives directly. The utility for each label is then applied to all the alternatives that have that label.

Assessing Weights

The weights in a preference set define the relative importances of the measures and goals in your analysis. Technically, they form the scaling constants for the Multi-measure Utility Functions (MUFs) that Logical Decisions uses to compute the utilities for the alternatives on the goals.

The process for assessing weights in Logical Decisions consists of first identifying the goals that will have their own MUFs, selecting an assessment method and completing the assessment process for each goal.

Selecting Goals With a MUF

Logical Decisions lets you select which goals in the analysis will have their own utility function (MUF) and which will not. The only goal required to have a MUF is the "Overall" goal. If the "Overall" goal did not have a MUF it would not be possible to compute an overall ranking of the alternatives.

If a goal does not have a MUF, Logical Decisions includes all of its members in the assessments for the next higher level goal. In the extreme case, only the "Overall" goal will have a MUF. Then

Logical Decisions will include all of the measures in the analysis in a common pool under the "Overall" goal when you assess weights.

At the other extreme, each goal will have its own utility function. Then, only the measures and goals directly underneath each goal will appear in the weight assessment for the goal.

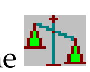
This approach lets you "compartmentalize" and simplify the weight assessments by reducing the number of members that need to be considered at once. It also lets you use different weight assessment methods for different goals, and to compute interactions for different goals.

The measures in a Logical Decisions analysis always appear in exactly one MUF.

Usually the MUF is a weighted average of the utilities of the measures and sub-goals included in the MUF.

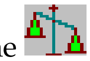
You can see Logical Decisions which goals will have their own MUF in the properties dialog box for the active preference set and in the Assess::Weights dialog box. You can use options in the Hierarchy menu to add or remove a MUF for a goal. The Hierarchy menu appears when a Goals Hierarchy view is the active window.

You add or remove a MUF for the active goal in the Goals hierarchy view, by toggling the Hierarchy::Has a MUF option.

You can also change the goals with a MUF in the  Assess::Weights dialog box. The dialog box has a mini-goals hierarchy. To add a MUF for a goal, select it and click the “Has a MUF” radio button.

You can delete the MUF for a goal in a similar manner by clicking the “No MUF” radio button.

Preparing for Assessing Weights

You prepare for and assess the weights for a goal using the  Assess::Weights option. The assess weights dialog box lets you select the weight assessment method and do the assessments for the active goal. Each goal can have its own assessment method and will have its own assessment status.

The Mini-goals Hierarchy. The “Organize/Review” tab in the assess weights dialog box contains a mini-goals hierarchy that provides information about the status of the weight assessments.

Each goal in the analysis is shown along with a symbol indicating its assessment status. A red X indicates that the goal has a MUF and that no weight assessment has been done. A Blue X indicates that the goal has a MUF and that some but not all of the weight assessments have been completed. A green check indicates that the goal has a MUF and that all needed assessments have been completed. A grey check indicates that the goal does not have a MUF.

Assessing Weights. The weight assessment options are located under the “Weights” tab in the assess weights dialog box. You select the active goal's weight assessment method from the list labeled "Weight Assessment Method:". The following methods are available:

- The "Smart" method lets you define the relative importances of the active members using "swing weights”.

- The "Smarter" method lets you define weights based on an ordering of the active members. The smarter method uses a geometric approach to find a reasonable set of weights based on your ordering.

- The "Tradeoff" method defines weights by having you compare simple alternatives that differ in two active members but that you prefer equally. Logical Decisions computes the weights that give these equally preferred pairs equal utilities for the active goal.

● The "Balance Beam" method lets you determine the weights by comparing hypothetical alternatives that have the most and least preferred levels on several different evaluation measures

● The "Pairwise Weight Ratios" method is like the "Smart" method except that you enter the relative importances of pairs of active members directly.

● The "Analytic Hierarchy Process (AHP)" is an extension of the "Pairwise Weight Ratios" method. Instead of entering ratios for selected pairs of members, you enter ratios for ALL possible pairs.

● Finally, Logical Decisions lets you directly enter the weights for the active members.

Each of these methods is discussed in detail in the following sections.

You begin the weight assessment process by clicking the "Assess" button. What happens next depends on the method you have selected.

You can restore the active goal's MUF to its initial default state by clicking the "Reset" button.

The status line below the weight assessment method tells you how much of the assessment for the active goal you have completed. A status of "Defaults Used" shows that you haven't done any assessments for the active goal or that you have initialized its MUF. "Partial Assessment" shows that you have completed part of the weight assessment but not all. Finally, "Assessment Complete" shows that you have completed all of the needed assessments for the selected method.

You can review or make changes by clicking the "Assess" button even if the status says "Assessment Complete".

The check box labeled "Allow Representatives for Sub-Goals" lets you use a member of a sub-goal as its representative in the weight assessment. Logical Decisions infers the sub-goal's weight from the member's weight in the active goal's assessment and its weight in the sub-goal's MUF. Not all assessment methods allow the use of representatives.

Assessing Weights with Tradeoffs

The "Tradeoff" method defines weights for a goal by having you identify pairs of simple alternatives that differ in two members but that you prefer equally. Logical Decisions identifies weights for the two members that give these equally preferred pairs an equal utility for the goal.

Each tradeoff defines the ratio of the weights for the two members in the tradeoff. These ratios --plus the fact that the weights must sum to one -- let Logical Decisions compute the weights for all the goal's members from the tradeoffs. This computation is more complicated if there are interactions between the members. The discussions on page 344 and in Appendix A describe how Logical Decisions computes weights using tradeoffs in more detail.

You begin the tradeoff assessment process by clicking the "Assess" button in the “Weights” tab in the assess weights dialog box.

When you do this you will see the tradeoffs dialog box shown in Figure 7- 18.

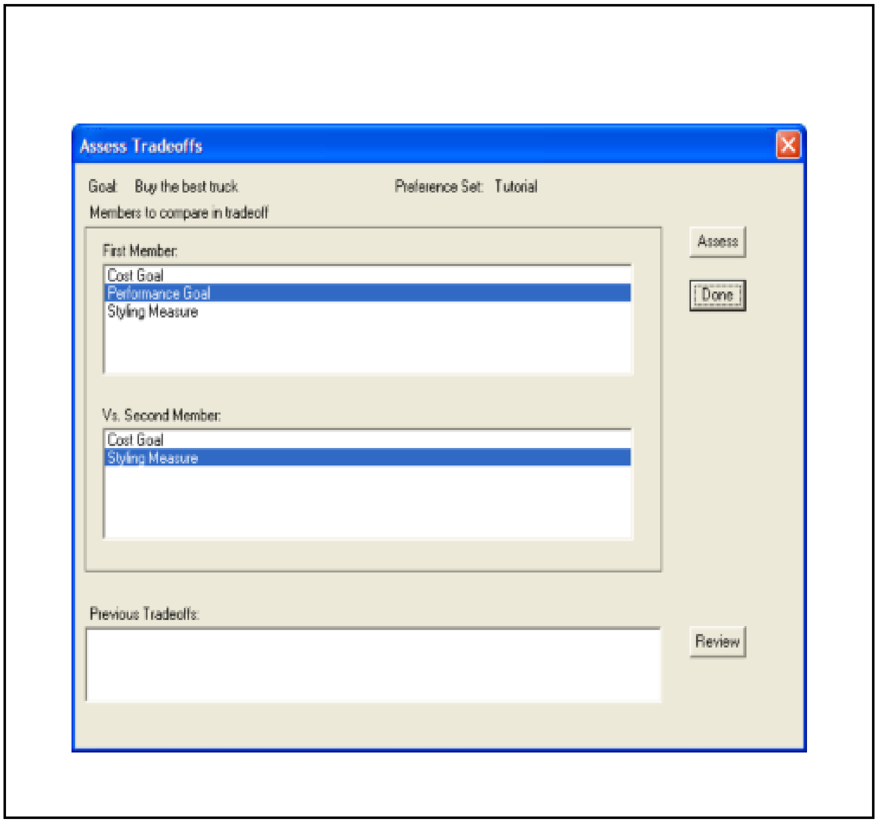


Figure 7- 18. Assess tradeoffs dialog box.

This dialog box lets you select pairs of members and assess a tradeoff for them. You select one member from the list labeled "First Member:". Logical Decisions will update the list of allowable second members based on the first member you select.

Only "non-redundant" pairs are allowed. Non-redundant tradeoffs define a weight ratio that can't be computed based on the other tradeoffs.

When you have selected two members to compare in a tradeoff, click the "Assess" button to begin the tradeoff process.

Selecting Representatives. If you select a goal as a tradeoff member and you have selected the "Allow Representatives for Sub-Goals" option in the assess weights dialog box, Logical

Decisions will next ask you to select a representative for the goal to use in the tradeoff. You can select the goal itself or any of the goals or measures under that goal as the representative.

Next you will see a tradeoff assessment window like the one shown in **Error! Reference source not found.**.

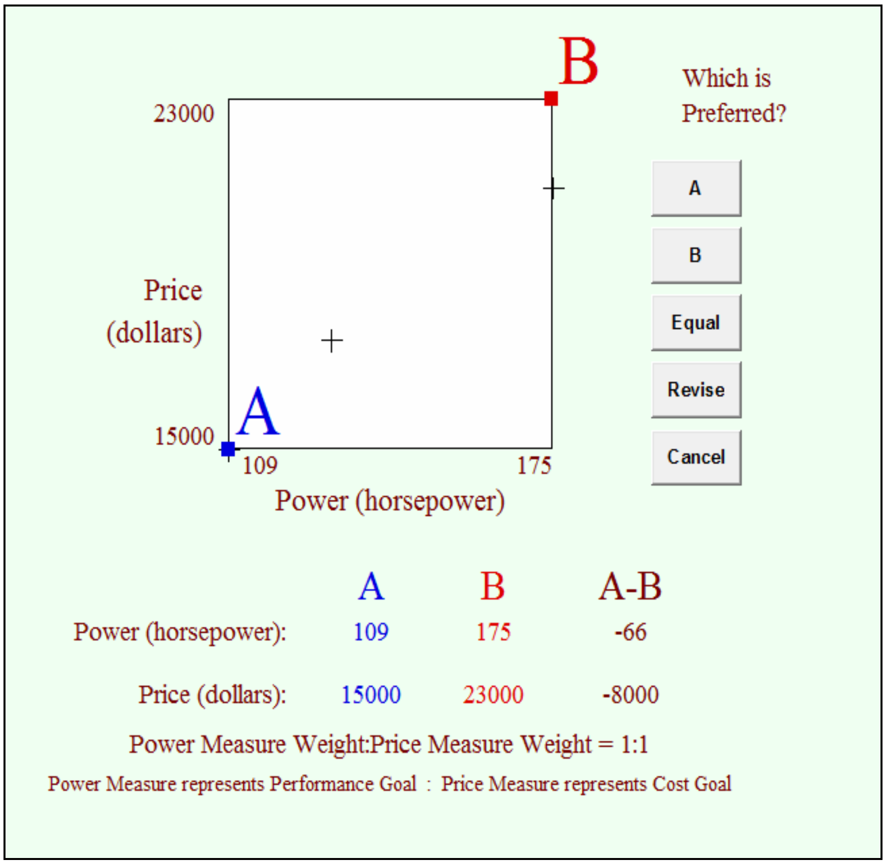


Figure 7- 19. Initial screen for tradeoff assessment

The graph's axes are the ranges of the members. Each point on the graph represents a possible alternative with a particular level on each of the two members.

You should assume that each possible alternative has the nominal level on the members not shown. Logical Decisions plots the actual alternatives' levels on the two members as crosses on the graph.

Logical Decisions labels two particular alternatives on the graph. Alternative **A** has the most preferred level on the first member and the least preferred level on the second member. Alternative **B** has the opposite situation -- the most preferred level of the second member and the least preferred level of the first. Logical Decisions asks you to decide whether you prefer alternative **A** or **B**.

You tell Logical Decisions which you prefer by clicking one of the buttons at the right of the tradeoff assessment window. If you click the "Equal" button, the two members will be weighted equally. If you click the "A" button, Logical Decisions will ask you to improve the **B** alternative by improving its level on the first member. If you click the "B" button, Logical Decisions will ask you improve the **A** alternative by improving its level on the second member. If you would like to revise the question, click the "Revise" button. You can then modify the graph with the options in the Tradeoff menu.

If you click the "A", "B" or "Revise" button, you will begin the next part of the tradeoff assessment. Suppose **A** was less preferred. Logical Decisions will ask you to improve **A** until you prefer it equally to **B**. You do this by changing its level on the member where it had the lower utility -- "Price" in the example. There should be a point on the range of "Price" where you would prefer **A** and **B** equally.

Logical Decisions highlights the line where you should improve **A** in green. You can use your mouse to change **A**'s level on price by dragging it along the line. Logical Decisions reflects your changes in the edit box at the bottom of the window. You can also enter a new level for "Price" directly in this edit box. When you confirm the new level by pressing **Enter**, Logical Decisions moves **A** to the correct location on the graph.

When you have found a level for **A** that makes it equally preferred to **B**, click the "Equal" button to let Logical Decisions know.

Logical Decisions will ask you to confirm that the tradeoff is OK. Before confirming, Logical Decisions redraws the tradeoff using the original ranges of the members. It connects the **A** and **B** alternatives with a line of equally preferred alternatives based on the SUFs for the measures. You should feel that you prefer any point along that line equally to **A** and **B**.

If you select "OK", Logical Decisions will save the tradeoff and return to the tradeoff assessment dialog box. If you select "Delete" or "Cancel", Logical Decisions will discard the tradeoff before returning to the dialog box. If you select "Redo", Logical Decisions will return to the initial tradeoff assessment question.

Options for revising the tradeoff. The Tradeoff menu provides two methods for adjusting the ranges for the members in the tradeoff.

The Tradeoff::Revise Range option lets you directly enter revised ranges for the two members in the tradeoff. These new ranges will define the axes in the tradeoff graph but will not affect the ranges for the members elsewhere. When you select this option, Logical Decisions will let you enter the new ranges in a dialog box. Logical Decisions redraws the tradeoff question to reflect the new range and restarts the tradeoff assessment process.

The Tradeoff::Use Alternatives to Set Range option lets you automatically revise the ranges for the current tradeoff based on the alternatives in the analysis. Logical Decisions reviews the alternatives to find the one that has the most preferred level on one of the two members in the tradeoff. Since that alternative may not have the least preferred level on the other measure, it may not be necessary to give up the entire range of one measure to achieve the most preferred level of the other. This option sets each measure's least preferred level as the best level achieved by an alternative having the most preferred level on the other measure.

Example: Suppose measures 1 and 2 both range from 0 to 1, with 1 preferred. If alternative **A** = (1,0), **B** = (1,0.5), **C** = (0.25,1) then alternatives **A** and **B** have the most preferred level for measure 1 and **C** has the most preferred level for measure 2. Logical Decisions will compute measure 2's least preferred level as the best level attained on it by alternative **A** or **B** (since they have the most preferred level for measure 1). The best level for measure 2 is the 0.5 attained by alternative **B**. The least preferred level for measure 1 is the level attained by alternative **C**, or 0.25. Thus the computed ranges for measures 1 and 2 are the ranges defined by alternatives **B** and **C**: 0.5 to 1.0 for measure 1 and 0.25 to 1.0 for measure 2.

The Allow Free Float Option. Normally, Logical Decisions only lets you adjust one alternative and restricts it to the outside edge of the tradeoff assessment graph.

The <u>Tradeoff::Allow Free Float</u> option lets you move both **A** and **B** around the tradeoff assessment graph without restriction.

After you select the option, you can drag both alternatives with your mouse. You can move either alternative anywhere in the graph but you can't move an alternative outside the graph. You also can't move an alternative to a position where it is preferred to the other alternative on both members.

As you move the alternatives Logical Decisions will update their levels in the four edit boxes at the bottom of the window. You can also use these edit boxes to directly enter levels on the two members for the two alternatives.

The Directly Enter Tradeoff Option. The <u>Tradeoff::Directly Enter Tradeoff</u> option lets you directly enter the levels for the two alternatives that make up the tradeoff. When you select this option, Logical Decisions will display a dialog box where you can enter the levels for the two members in the tradeoff for the alternatives **A** and **B**. After you have entered the tradeoff, Logical Decisions will check to make sure it makes sense and can be used to compute the weights for the two members. Then Logical Decisions will redraw the tradeoff and ask you to confirm it just as it does for tradeoffs entered graphically.

Other Tradeoff Options. The two other options in the Tradeoff menu -- Tradeoff::Equal and Tradeoff::Cancel simply mimic the functions of the "Equal" and "Cancel" buttons in the tradeoff assessment window. The "Equal" button's function has already been described. The "Cancel" button returns you to the tradeoff assessment dialog box without saving the current tradeoff.

Assessing Additional Tradeoffs. After you finish assessing a tradeoff, Logical Decisions will add it to the list titled "Previous Tradeoffs" in the tradeoff assessment dialog box.

To complete the tradeoff assessments for the goal, you will need to assess as many tradeoffs as there are active members (less one). If the goal's MUF has three members, you will need to assess two tradeoffs.

To assess more tradeoffs, just select two more members (one from each list) and click the "Assess" button to begin the assessment for the next tradeoff. Continue this process until you see "No new tradeoffs needed" in the "First Member:" list. Now you can click the "Done" button to return to the assess weights dialog box.

Modifying Tradeoffs. You can modify a tradeoff you have already assessed by clicking its name in the list labeled "Previous Tradeoffs" in the tradeoff assessment dialog box and clicking the “review” button. Logical Decisions will redraw the tradeoff and will ask you if it is OK. If you click "OK" or "Cancel”, Logical Decisions won't make any changes. If you click "Delete”, Logical Decisions delete the tradeoff after you confirm. If you click "Redo", Logical Decisions will return you to the tradeoff assessment process for the tradeoff.

Assessing Weights by Direct Entry

Logical Decisions lets you directly enter the weights for a goal.

You can do this by selecting the "direct entry" method and clicking the "Assess" button in the assess weights dialog box. When you do this you will see a weight entry screen like the one in Figure 7-20.

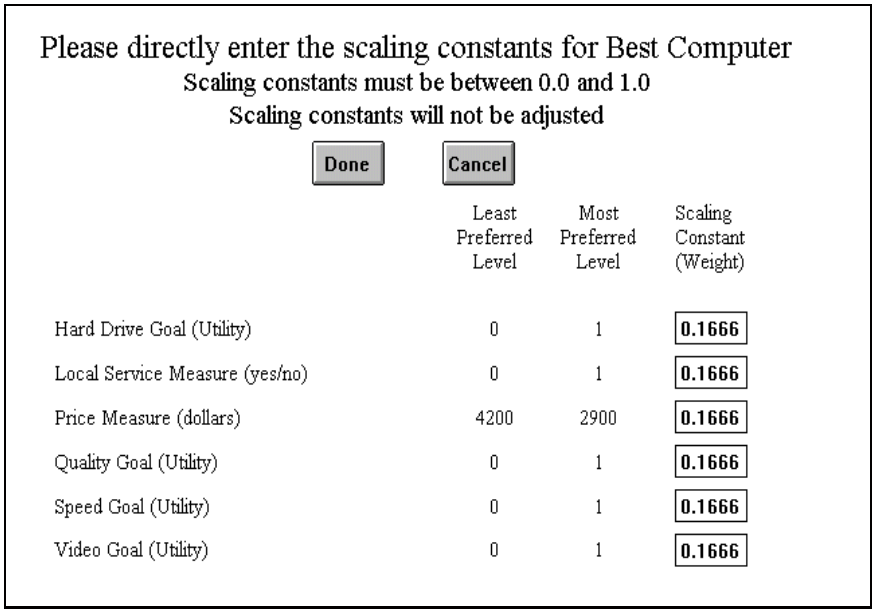


Figure 7- 20. Example of Direct Entry weight assessment screen.

This screen has an edit box for each of the active members. (Logical Decisions does not let you use representatives with the direct entry method.)

To enter the weights, just type each member’s weight in the proper edit box.

When you have finished entering the weights, click the "Done" button. Logical Decisions will let you review the weights. If you click "OK”, Logical Decisions will save the weights. If you click "Cancel" Logical Decisions won't save the weights.   In either case you Logical Decisions close the assessment window.

When using the Direct Entry option in under the “Weights” tab, Logical Decisions will adjust the weights you enter so that they sum to 1.0. Logical Decisions also has a direct entry option in under the "Interactions" tab. This option allows your weights to define interactions between the MUF members. See the discussion on page 359.

Assessing Weights with the "Smarter" Method

The "Smarter" method lets you have Logical Decisions compute the weights for the active members by simply ordering their importance. Based on your ordering, Logical Decisions computes a reasonable set of weights for the members using a "centroid" approach.

To use this method, select it from the list in the assess weights dialog box and click the "Assess" button. You will see a data entry screen like the one in Figure 7- 21.

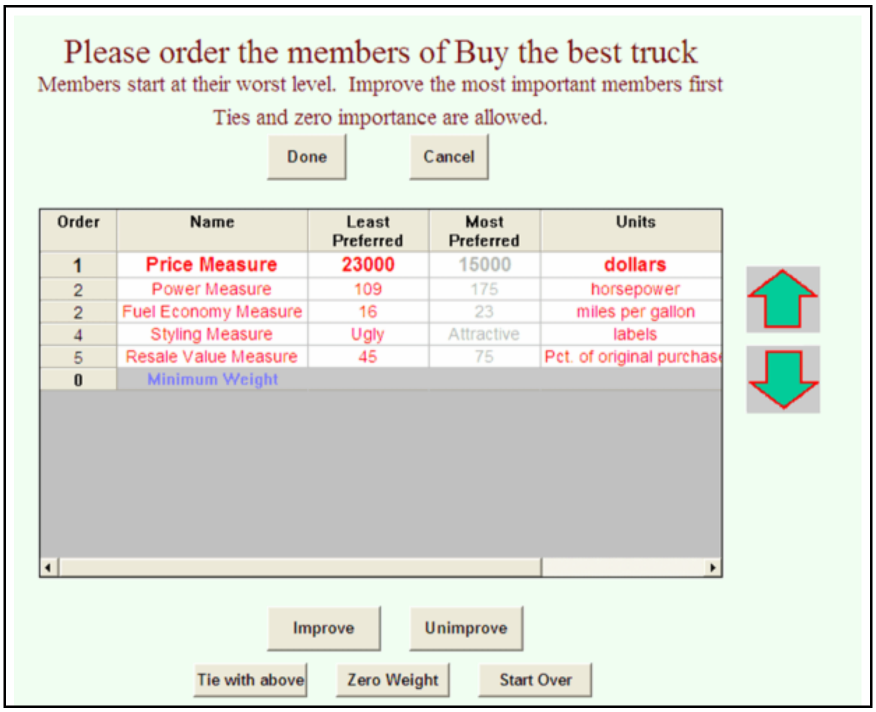


Figure 7- 21. Assessment screen for "Smarter" method

In this screen, you will see a line for each active member. (No representatives are allowed in this method.) Each line has the member's current order, name, most and least preferred levels and units.

You can think of the importance number as the order in which you would like to improve each member's level from its least preferred to most preferred level.

Initially, all of the members are at their least preferred level. To indicate this, the members are shown in red with the most preferred level greyed out.

To begin, identify the member you would most like to improve and click it in the spreadsheet. Logical Decisions will highlight it.

The "Improve" button. To improve the selected member from its least preferred to its most preferred level, click the "Improve" button. Logical Decisions moves the member to the top of the list and draws it in green with the least preferred level greyed out.

Now decide which member you would next most like to improve, select it and click the "Improve" button again. Logical Decisions will move the new member to the number 2 spot on the list and redraw it in green also.

Continue this process until you have improved all of the members and are happy with the ordering.

When you are finished, you can click the "Done" button and Logical Decisions will compute the weights and show them in the left hand column of the spreadsheet.

The other buttons in the window provide you with more flexibility in assessing the order of the members.

The "Unimprove" button. Moves the selected member below the last improved member and redraws it in red with the most preferred level greyed to indicate that the member is now at its least preferred level.

The "Zero Weight" button. Moves the member to the bottom of the list and assigns it an order of 0 to indicate it should get zero weight.

The "Tie With Above" button. Ties the selected member with the one directly above it in the ordering.

The "Start Over" button. Unimproves all members and returns them to their original ordering.

The up and down arrow buttons. Move the selected member up or down one spot in the ordering. Logical Decisions will ask you to improve a member if you move it above one that is already improved and will ask you to unimprove an improved member if you move it below an unimproved member.

Minimum weights. The smarter method tends to assign very low weights to members far down in the ordering. To prevent this, you can use the minimum weight line at the bottom of the spreadsheet to enter a minimum weight. Logical Decisions will assign the minimum weight to all members with an importance greater than zero. The minimum weight can have a value from zero to 1/n, where n is the number of members.

Assessing Weights with the "Smart Method"

The "Smart" method lets you define the relative importances of the active members using "swing weights". Swing weights are the relative importance of changing a member from its least preferred level to its most preferred level. You assign the most important member a swing weight of 100 and less important members swing weights between 0 and 100.

Logical Decisions will compute the weights for the members by adjusting the swing weights so they sum to one.

To use this method, select it from the list of weight assessment options in the assess weights dialog box and click the left "Assess" button. When you do this, you will see a data entry screen like the one in Figure 7- 22.

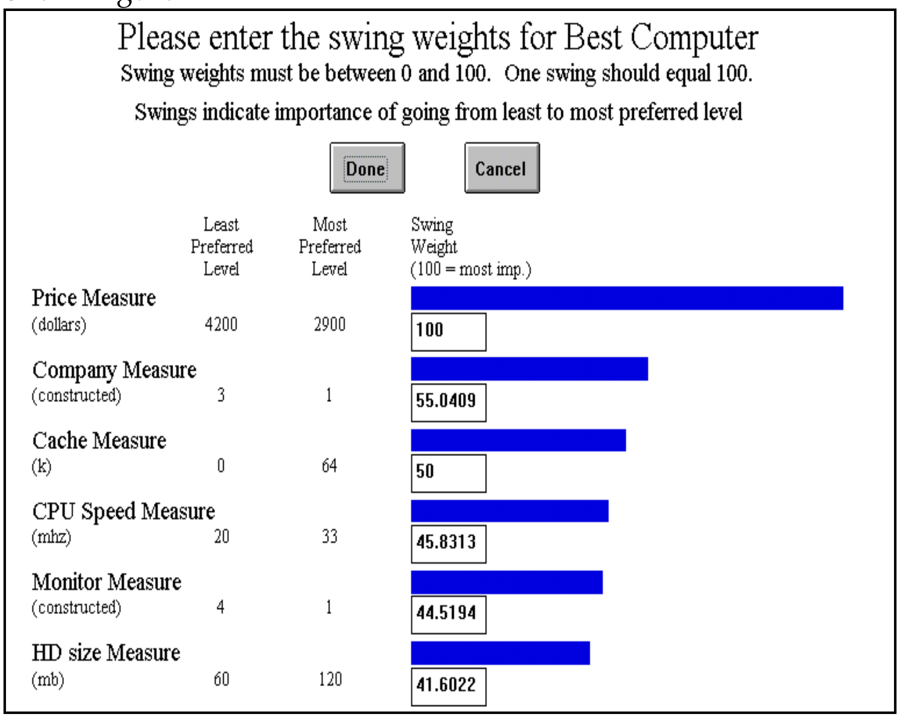


Figure 7- 22. Assessment Screen for Smart Method

Representatives are allowed for sub-goals in this method. If you have checked the "Use Representatives for Sub-Goals" option in the assess weights dialog box, Logical Decisions will ask you to select a representative for each active sub-goal. These representatives appear instead of the goal they represent in the assessment window.

Each member or representative has a line showing its most and least preferred level. At the left of each line is an edit box where you can enter each member's swing weight and a bar where you can adjust swing weights graphically.

You can think of the swing weight as the relative importance of improving the member from its least preferred to most preferred level. One way to assess swing weights is to first think of an alternative with all members at their least preferred level. Then think of being allowed to improve just one member from its least preferred to its most preferred level.

When you have decided which member you would most like to improve, assign it a swing weight of 100.

Then identify the member you would next most like to improve, and assign it a swing weight that reflects your estimate of the relative importance of improving this member compared with improving the first member. For example, if you feel that improving the second member is 75 percent as important as improving the first member, give the second member a swing weight of 75.

You can continue to assign swing weights by comparing the importance of improving each of the remaining members to the first member's importance.

You can also enter swing weights by changing the lengths of the bars. To change a bar's length, drag its right hand edge.

When you have finished assigning the swing weights, click the "Done" button. Logical Decisions will adjust the swing weights so they sum to one and will let you review the adjusted weights. If you click "OK", Logical Decisions will save the weights. If you click "Cancel" Logical Decisions won't save the weights. In either case you will return to the assess weights dialog box. If you click "Redo", Logical Decisions will return to the smart method assessment screen.

Assessing Weights with Weight Ratios

The weight ratios method for assessing weights is similar to the tradeoffs method. However, instead of defining tradeoffs between pairs of members, you directly define the ratio of the weights for the members in the pair.

To begin the weight ratios assessment process, select the "pairwise weight ratios" assessment method and click the "Assess" button in the assess weights dialog box. When you do this will see the tradeoffs dialog box shown in Figure 7- 18.

This dialog box lets you define and assess the weight ratios that will define the weights for the active goal's members.

You pick a weight ratio to assess by selecting two members to compare. First you select one member from the list labeled "First Member:". Then Logical Decisions updates the list of allowable second members based on the first member you select. Only pairs that are "non-redundant" are allowed. Non-redundant weight ratios can't be computed based on the other weight ratios.

When you have selected two members you would like to compare, click the "Assess" button. You will see a dialog box that lets you directly enter the ratio of the weights for the two measures.

If you selected a goal and you had previously selected the "Allow Representatives for Sub-Goals" option in the assess weights dialog box, Logical Decisions would next ask you to select a representative for the goal to use in the ratio.

After you return to the tradeoff assessment dialog box from assessing a weight ratio, the ratio you assessed will be added to the list titled "Previous Tradeoffs". To complete the assessments for the goal, you will need to assess as many weight ratios as there are active members (less one).

To assess more ratios, just select two more members (one from each list) and click the "Assess" button to begin the assessment for the next ratio. Continue this process until you see "No new tradeoffs needed" in the "First Member:" list. Now you can click the "Done" button to return to the assess weights dialog box.

You can modify a weight ratio you have already assessed by clicking on its name in the list labeled "Previous Tradeoffs" in the tradeoff assessment dialog box and clicking the “Review” button. When you do this you will see the dialog box for assessing weight ratios with the previously entered ratio as the default.

Assessing Weights with the Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a variation on the pairwise weight ratios method for assessing weights. However, instead of selecting a minimum number of pairs of members to assess weight ratios for, you enter ratios for all possible pairs of members. Since you enter more ratios than are strictly needed, they are likely to be inconsistent. The AHP method then uses an approach based on linear algebra to compute a best fit set of weights based on the weight ratios you enter.

The AHP method for assessing weights is like the AHP method for converting measure levels to common units. You will enter the weight ratios in the same matrix used for AHP common units.

You begin the AHP weight assessment process by selecting the "Analytic Hierarchy Process" assessment method and clicking the "Assess" button in the assess weights dialog box.

Representatives are allowed for sub-goals in this method. If you have checked the "Use Representatives for Sub-Goals" option in the assess weights dialog box, Logical Decisions will ask you to select a representative for each sub-goal. These representatives will appear instead of the goal they represent in the AHP matrix.

Next you will see an assessment matrix like that in **Figure 7-16**.

l-max = 6.000 C.I. = 0.000 C.R. = 0.000	Hard Drive	Local Service	Price	Quality	Speed	Video
Hard Drive	0.166667	1	1	1	1	1
Local Service	1	0.166667	1	1	1	1
Price	1	1	0.166667	1	1	1
Quality	1	1	1	0.166667	1	1
Speed	1	1	1	1	0.166667	1
Video	1	1	1	1	1	0.166667

Figure 7- 23. Weight assessment screen for Analytic Hierarchy Process.

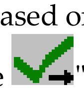
In this matrix, the rows and columns both represent active members or their representatives. The cells in the matrix represent the ratio of the importance of the row member as compared to the column member. Since the ratio of a member to itself must be one, Logical Decisions does not show the ratios on the diagonal of the matrix. Instead, Logical Decisions uses the diagonal cells to show the current weight for each member. Initially, Logical Decisions assumes that all of the members have equal importance. This means that all the ratios equal one and all the weights are equal to 0.167 (for the example in Figure 7- 23).

To complete the assessment for the AHP method, you need to enter the weight ratio for each possible pair of members. This means you need to enter a ratio in each non-diagonal cell in the matrix. Since each pair appears twice in the matrix (once above the diagonal and once below it), you really only need to enter ratios for the cells above the diagonal. Logical Decisions automatically enters the proper ratio in the corresponding cell below the diagonal.

You enter the ratios between alternatives by highlighting the cell you want to enter and typing in the ratio you think is appropriate. You can get help with this by double clicking on the cell. When you do this, you will see a dialog box like the one in Figure 7- 14 on page 158.

This dialog box helps you define the relative importance of the two members using terms created by the developers of the AHP approach. To set a weight ratio using the dialog box, first click on the radio button at the top of the dialog box that best describes the order of the members. Next click on the importance ratio ("importance strength") that best describes the ratio of importance of the better performing member to the other member. You may find the descriptions associated with the odd numbered ratios helpful in doing this. Once you have selected an ordering and an importance ratio, click OK and Logical Decisions will enter the proper ratio in the active cell.

After you have entered a weight ratio, Logical Decisions uses the AHP computation process to compute a new set of weights for the members. Logical Decisions shows the computed weights in the diagonal cells.

If you have checked the AHP::Estimate Ratios option has been checked, Logical Decisions also estimates the weight ratios for cells you have not yet entered and displays them. Logical Decisions marks cells where you have entered weight ratios in blue. Your assessment will be complete when all the non-diagonal cells in the matrix are marked in blue. You can, however, leave the assessment process at any time. The weights for the members will be computed based on the ratios you have entered to that point. Just click the "Done" button when you have completed your assessments.

The AHP process collects more preference judgments than are required to compute a set of weights. Thus, some judgments are likely to be inconsistent. Logical Decisions represents the degree of inconsistency by the numbers in the upper left corner of the matrix. The number labeled "C.I". is the "Consistency Index" for the matrix. It is an absolute measure of the consistency of the ratios in the matrix. The number labeled "C.R". is the consistency ratio and is a relative measure of consistency. The developers of the AHP approach suggest that C.R.s above 0.10 suggest that you should adjust the matrix to make it more consistent.

AHP Method Options. When you are assessing weights using the AHP method, the AHP menu item appears in the main menu bar. The options in this menu item are described on page 399.

Assessing Weights With the Balance Beam Method

The balance beam method is an approach to weights assessment that works by comparing the levels of a single (more important) member with the levels of several (less important) other members. Two alternatives are compared, one with the most preferred level on the single member and the least preferred level on the other members and the other with the least preferred level on the single member and the most preferred level on the other members. If you prefer the alternatives equally, the balance beam method sets the weight of the more important member equal to the sum of the weights of the members in the bundle.

To start the Balance Beam process, select the Balance Beam method from the list in the Assess Weights dialog box and click "Assess". You will see an assessment window similar to the one in Figure 7- 24.

Figure 7- 24. Starting screen for Balance Beam example

The example in the figure is measures for prioritizing a set of broad research initiatives. Note that in this balance beam screen, the most and least preferred levels of selected measures are shown. The first thing we want to do is order the measures.

Ordering the Measures. When you click a measure, it is highlighted as shown above. An up-down arrow also appears to the left of the measure. You can move the measure in the list by clicking the up or down arrow or with the up or down arrow keys. We'll assume the measures are already ordered from most to least important.

Setting a lower bound. Now we select the most important measure and try to establish upper and lower bounds for its score. What we are comparing are hypothetical alternatives that have either the best level on Usefulness and the worst levels on the bound measures or the worst level on Usefulness and the best level on the bound measures. Suppose we feel that having the best level on Usefulness is preferred to having the best levels on Probability of success and Time to Complete, assuming everything not mentioned is at its worst level. This means that the weight for usefulness must be greater than the combined weights of Probability of Success and Time to Complete. In other words, the two measures form a lower bound for usefulness. To show this, we make sure that Usefulness is highlighted as above and click the ovals for Probability of Success and Time to Complete as shown in Figure 7- 25.

Figure 7- 25. Setting a lower bound for Usefulness measure weight

In the figure, most of the ovals have question marks, indicating that Logical Decisions can't yet compute scores for the measures. As we add more bounds, that will become possible and Logical Decisions will replace the question marks with scores.

Adding an upper bound. Suppose we feel that the combination of Probability of Success, Time to Completion and Novelty is preferred to Uniqueness alone. We indicate that by clicking ovals in the Upper Bound column as shown in .

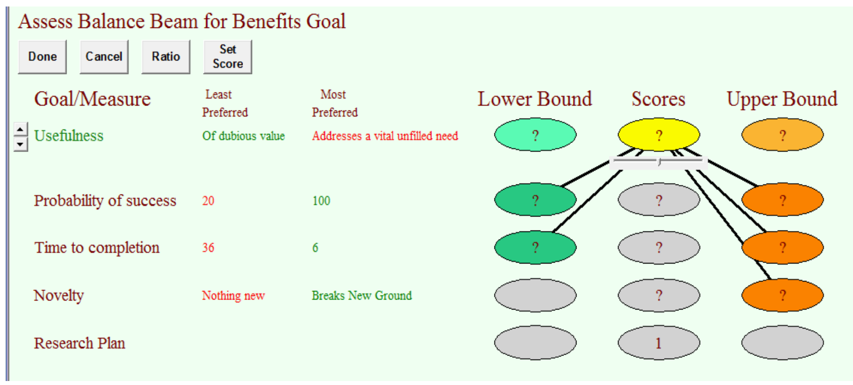


Figure 7- 26. Setting an upper bound for Mars Mission alternative score

Setting the score between the bounds. Logical Decisions needs to know where in the range between the upper and lower bounds it should set the score for the Uniqueness measure. You indicate this with the slider that appears below the yellow score circle for Uniqueness. Logical Decisions uses a default of 50% of the way between the bounds, but you can set to percentage to any number you want between 0 and 100%. When Logical Decisions is able to compute the exact scores for the upper and lower bounds, it replaces the percentages in the slider with the actual numbers in the range between the bounds.

Note that you can set an equality bound by selecting the same set of measures for both the upper and lower bound.

You continue the Balance Beam process by working your way down the list of measures and setting upper and lower bounds. Figure 7- 10 shows the Balance Beam window with upper and lower bounds marked for the Probability of Success, Time to Complete and novelty measures. The thin black lines indicate the upper and lower bounds for the measures above the selected measure in the priority list.

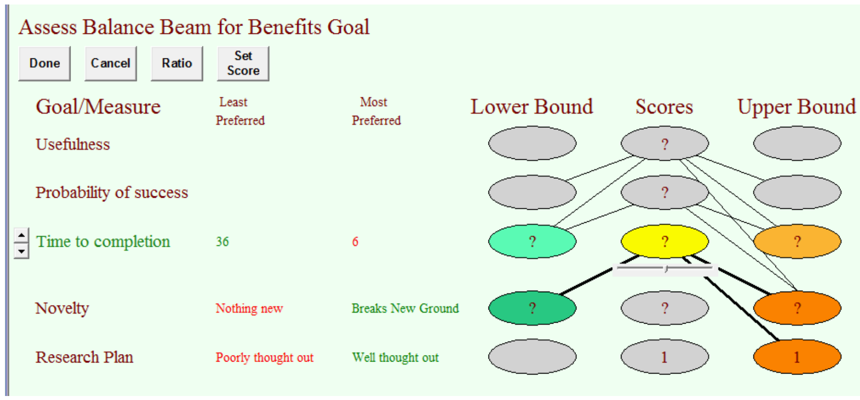


Figure 7- 27. Balance Beam with additional bounds entered

At the bottom of the priority list there are few measures to use to create bounds. For this reason, it is common to set the score for the next to last measure as a ratio to the score of the last measure. Suppose we think that Novelty is twice as important as Reseach Plan. We enter this ratio by first selecting the Novelty measure, then selecting Research Plan as a lower bound and finally clicking the "Ratio" button. After you enter "2" in the dialog box Logical Decisions will update the display as shown in Figure 7- 28.

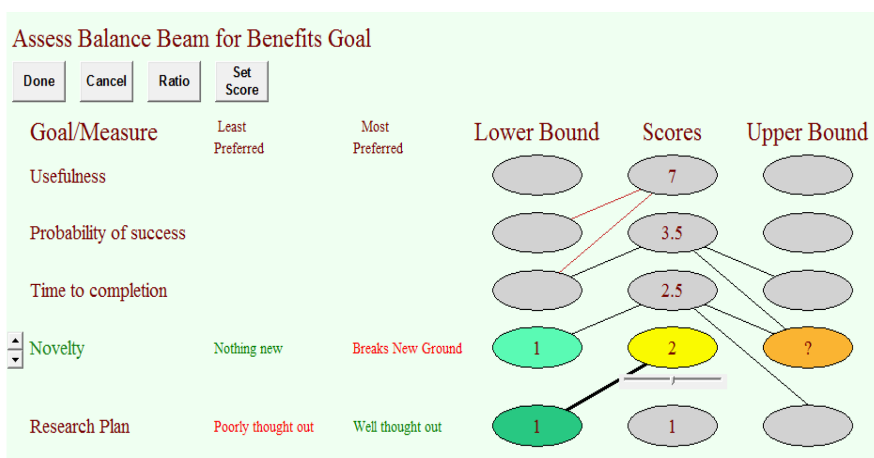


Figure 7- 28. Completed Balance Beam process

You can assign a ratio to a lower bound that includes more than one alternative if you like.

Computing the scores and weights. Logical Decisions can now compute the scores for the measures, since it assigned a score of 1.0 to the least important measure as a default. Logical Decisions computes the other scores as follows:

> Novelty's score must be 2.0 times Research Plan's score. Time to Completion's score is halfway between Novelty's score (2) and the sum of Novelty's and Research Plan's scores (3). The other scores are computed similarly.

Logical Decisions computes the weight for each measure by dividing its score by the sum of the scores for the measures.

Changing Assessment Methods

A powerful feature of Logical Decisions is its ability to convert from one assessment method to another with little loss of preference data. Thus, you could first use the "Smarter" method to get a preliminary set of weights, change the assessment method to "Smart" and see an initial set of swing weights based on the smarter weights. Or, you could assess an AHP matrix and then switch to the tradeoff approach. Logical Decisions will compute a set of tradeoffs based on the AHP weights that will be available for your review.

Defining Interactions

You can define interactions between the active members with the options under the "Interactions" tab of the assess weights dialog box. These options parallel the options for assessing weights under the "Weights" tab. Since interactions are an advanced Logical Decisions feature, you should generally use the default of no interactions. When you select no interactions, the weights will sum to one and Logical Decisions will compute the utility for the active goal as a simple weighted average of the utilities for the active members. You don't need to do any interaction assessments if you use this default option. See the discussion on page 359 for more information on interactions.

Logical Decisions provides two general categories of interactions – the multiplicative MUF formula and special interactions. The multiplicative MUF formula interaction assessment methods keep the weights you have assessed under the “Weights” tab, while the special interactions use formulas that do not require weights.

You select the method for assessing interactions for the active goal from the either the list labeled "Multiplicative MUF" or the list labeled “Special MUF Formula”. The following methods are available:

Multiplicative MUF:

- "No Interactions" -- forces the MUF formula to be additive (this is the default).

- "Set all weights" – directly defines the interactions by entering weights for all the members that do not necessarily sum to 1.0.

- "Additional Tradeoff" -- defines the interactions by entering a second tradeoff for two of the active members.

- "Probability Method" -- defines the interactions by identifying two equally preferred alternatives that involve uncertainties.

- "Set a single weight" -- directly enter the weight for a member. (This along with the weights or tradeoffs will completely define the MUF formula.)

Special MUF Formulas:

- "Multiply Utilities (AND formula)" -- computes a goal's utility as the product of the utilities of its members

- "OR formula" -- computes a goal's utility as 1 minus the product of 1 minus the utilities of its members; the formula for computing the likelihood of A OR B in probability theory.

- "Minimum Utility" -- computes a goal's utility as the minimum of its members' utilities.

- "Maximum Utility" -- computes a goal's utility as the maximum of its members' utilities.

Each of these methods is discussed in more detail in the following sections.

You begin the interactions assessment process for the selected method by clicking the "Assess" button. What happens next depends on the assessment method you have selected. You can delete any interactions information you have assessed by clicking on the "Reset" button. Logical Decisions will ask you to confirm before it initializes the interactions.

The status line above the interaction assessment method tells you how much of the assessment you have completed. A status of "Defaults Used" shows that you haven't done any interactions assessments for the active goal or that you have initialized the interactions for the goal. A status of "Completed" shows that you have completed all of the needed assessments for the selected method. You can still go back and review or make changes by clicking the "Assess" button even if the status says " Completed".

No Interactions. The "No Interactions" method forces the active goal's MUF to be the weighted sum of the utilities of the active members.

An Additional Tradeoff. The "Additional Tradeoff" method lets you define the MUF formula by assessing a second tradeoff for two active members.

You begin this method by selecting it and clicking the "Assess" button. When you do this, Logical Decisions asks you to select two members of the active goal to use in the second tradeoff. If you are using the "tradeoff" or "pairwise weight ratios" weight assessment method Logical Decisions shows you a list of the tradeoffs for the active goal.

Logical Decisions then shows you a tradeoff assessment screen like the one in the "tradeoff" weight assessment method described on page 169. Typically, the second tradeoff will include one hypothetical alternative with levels at the extremes of the measures' ranges and one with levels in the middle of the measures' ranges. Logical Decisions will let you move both members as in the Tradeoff::Allow Free Float option to do this.

For example, suppose measures m1 and m2 both range from 0 to 1 with straight line SUFs and an initial tradeoff of

(m1 = 0, m2 = 1) equally preferred to (m1 = 1 and m2 = 0)

that implies the measures have equal weights. If a second tradeoff of
(m1 = 0, m2 = 1) equally preferred to (m1 = .5 and m2 = .5)

is defined, an additive MUF formula is implied. If a second tradeoff of

(m1 = 0, m2 = 1) equally preferred to (m1 = .3 and m2 = .3)

is defined, destructive interaction, where a low utility on one measure leads to a low overall utility, is implied. If a second tradeoff of

(m1 = 0, m2 = 1) equally preferred to (m1 = .7 and m2 = .7)

is defined, constructive interaction, where a high utility on one measure leads to a high overall utility, is implied.

Probability Method. The "Probability" method lets you define the MUF Formula for the active goal by answering a probabilistic question about two goal members.

When you select the method and click the "Assess" button, Logical Decisions asks you to select two of the active members to use in the probability method assessment. If you are using the "tradeoff" or "pairwise weight ratios" weight assessment method, Logical Decisions shows you a list of the tradeoffs defined for the active goal. Then Logical Decisions shows you two simplified alternatives involving the selected members. The first alternative is an equal chance of **A**) having the first member at its best level and the second member at its worst or **B**) having the first member at its worst level and the second member at its best.

The second alternative is a probability of P of having both members at their best level and a probability (1 - P) of having both members at their worst level. See Figure 9- 16 on page 367 for an example of these alternatives. Logical Decisions asks you to identify the probability P that makes the two alternatives equally preferred.

In the first alternative the members compensate for one another. The second is all or nothing. If the two members don't interact strongly, the alternatives should seem the same and P should be 0.5. If the members interact destructively, where a low utility on one member makes an alternative undesirable, P will be between 0.0 and 0.5.

If the members interact constructively, where a high utility on only one member is needed to make an alternative desirable, P will be between 0.5 and 1.0.

Set a single weight. The Set a single weight option lets you directly enter the weight (scaling constant) for a goal member. The weight you enter can be any number between 0.0 and 1.0.

Defining one weight explicitly lets Logical Decisions adjust the other weights for the goal based on the weight assessments so that they don't necessarily sum to 1.0 resulting in a multiplicative MUF formula.

When you select this option, Logical Decisions asks you to choose a goal member and then to enter the weight for that member.

If you enter a weight smaller than the one that would have been computed based on the weight assessments alone, Logical Decisions will define a MUF formula that shows destructive interaction.

Entering a weight larger than the one that would have been computed based on the weight assessments alone will result in a MUF formula that shows constructive interaction.

Set all weights. The Set all weights option lets you directly enter the weights (scaling constants) for all of the active goal's members. Entering weights that don't necessarily sum to 1.0 results in a multiplicative MUF formula.

When you select this option, Logical Decisions display the weight entry screen used for the "Directly Enter Weights" option under the "Weights" tab, but with no requirement that the weights sum to 1.0. The only requirement is that each individual weight be between 0.0 and 1.0

If you enter weights that sum to less than 1.0, Logical Decisions will define a MUF formula that shows destructive interaction.

Entering weights that sum to more than 1.0 will result in a MUF formula that shows constructive interaction.

Special MUF Formulas

Multiply Utilities (AND formula). This option tells Logical Decisions to compute the active goal's utility as the product of the utilities of its members. No further assessment is needed. In fact, no further weight assessment is needed either, since no scaling constants are needed when multiplying utilities. All the members will effectively have equal weights. Any weight assessments done for the goal will be ignored.

Products of utilities are useful in situations where you want to treat the goal members like probabilities and the goal utility like the joint probability of all of the members (the probability of A AND B).

Products of utilities are also useful when you want to combine a "quality" measure with a "quantity" measure. An example might be measuring health care services by the number of people served and the quality of service. If the either number of people served is 0 or the quality of service is 0 then the overall health services score should also be 0. Multiplying the utilities achieves this result.

OR formula. This option tells Logical Decisions to compute the active goal's utility as the one minus the product of one minus the utilities of its members. For two measures the formula is $U = 1 – (1 – U1)(1 – U2)$. No further assessment is needed. In fact, no further weight assessment is needed either, since no scaling constants are needed when using the OR formula. All the members will effectively have equal weights. Any weight assessments done for the goal will be ignored.

The OR formula is useful in situations where you want to treat the goal members like probabilities and the goal utility like the union probability of all of the members (the probability of A OR B).

Minimum and Maximum formulas. These options tells Logical Decisions to compute the active goal's utility as either the minimum or the maximum of the utilities of the individual goal members.

The minimum or maximum formulas could be useful in situations where you have several performance categories and want each alternative's overall utility to reflect its performance on the category it does best in.

Printing Questionnaires

The Assess::Print Questionnaire option lets you print a copy any of Logical Decisions' preference assessment screens. This lets you obtain a hard copy of the preference assessment question(s) currently being posed by Logical Decisions. You can then distribute the questionnaire to participants in the study who may not be available for direct questioning. When you select this option, Logical Decisions displays a copy of the of the currently displayed assessment screen. Any assessment edit boxes on the screen are replaced by underlines. Questionnaires for AHP assessment screens have all possible pairs in the matrix in a format that lets users graphically indicate relative importances.

Consistency Checks for Tradeoff Method

The Assess::Consistency Checks option lets you compute the tradeoff implied between any two measures. You can also revise the existing tradeoffs if the computed tradeoff does not look reasonable. You can only make these adjustments if you have used the "tradeoffs" weight assessment method for all goals with a MUF.

When you select this option, Logical Decisions asks you to select two measures. The program computes and displays a tradeoff between the two selected measures implied by the current MUF. Logical Decisions then asks you if you would like to adjust this tradeoff. If you say **y**es, you will use the assessment procedure from the Assess::Weights::Tradeoffs option to identify a new tradeoff between the selected measures. This procedure will result in two new simplified alternatives involving the two selected measures that you should prefer equally, but that have different utilities on the current MUF.

To make the equally preferred alternatives in the new tradeoff have the same utility, you must modify an existing tradeoff. The program identifies all of the existing tradeoffs that could influence the new tradeoff and displays them. Logical Decisions asks you to select the tradeoff you would like to modify. In some situations, it is possible to replace the selected tradeoff with the new tradeoff just assessed. If it is possible, Logical Decisions asks you if you would like to replace the old tradeoff with the new.

If you retain the old tradeoff, there are several ways Logical Decisions can make the adjustments. The simplest way is to adjust the original tradeoff and make no changes to the other tradeoffs. This has the desired result of making the new tradeoff hold, but may have side effects of changing the relative weights of other measures. More complex adjustments are possible, which preserve as many of the original weights as possible while still making the consistency tradeoff hold. Thus, when you get to this stage of the consistency check, Logical Decisions shows you the picture in Figure 7- 29. In this figure, the measures have been grouped according to those whose relative weights must be adjusted simultaneously. The circles in this figure represent the relative weights of the measures in the different sets. The lines connecting the circles represent one or more tradeoffs. In particular, the line connecting sets B and C represents the single tradeoff being adjusted. The two consistency check measures will be in sets B and C respectively. Logical Decisions gives you three options for adjusting these sets.

- **Adjust Weights for All Sets**. The tradeoff being adjusted is represented in the figure by the line connecting set B to set C. If only this tradeoff is changed, the weights of sets A and B will change in relation to sets C and D, but the relative weights of sets A and B and of sets C and D will not change. In terms of the picture, the size of the circles for sets A and B will become proportionally larger or smaller in relation to the circles for sets C and D.

- **Adjust Weights for Set B Only**. In this option Logical

Decisions holds the relative weights of sets A, C and D constant, while it changes the relative weight of set B. To do this, Logical Decisions must adjust the tradeoff(s) connecting sets A and B and the tradeoff connecting sets B and C. In terms of the figure, the relative size of the circles for sets A, C and D will remain constant, while the circle for set B will get larger or smaller.

- **Adjust Weights for Set C Only**. This option is like the previous option, except that set C is the one that changes relative to the others.

- **Cancel.** This option aborts the consistency check process without making any changes.

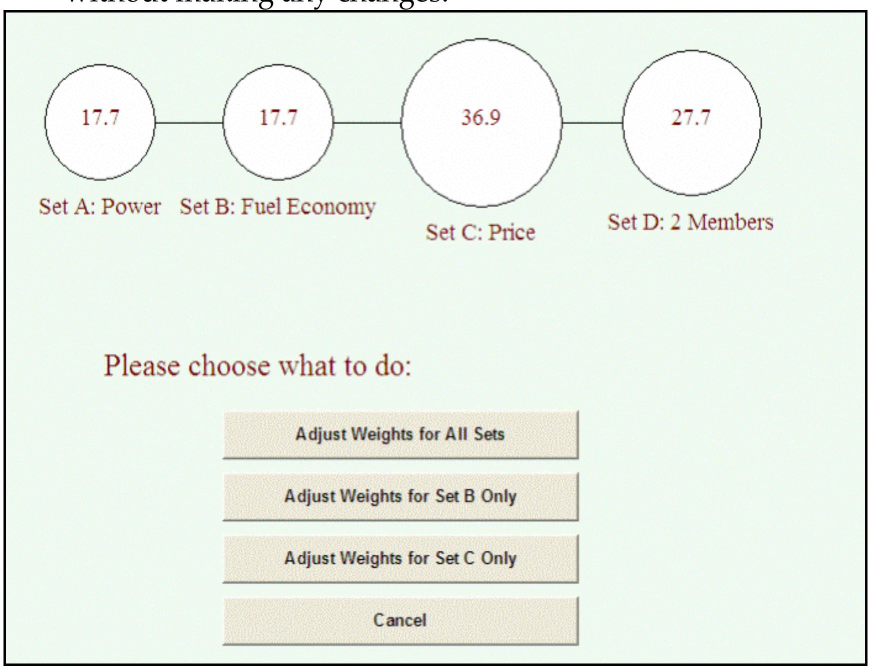


Figure 7- 29. Options for consistency check adjustments

When you select an option, the program begins adjusting tradeoffs. For each tradeoff that Logical Decisions modifies, it shows you a screen displaying the original tradeoff and the proposed adjustment. You can accept or reject any of the proposed adjustments. When the adjustments have been completed, Logical Decisions shows you a graph with the effects of the adjustments, like that in Figure 7- 30. There, the "Adjust Weights for Set B Only" option has been selected, and the circle for Set B has gotten larger while the circles for the other three sets have gotten proportionally smaller.

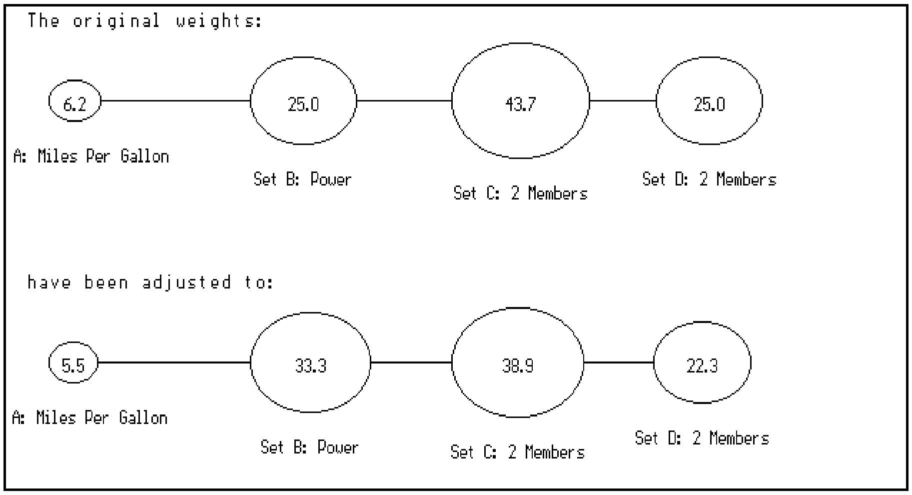


Figure 7- 30. Effects of consistency check adjustments

SECTION

Using Logical Decisions 3: Reviewing Results

8

Using Logical Decisions 3: Reviewing Results

Introduction

This section describes the Logical Decisions' displays for reviewing your analysis. Typically you will look at these displays after you have finished structuring your problem and assessing preferences. Often, reviewing these displays will motivate you to return to the structuring and preference assessment steps to make adjustments. This is a normal and important part of the decision analysis process.

This section also describes how to print displays and how to save them or copy them to other Windows programs.

It also includes information on how to modify your results displays. Logical Decisions provides options to change the colors and text fonts of your charts and tables as well as to add new text labels.

Finally, this section describes the options under the File menu, where you open and close Logical Decisions data files and where there are options to import and export Logical Decisions data to and from other formats such as spreadsheets.

Reviewing Your Preferences

Logical Decisions lets you to generate several displays of the information in a preference set. The following displays are available:

- Common Units Graphs
- Computations of Utilities from Levels

- Graphs of Single Tradeoffs
- Tradeoff Bubble Diagrams
- Tradeoffs Computed Against a Single Measure
- Graphs of Pairs of Measures
- A Summary of All Comments in the Analysis
- Preference Assessment Summary
- Percentage Weights
- Scaling Constants
- SUF Formulas
- Weight Graph

Each of these displays can be selected with a Review menu item.

Common Units (SUF) Graphs

Single measure utility functions (SUFs) convert the level (or "raw score") of a measure into the common units of "utility". You can display the SUF for any measure by selecting the Review::Common Units option.

The option duplicates the SUF assessment screen in the Assess::Common Units option in a form that lets you print it or copy it to the clipboard.

When you select the option, you first select a measure to display. Logical Decisions then displays the SUF for that measure for the active preference set. An example is shown in Figure 8- 1.

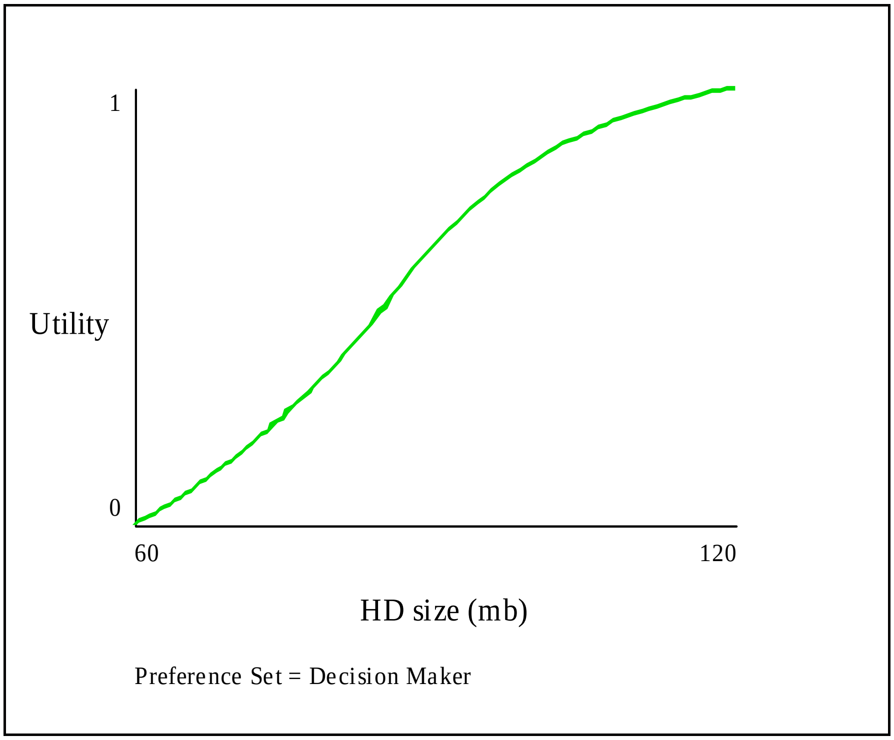


Figure 8- 1. Example of Review::Common Units display

The horizontal axis (X-axis) of this display shows the nominal units and range for the measure. The vertical tics on that axis show the levels on the measure for the alternatives. The vertical axis (Y-axis) is in units of utility (usually scaled from zero to one). The curve shows how the utility function converts any level in the measure's nominal units to a utility.

For measures that use labels, Logical Decisions also lets you display the SUF as a histogram similar to that used in the direct assessment method. Just click “Yes” to the question Logical Decisions asks when you select this option.

Computing Utilities From Measure Levels

The Review::Compute Utilities option lets you compute utilities for a measure based on its SUF in the active preference set. You can also use the option to compute the measure level on the measure that would result in a particular utility.

When you select this option you will see the dialog box in Figure 8- 2.

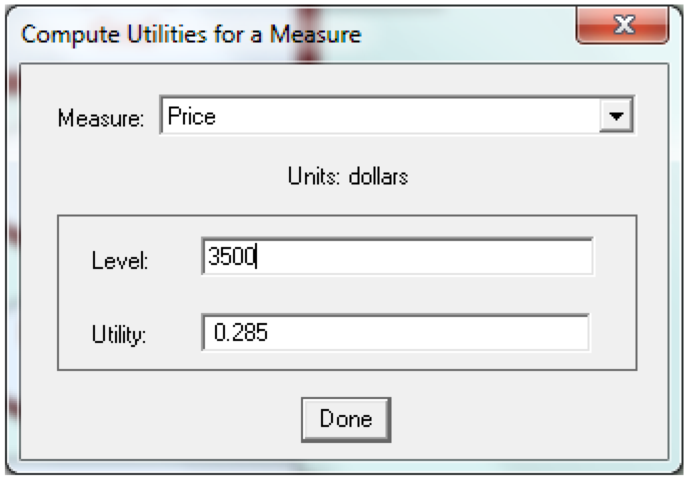


Figure 8- 2. Dialog box for Review::Compute Utilities option.

To select the active measure, just choose it from the combo box at the top of the dialog box. To compute the utility for a level on the active measure, just enter a level in the edit box labeled "Level:". After you press **Enter**, Logical Decisions will display the utility for that level in the edit box labeled "Utility:".

To compute the level that would result in a particular utility, just enter a utility in the edit box labeled "Utility:". After you press **Enter**, Logical Decisions displays the level that would result in that utility in the edit box labeled "Level:".

Graphs of Single Tradeoffs

The Review::Single Tradeoffs option duplicates the tradeoff assessment screen in the Assess::Weights option in a form that lets you print, or copy it to the clipboard.

Logical Decisions lets you select any pair of measures or goals to display. If you select a pair of measures that were not assessed directly in a tradeoff, Logical Decisions will compute a tradeoff for the pair. Logical Decisions will indicate this by printing "Tradeoff computed by Logical Decisions" at the bottom of the tradeoff window.

When you select the option, Logical Decisions shows you a dialog box with two lists of the currently defined measures and goals. Just select one member from each list and Logical Decisions will compute and display a tradeoff for the pair. An example is shown in Figure 8- 3.

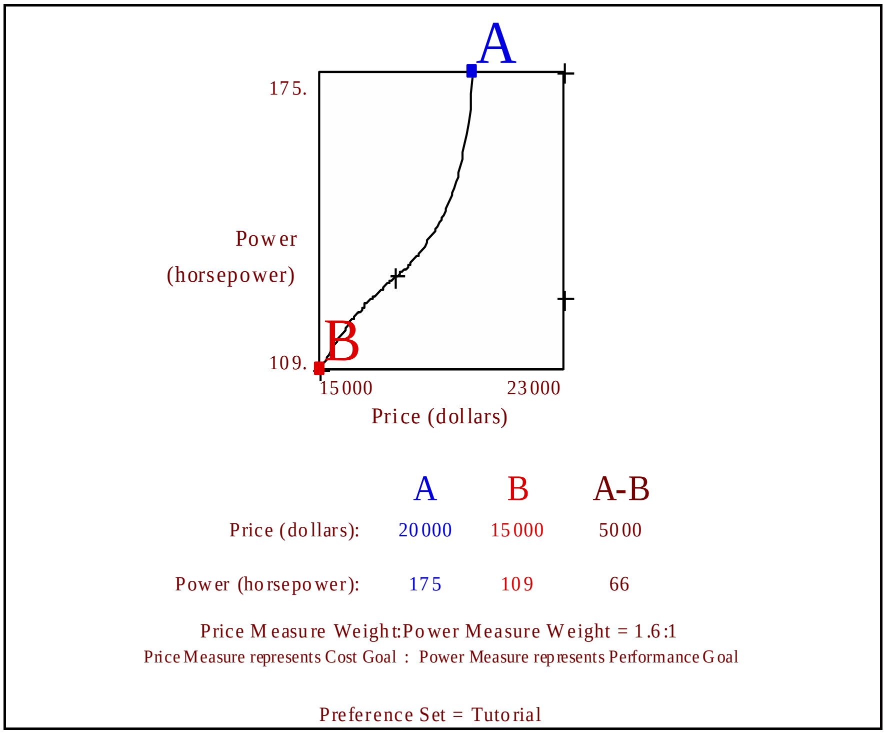


Figure 8- 3. Example of Review::Single Tradeoffs option

The tradeoff graph has one measure (or goal) on the horizontal axis and one on the vertical axis. You can think of any point in this rectangle as a simplified alternative that has the indicated levels on the two measures and a nominal level on all of the other measures.

For example, a point in the upper left corner of the rectangle represents a truck alternative with a price of $15,000 and 175 horsepower. A point in the lower right corner represents a truck alternative with a price of $23,000 and 109 horsepower. A point in the very center of the rectangle would represent a truck alternative with a price of $18,500 and 142 horsepower. Logical Decisions marks actual alternatives with small crosses showing their levels on the two measures.

The points labeled "A" and "B" on the graph represent a pair of simplified alternatives that you should prefer equally. Thus, above, you should prefer a truck alternative with a price of $15,000 and 109 horsepower and one with a price of $20,000 and 175 horsepower equally. The line connecting the A and B points represents a set of potential price/horsepower combinations that you should prefer equally to A and B. Logical Decisions computes this line based on the single measure utility functions for the price and horsepower measures.

The line at the bottom of the display shows the relative weights of the two measures. The relative weights are those necessary to allow points A and B to have the same overall utility given the ranges of the two measures and their single measure utility functions. In the display above, the price measure will have about sixty percent more weight than the horsepower measure. The absolute weights of these two measures will depend on the number of other measures in the analysis and their relative weights based on other tradeoffs. You can view the tradeoff relationships for all the measures with the Review::Tradeoff Summary Graph option.

Tradeoffs by One Measure

The Review::Tradeoffs by One Measure option lets you review the relative importance of the various measures by computing tradeoffs for all of them against one selected measure. For example, you could select this option to see how each of the measures in your analysis would be traded against price, even if another weight assessment method were used or not all tradeoffs were done against price. When you select this option, Logical Decisions will ask you to select a measure to compute the tradeoffs against. Then, Logical Decisions will compute the tradeoffs and show them in a display like that in Figure 8- 4.

Tradeoffs computed against Price

	A	B
Price (dollars)	20000	15000
Fuel Economy (miles per gallon)	23	16
Price (dollars)	20000	15000
Power (horsepower)	175	109
Price (dollars)	19000	15000
Resale Value (Pct. of original purchase price)	75	45
Price (dollars)	17000	15000
Styling (labels)	1	5

Preference Set = Tutorial

Figure 8- 4. Example of Review::Tradeoffs By One Measure option.

In the figure, each measure (besides the selected one) has a tradeoff, comprised of lines showing the levels for the measure and the selected measure for equally preferred alternatives **A** and **B**.

Tradeoff Summary Graphs

Tradeoff summary graphs show a network of lines and circles that show which measures you compared in tradeoffs and the relative weights that resulted from the tradeoffs.

You can display a tradeoff "bubble diagram" for the active preference set by selecting the Review::Tradeoff Summary Graph option.

When you select the option, you are first shown the dialog box in Figure 8- 5.

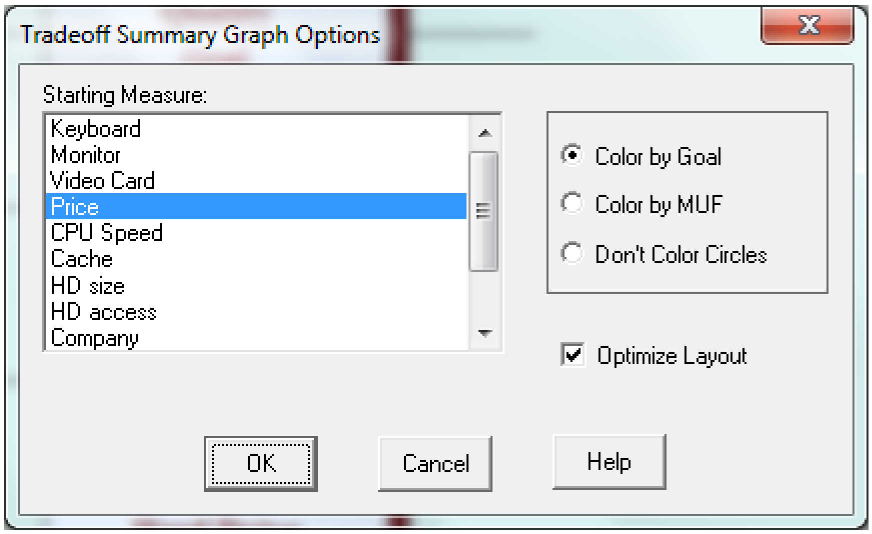


Figure 8- 5. Dialog box for Review::Tradeoff Summary Graph option.

The measure selected from the list at the left of the dialog box determines which measure will be in the upper left corner of the bubble diagram. The radio buttons at the right of the dialog box determine how the diagram will be colored. The "Don't Color Circles" button results in a diagram with black outlined circles with white interiors. The "Color by Goal" button results in the circle for each measure colored based on the goal the measure is directly below. The "Color by MUF" option results in the circle for each measure colored based on the MUF the measure belongs to. If you check the "Optimize Layout" button, Logical Decisions will attempt to reduce the area of the diagram by rearranging the locations of the circles in the diagram. Not checking the option will result in a longer but narrower diagram.

An example of a tradeoff summary graph is shown in Figure 8- 6.

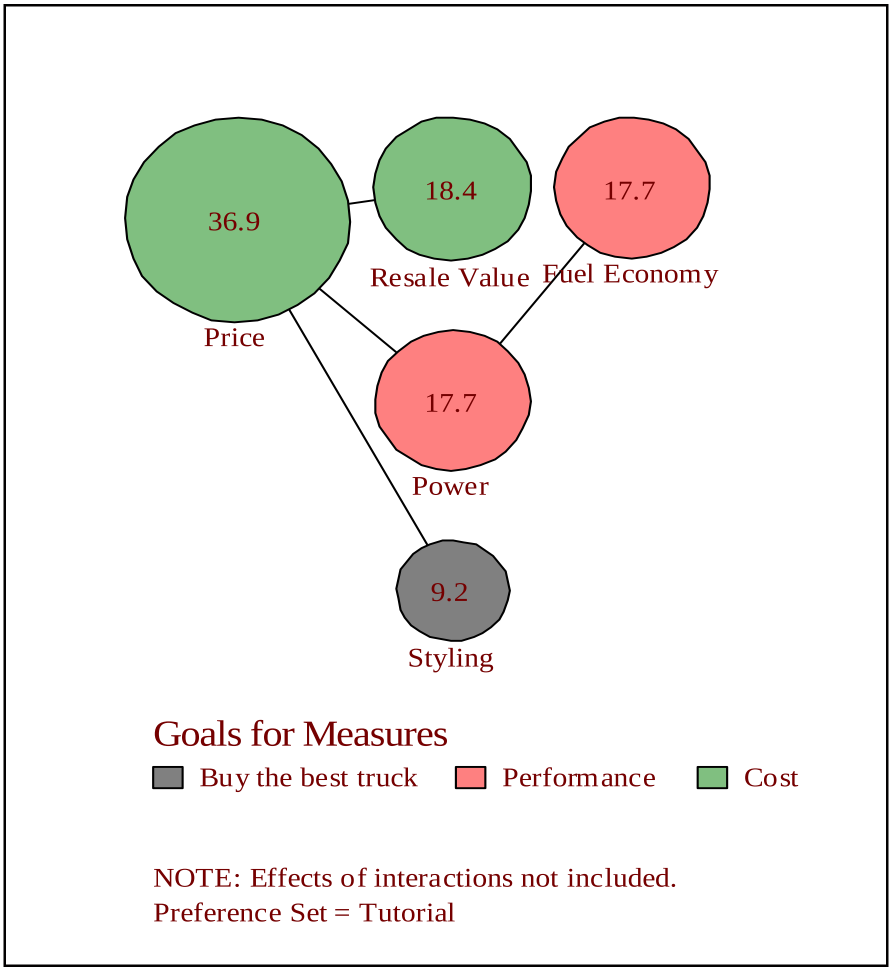


Figure 8- 6. Example of Review::Tradeoff Summary Graph option.

In the diagram, the measure "Price" was selected from the dialog box and appears in the upper left. The "Price" measure was included in a tradeoff with the "Power" measure as shown by the line connecting the "Power" and "Price" circles. The relative size of the two circles shows that the weight for the "Power" measure is about half of the weight for the "Price" measure. The lines show that the "Fuel Economy" measure appears in only one tradeoff while the "Price" measure appears in all but one tradeoff.

In the diagram, you can also see the relative weights for measures not directly compared in a tradeoff. For example Logical

Decisions computes the relative weights of the "Price" and "Fuel Economy" measures indirectly by comparisons with the "Price" and "Power" measures. The relative size of the circles shows that the "Fuel Economy" measure also has about half as much weight as the "Price" measure.

The numbers in the circles represent the percentage weights for the measures computed by keeping the proper ratios between the weights of the measures and forcing the weights to sum to 100 percent.

Graph Pairs of Measures

The graph pairs of measures display lets you view sets of equally preferred levels on two measures.

You can view the graph pairs of measures display by selecting the Review::Graph Pairs of Measures option. When you select it, Logical Decisions will display the dialog box shown in Figure 8- 7.

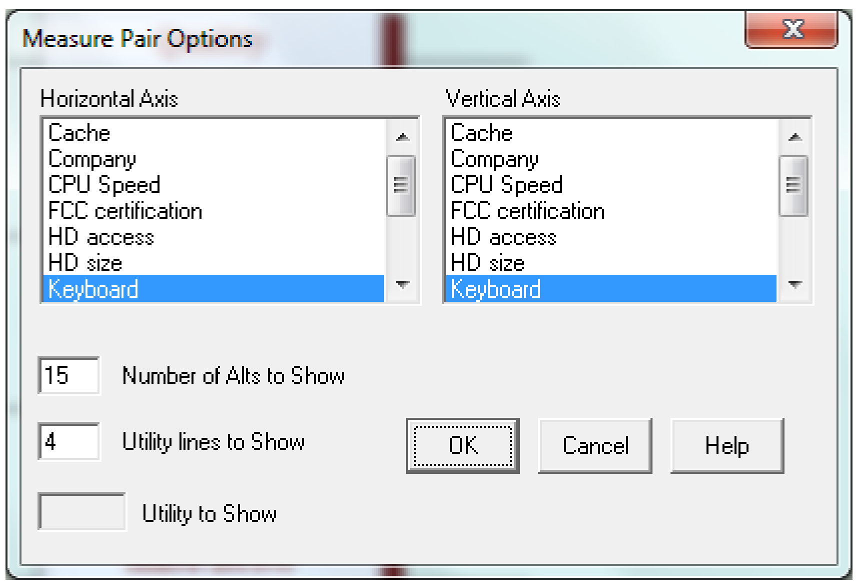


Figure 8- 7. Dialog box for Results::Graph Pairs of Measures option.

The dialog box has two lists of measures, one for the horizontal axis and one for the vertical axis. The edit box labeled "Number of

Alts to Show" determines the number of alternatives to show as small crosses in the figure. Logical Decisions will display the alternatives with the highest overall utility. The edit box labeled "Utility Lines to Show" determines how many "iso-utility" lines Logical Decisions will draw in the figure. The lines will be color coded, with red lines indicating lower utilities and green lines indicating higher utilities. You can select up to 250 lines. Selecting a large number of lines will result in the area of the graph being almost completely covered with varying shades of red and green. If you select only one line, you can enter the utility to show with the single line in the edit box labeled "Utility to Show". Logical Decisions will display 10 points along the line and will label them with their levels on the selected measures (see Figure 8- 9).

When you click "OK", Logical Decisions will display a graph like the one in Figure 8- 8.

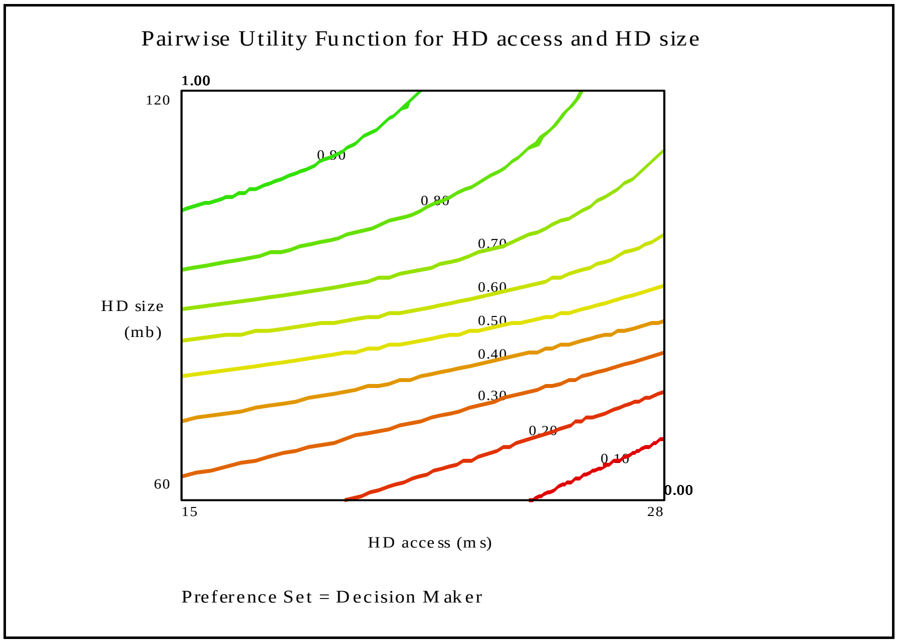


Figure 8- 8. Example of Review::Graph Pairs of Measures option.

The graph is like the tradeoff graph from the <u>Review::Single Tradeoffs</u> option. It shows a rectangle with one measure on the horizontal axis and one on the vertical axis. You can think of any point in this rectangle as a simplified alternative that has the indicated levels on the two measures and a nominal level on all of the other measures. For example, a point in the upper left corner of the rectangle represents a computer alternative with a hard disk size of 120 mb and a hard disk access time of 15 ms (the best hard drive in the rectangle). A point in the lower right corner represents a computer alternative with a hard disk size of 60 mb and a hard disk access time of 28 ms. A point in the very center of the rectangle would represent a computer alternative with a hard disk size of 90 mb and a hard disk access time of 21.5 ms.

The lines on the graph represent sets of simplified alternatives that you prefer equally.   Logical Decisions labels each line with the utility that would be assigned to that line if the two measures were the only ones in the analysis and had their own Multi-Measure Utility Function (MUF) based in their relative weights and Single Measure Utility Functions. Crosses that appear on the graph represent the levels of actual alternatives on the two measures. Figure 8- 9 shows an example of the option with a single utility line of u = 0.75 displayed. Logical Decisions draws 10 points along the line and labels them with their levels on the horizontal axis and vertical axis measures.

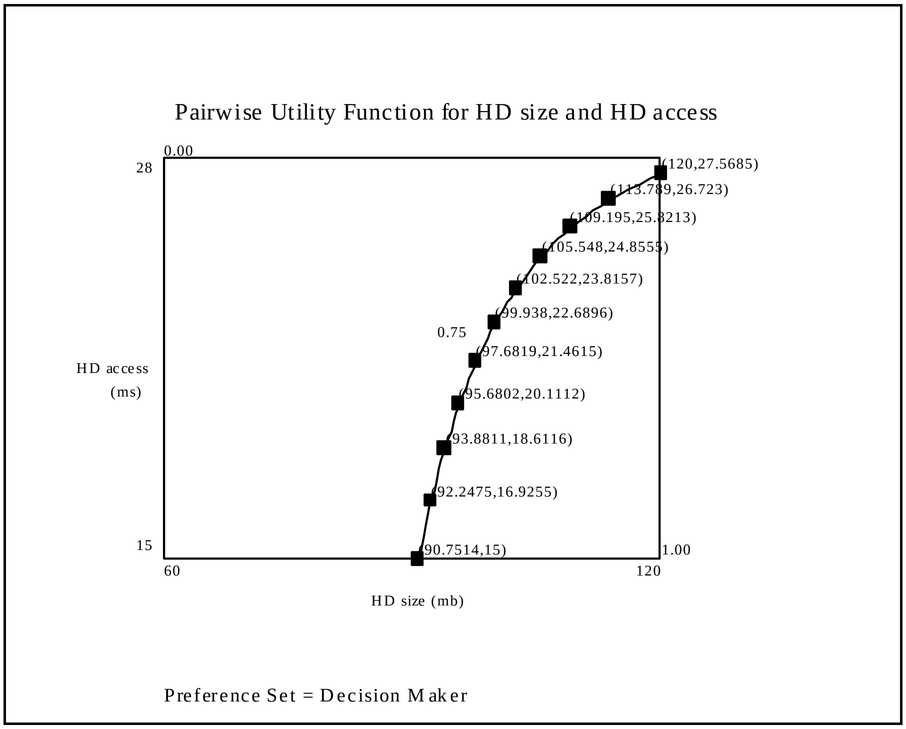


Figure 8- 9. Review::Graph Pairs of Measures option with one utility line.

Comments Summary

The Results::Comments Summary option displays a table with the comments from each of the objects in the current analysis. When you select this option, Logical Decisions will display a table similar to that shown in **Figure 8-10**

```
Comment for entire Buying a Computer analysis
 This analysis is to select a computer system for small business use.
 The systems are based on technology circa 1989.

Comments for Alternatives

Regional 1 20 MHZ Alternative:
 This is a 20 MHZ machine from a regional company in the area of the
  decision maker but requiring about a 2 hr drive.

Regional 1 25 MHZ Alternative:
 This is a 25 MHZ machine from a manufacturer in the area of the decision
  maker but requiring about a 2 hr. drive.

Local 1 25 MHZ A Alternative:
s is a 25 MHZ machine from a local manufacturer.
```

Figure 8- 10. Partial example of Review::Comments Summary display

Clicking on the comment for any goal, measure, alternative or preference set will tell Logical Decisions to display its properties dialog box. You will be able to edit the comments, but not to make any other changes.

Assessment Summary

The Results::Assessment Summary option displays a table with a summary of the preference assessments done for the active preference set. When you select it, Logical Decisions will display a table like that shown in Figure 8- 11.

Assessment summary for Preference Set MAUT Oriented

Common units

Fuel Economy: A continuous single-measure utility function with the following ranges:

range	least preferred Level	least preferred Utility	most preferred Level	most preferred Utility	mid-preference Level	mid-preference Utility
0	17.4556	62	21	100	18.6	94
1	16	0	17.4556	62	17.1889	31

Power: a Utility function assessed using adjusted AHP:

	Chevy S-10	Dodge Dakota	Dodge Ram-50	Ford Ranger	Mitsubishi	Toyota
Chevy S-10	0.0752433	0.25	1	0.5	2	0.5
Dodge Dakota	4	1	3	2	4	3
Dodge Ram-50	1	0.333333	0.0467244	0.5	1	0.5
Ford Ranger	2	0.5	2	0.338732	2	1
Mitsubishi	0.5	0.25	1	0.5	7.64363e-18	0.5
Toyota	2	0.333333	2	1	2	0.303684

Consistency Ratio = 0.281751

Price: A continuous single-measure utility function with the following ranges:

range	least preferred Level	least preferred Utility	most preferred Level	most preferred Utility	mid-preference Level	mid-preference Utility
0	15000	0	9000	100	12280	51

Resale Value: A continuous single-measure utility function with the following ranges:

range	least preferred Level	least preferred Utility	most preferred Level	most preferred Utility	mid-preference Level	mid-preference Utility
0	45	0	75	100	60	50

Styling: utilities assessed directly:

Label	Utility
Attractive	1
Muscular	0.9175
Nondescript	0.2475
Mediocre	0.07
Ugly	0

Weights

Performance: a Utility function assessed with the SMARTER method:

Member	Importance Order
Fuel Economy Measure	1
Power Measure	2
Minimum Weight	0.3

No interactions assessed

Best Truck: a Utility function based on these tradeoffs:

	A	B
Styling (beauty)	0	1
Price (dollars)	9000	12000
Price (dollars)	13000	9000
Power (horsepower)	175	106.091

Interactions assessed with a second trade off:
tradeoff not assessed yet

Appearance: a Utility function with directly entered Weights:

Member	Weight
Styling Measure	1

No interactions assessed

Cost: a Utility function assessed with the SMART method:

Member	Swing Weight
Price Measure	100
Resale Value Measure	50

Interactions assessed with probability question involving
Resale Value Measure and Price Measure -- answered 0.45

Figure 8- 11. Example of Review::Assessment Summary option.

The information provided in the assessment summary varies depending on the assessment methods used. Separate sections are provided for conversion to common units and for weight assessment. Information about probabilistic levels is also included.

Percentage Weights

The Percentage Weights table lets you view the weights for the measures for the current preference set. You can view the percentage weights table by selecting the Review::Weights::Percentage Weights option. When you select it, Logical Decisions displays a table like the one in Figure 8- 12.

Percentage Weight for Preference Set Decision Maker

Measure	Percentage Weight	Effective Weight
Price	20.12	20.29
Company	11.07	11.37
Cache	10.06	10.33
CPU Speed	9.22	9.46
Monitor	8.96	6.90
HD size	8.37	8.61
FCC certification	7.76	7.96
Review	6.45	6.63
Local Service	6.45	6.63
Video Card	5.04	5.17
Keyboard	3.50	3.59
HD access	2.99	3.07

Figure 8- 12. Example of Review::Weights::Percentage Weights display.

Logical Decisions displays the weights as percentages that sum to 100 percent. It includes all measures in the analysis, no matter which goal they belong to or whether individual goals have their own MUFs. The table does not include any effects from interactions.

The first column, labeled "Percentage Weights", contains the weights that result from using the "nominal" ranges of the measures defined using the dialog box for each measure.

The second column, labeled "Effective Weight" contains the weights that would result if the range for each measure specified in its properties dialog box corresponded to the range of the alternatives on that measure. If the alternatives vary over a wider range than the properties range for a measure, the effective weight will be higher than the percentage weight (assuming no changes in the other measure's ranges). Conversely, if the alternatives vary over a narrower range than the properties range, the effective weight will be lower than the percentage weight. In the extreme case where the alternatives all have the same level on a measure, the effective weight will be zero, since that measure does not help to distinguish between the alternatives. This may be true even if the measure has a very high percentage weight. All of the other displays in Logical Decisions are based on the percentage weights rather than the effective weights.

MUF Formulas

The MUF Formulas display lets you view the scaling constants that define the Multi-measure Utility Functions (MUFs) for the current preference set.

You can view the MUF Formulas table by selecting the Review::Weights::MUF Formulas option. When you select it, Logical Decisions displays a table like the one in Figure 8- 13.

Scaling Constants for Preference Set Decision Maker

Best Computer Goal has K = 0, defined by tradeoffs and no interactions
Hard Drive Goal weight = 0.1136
Local Service Measure weight = 0.0645
Price Measure weight = 0.2012
Quality Goal weight = 0.2878
Speed Goal weight = 0.1928
Video Goal weight = 0.1400

Hard Drive Goal members are in Best Computer Goal MUF
HD access Measure weight = 0.0299
HD size Measure weight = 0.0837

Quality Goal members are in Best Computer Goal MUF
Company Measure weight = 0.1107
FCC certification Measure weight = 0.0776
Keyboard Measure weight = 0.0350
Review Measure weight = 0.0645

Speed Goal members are in Best Computer Goal MUF
CPU Speed Measure weight = 0.0922
Cache Measure weight = 0.1006

Video Goal members are in Best Computer Goal MUF
Monitor Measure weight = 0.0896
Video Card Measure weight = 0.0504

Additive MUF formula used if K = 0,
Multiplicative MUF formula used otherwise.

Figure 8- 13. Example of Review::Weights::MUF Formulas display.

In this table, each goal has a line that describes the method used to compute its MUF. The line also shows the "Big K" scaling constant that defines the degree of interaction between the members of that goal.

The first goal displayed is the "Overall" goal, which always has a MUF. If a lower level goal does not have its own MUF, its line shows the MUF that includes its members. All of the measures in an analysis are included in exactly one MUF, as are all of the goals that have their own MUF. Goals that do not have their own MUF do not appear explicitly in any other MUF.

Under each goal is a line for each of the goal's members. The line for each member includes the "small k" scaling constant (weight) for that member in the MUF it belongs to. The Big K scaling constant for a goal plus the small k scaling constants for the lower level goals and measures in the goal's MUF uniquely define the formula for the MUF. See Section 9 and the Appendix for more information on how the scaling constants define a MUF.

Goals that do not have their own MUF (such as the Quality goal in the figure) are not included explicitly in the MUF of the goal they belong to. The scaling constant on the line for that goal (0.2430 for the Quality goal) is simply the sum of the scaling constants of the goal's members (Company, FCC Certification, etc., for the Quality goal).

SUF Formulas

The SUF Formulas display lets you view the scaling constants that define the Single-measure Utility Functions (SUFs) for the measures for the active preference set.

You can view the SUF Formulas table by selecting the Review::Weights::SUF Formulas option. When you select it, Logical Decisions displays a table like the one in Figure 8- 14.

SUF Formulas for Preference Set Decision Maker

Range		Midpoint		SUF Parameters		
Minimum	Maximum	Level	Utility	a	b	c
CPU Speed						
25	33	29	0.85	-0.2375	0.0375	0
20	25	22.5	0.35	-2.8	0.14	0
Cache						
32	64	48	0.7	-0.2	0.01875	0
0	32	16	0.2	0	0.0125	0
Company						
0	1	0.5	0.5	0	1	0
FCC certification						
0	1	0.5	0.5	0	1	0

SUF Parameters: if c = 0, U(x) = a + bx, if c # 0, U(x) = a + b(EXP(-cx))

Figure 8- 14. Example of Review::Weights::SUF Formulas display.

In this table each measure's SUF has one or more lines. Each line represents the SUF formula for one sub-range of the measure's utility function. SUFs in Logical Decision can have several sub-ranges that cover the range of the measure specified in its properties dialog box.

Each line in the table contains the following information. The Minimum column contains the minimum level for the sub-range. The Maximum column contains the maximum level. The Level column identifies the measure level for which a utility was assessed. The Utility column is the utility value assigned to the midpoint level. The last three columns define the SUF formula for the sub range. If the "c" column is zero, the formula for the sub-range is U(x) = a + bx, while if the "c" column is non-zero, the formula is $U(x) = a + be^{-cx}$.

Graph Weights

The Graph Weights display lets you view a bar graph of the weights for the goals and measures for the active preference set.

You can view the Graph Weights window by selecting the Review::Weights::Graph Weight option. When you select this option, Logical Decisions displays a dialog box like the one in Figure 8- 15.

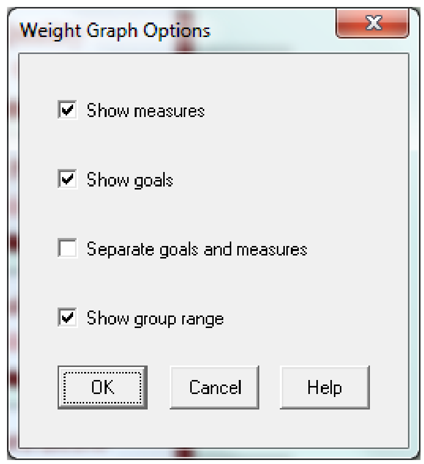


Figure 8- 15. Dialog box for Graph Weights option

When you click OK, Logical Decisions displays a graph like the one in Figure 8- 16.

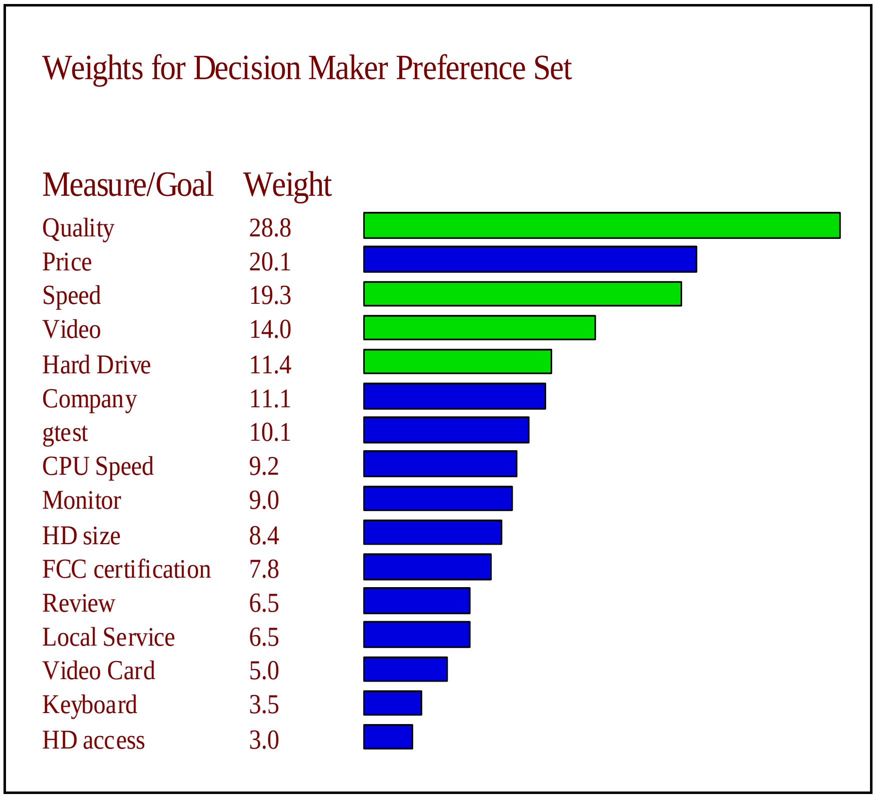


Figure 8- 16. Example of Review::Weights::Graph Weights display.

In this graph each goal and measure has a bar proportional to its weight. Goals have green bars and measures have blue bars. The bar length for a goal is the sum of the bar lengths for all of the measures beneath it in the goals hierarchy.

Viewing Your Results

Logical Decisions lets you generate displays of ranking results based on the active preference set. The following displays are available:

- Rank Alternatives
- Stacked Bar Ranking
- Measure Equivalents Ranking

- Uncertainty Summary
- Dynamic Sensitivity
- Sensitivity Graph
- Sensitivity Table
- Scatter Diagrams
- Efficient Frontier
- Ranking Results Graph
- Ranking Results Matrix
- Preference Set Summary
- Cutoff Summary
- Graph an Alternative
- Alternative Uncertainty Graph
- Compare Alternatives

Each of these displays can be selected with a menu item in the Results menu.

Rank Alternatives

The rank alternatives display lets you show a ranking of the alternatives based on any of the goals or measures. The ranking is based on the active preference set.

You can view the rank alternatives display by selecting the Results::Rank Alternatives option. When you select it, Logical Decisions displays the dialog box shown in Figure 8- 17.

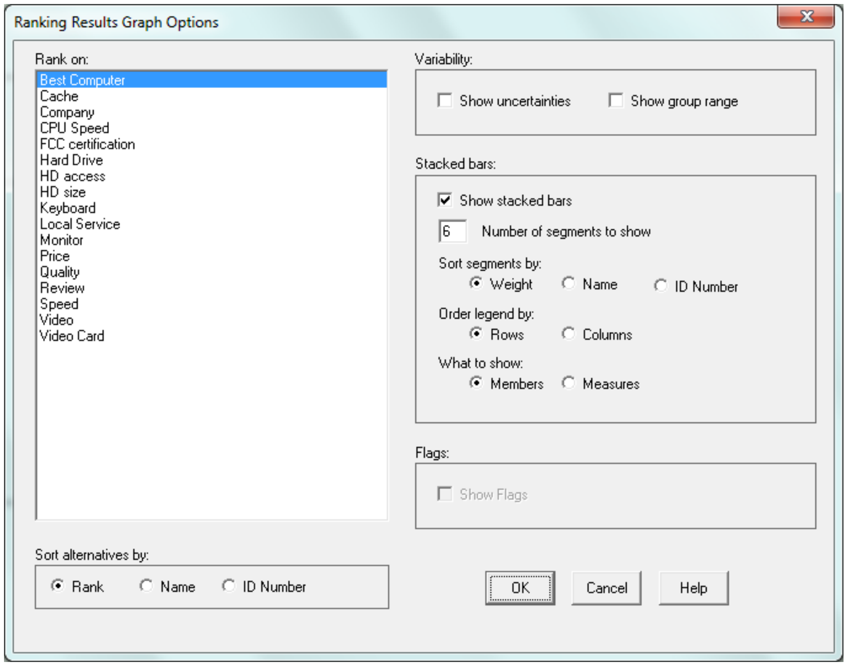


Figure 8- 17. . Results::Rank Alternatives dialog box

You select a goal or measure to rank on from the list at the top of the dialog box. If you check the "Show Uncertainties" button, Logical Decisions will add a bar showing the range of uncertainty for each alternative.

If you click the “Show stacked bars” option, Logical Decisions will created a stacked bar graph where the bar for each alternative is made up of sub-bars representing the alternative’s utility on lower level measures or goals. The options in the Stacked bars box control how the bars are created. The “What to show” buttons control whether the bars represent the members at the lowest level of the hierarchy below the selected goal or the members (goals and measures) directly below the goal in the hierarchy. The number of bars to show controls the maximum number of sub-bars to show for each alternative. If there are more measures or goals than the number you select, Logical Decisions creates an “Other” bar. The “Sort segments by” option controls the order in which the sub-bars are displayed. Finally, the “Order legend by” options control whether the legend for the sub-bars increases by rows then columns or columns then rows.

The “Sort alternatives by” options let you sort the alternative bars by the rank (utility), name or ID Number or each alternative.

The “Show flags” option lets you display flags for the alternatives. See page 111 for a discussion of flags.

The When you click "OK", Logical Decisions will display a bar chart like the one in Figure 8- 18 is shown.

Figure 8- 18. Example of Results::Rank Alternatives display

Selecting the "Overall" goal gives you the overall ranking results for the analysis. If you select a measure rather than a goal, Logical Decisions also shows the measure level for each alternative. The black lines for the alternatives represent the range of uncertainty for each alternative. Alternatives failing one or more cutoffs are shown with yellow bars. All other alternatives are shown with green bars.

The uncertainty bar shows the following details: bar ends - minimum and maximum results from the simulation; small circles

- 5% and 95% points; short lines - 25% and 75% points; long line - median.

Figure 8- 19 shows an example of the rank alternatives display with the stacked bars option selected.

Figure 8- 19. Rank alternatives option with stacked bars

In the figure, each alternative has a bar with length proportional to its utility on the selected goal. This bar is made up of other bars that show the influence of the various measures and goals on the utility result.

If an alternative has a long bar for a member, it means that the member is important and that the alternative does well on it. If the bar for a member is short, it means that the member is relatively unimportant or that the alternative does relatively poorly on the member.

Not all alternatives will have bars for all members, since some alternatives may have a utility of 0.0 (no contribution) for a member.

Measure Equivalents Ranking

The Results::Measure Equivalents Ranking option lets you display an overall ranking of the alternatives along with the levels on a particular measure that would result in the same overall utilities *if all other measures had their most preferred levels*.

You can use the measure equivalents ranking to compare alternatives using an indicator other than overall utility.

Figure 8- 20 shows an example of a measure equivalents ranking based on price. Each equivalent in the figure represents the price of an "equivalent" truck that you should prefer equally to the alternative if the "equivalent" truck had the most preferred level on all of the measures besides price.

Thus you should equally prefer the "Mountain Lion" (with a price of $17,500) and a truck with the most preferred level on each measure except a price of $24,511.70, given the preferences set called **Decision Maker.**

Equivalent Levels of Price (dollars)

Alternative	Utility	Equivalent
Coyote	0.647	22668
Mountain Lion	0.562	24511.7
Tiger	0.358	28925.8
Wolf	0.310	29976.6

Preference Set = Tutorial

Figure 8- 20. Example of Results::Measure Equivalents Ranking option.

Uncertainty Summary

The Results::Uncertainty Summary option lets you view a table summarizing the uncertainties for the alternatives with respect to a single measure or goal. When you select it, Logical Decisions will display the dialog box shown in Figure 8- 21.

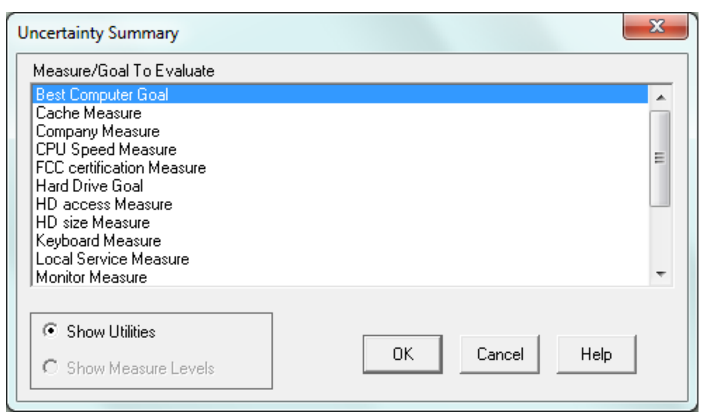


Figure 8- 21. . Dialog box for Results::Uncertainty Summary option.

In the dialog box, the list tells Logical Decisions which measure or goal to prepare the table for. If you select a measure, you can select to show either measure levels or utilities in the table by clicking one of the radio buttons at the bottom of the dialog box.

When you click "OK", Logical Decisions will display a table like the one in Figure 8- 22.

Utility uncertainty summary for Best Truck Goal

Alternative	Mean	Std. Dev.	Median	Min.	5%P	95%P	Max.
Coyote	0.686	0.038	0.695	0.626	0.626	0.730	0.730
Mountain Lion	0.616	0.028	0.616	0.559	0.573	0.670	0.682
Tiger	0.347	No uncertainties					
Wolf	0.265	0.035	0.267	0.149	0.204	0.324	0.367

Preference Set = Tutor

Figure 8- 22. Example of Results::Uncertainty Summary option.

In the figure, each row represents an alternative and each column represents one aspect of the uncertainty for the alternative on the active goal or measure. The results are based on a Monte Carlo simulation for each alternative using the simulation parameters set using the Preferences::Simulation Preferences option.

All of the columns should be self explanatory except for the 5%P and 95%P columns. The 5%P column represents a utility which only five percent of the simulation trials were below, while the 95%P column represents a utility which only five percent of the simulation trials were above.

Dynamic Sensitivity

The Results::Dynamic Sensitivity option lets you quickly see the effects of changes in the weights for the goals and measures. When you select the option, Logical Decisions will display the dialog box shown in Figure 8- 17 and then draws a window with two panes as shown in Figure 8- 23.

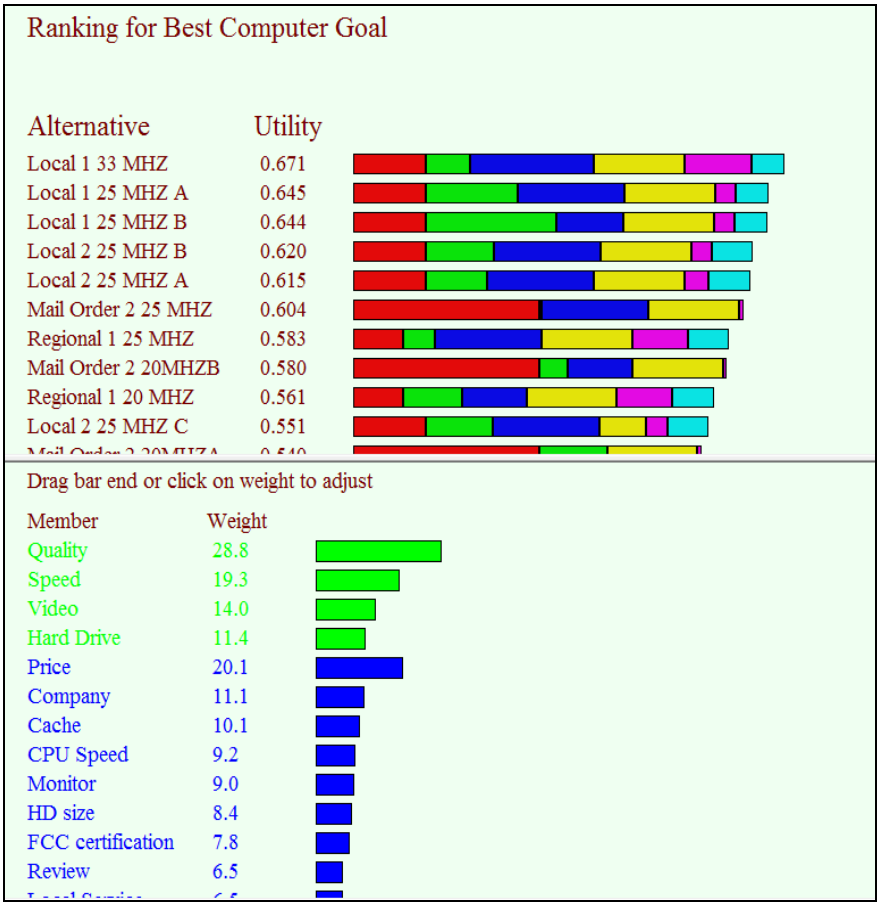


Figure 8- 23. Example of Results::Dynamic Sensitivity option.

In the window, the upper pane shows the current overall utilities for the alternatives. The lower pane shows the weights for the goals and measures. (The weights are adjusted to sum to 1.0 if there are interactions).

Goals are shown in green at the top of the pane, and measures are shown in blue below the goals. You can temporarily adjust the weight for a measure or goal in the lower pane and see the effect on the alternatives' utilities in the upper pane.

You adjust a weight for a measure or goal by changing the length of its bar. To change a bar's length, you drag its right hand edge. When finish dragging, Logical Decisions will redraw the bar and the weight for the member will be updated based on the bar's proportional length.

You can also directly enter a new weight by clicking on the current weight. An edit box where you can enter the new weight will appear.

After you adjust a weight, the weights for the other goals and measures will be increased or decreased to ensure that the weights sum to 1.0. Logical Decisions will then use these adjusted weights to recalculate the overall utilities for the alternatives. The upper pane will be adjusted to reflect the new utilities.

The changes you make in the dynamic sensitivity graph are only temporary. When you close the window the weights and alternative utilities will revert to what they were before.

Dynamic Sensitivity Options. The Sensitivity menu appears when you select the Results::Dynamic Sensitivity option. It has three options.

The Sensitivity::Restore Weights option restores all of the weights (and bars) to the values they had when you first created the window.

The Sensitivity::Save Weights option saves the current weights in a new preference set called "Sensitivity". The other information, such as the single measure utility functions (SUFs), is copied from the active preference set with no change.

The Sensitivity::Local Weights option displays the weights for the goals and measures under the active goal rather than the overall weights in the dynamic sensitivity window.

Sensitivity Graphs

Sensitivity graphs let you display the effect of varying a measure or goal's weight from 0 to 100 percent.

You can view a sensitivity graph by selecting the Results::Sensitivity Graph option. When you select the option, Logical Decisions shows you the dialog box shown in Figure 8- 24.

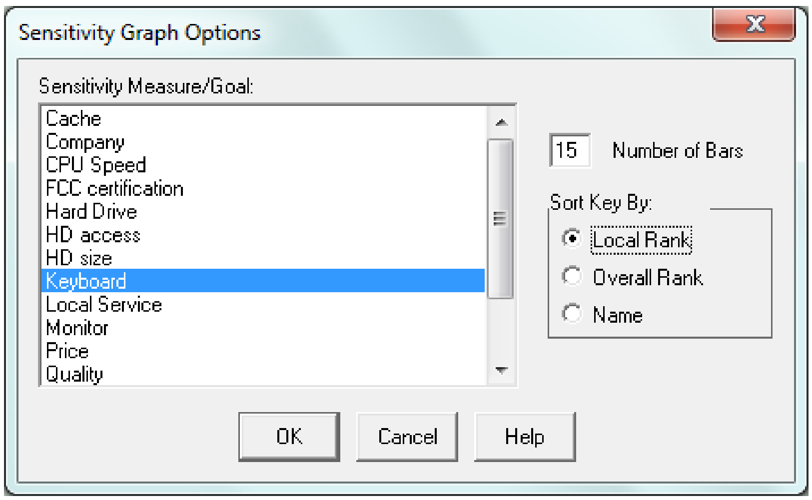


Figure 8- 24. Dialog Box for Results::Sensitivity Graph option.

At the left of the dialog box is a list of the goals and measures in the analysis. Select the member that will appear in the horizontal axis of the group from this list.

The "Number of Bars" line at the upper right of the dialog box determines how many alternatives Logical Decisions should draw. Logical Decisions will draw the alternatives with the highest overall utilities.

The buttons at the right of the dialog box tell Logical Decisions how to draw the key at the left of the sensitivity graph. The "Local Rank" button tells Logical Decisions to sort the alternative lines by their ranking on the selected measure. This will make them correspond to their order at the right of the graph. The "Overall Rank" button tells Logical Decisions to sort the alternative lines by their overall ranking. This will make them correspond to their order at the vertical line in the center of the graph. The “Name” button tells Logical Decisions to sort the alternatives by name.

After you click "OK”, Logical Decisions creates a graph like the one in Figure 8- 25.

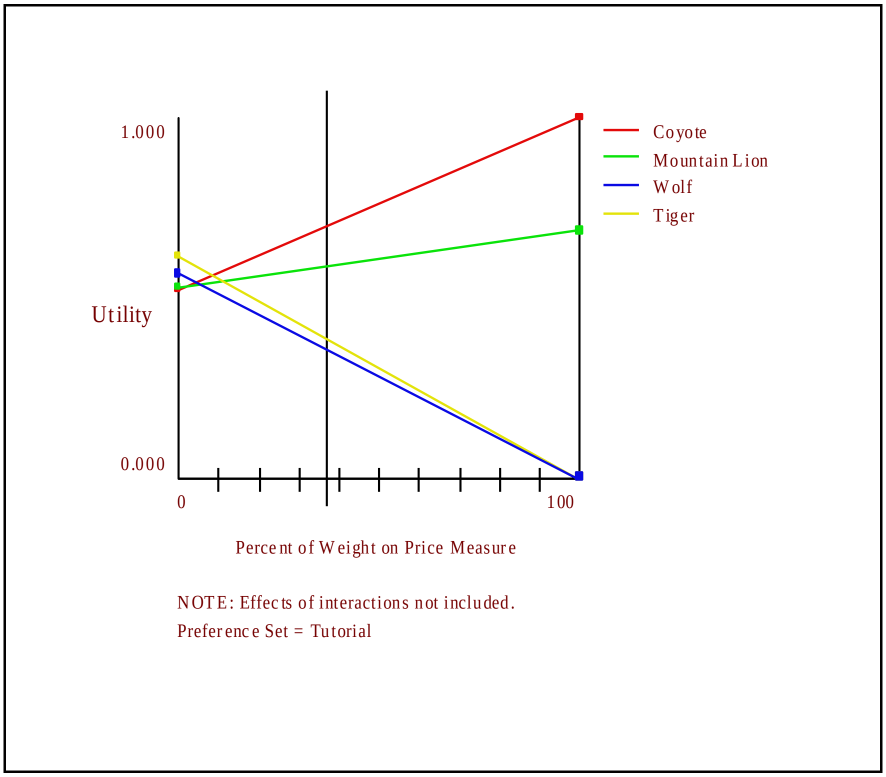


Figure 8- 25. Example of Results::Sensitivity Graph display.

The graph has relative utilities as its vertical axis and the percent of total weight on the member as its horizontal axis.

The left side of the graph represents no weight at all on the active member and the right side represents 100 percent of the weight on the member.

The lines represent overall utilities for the alternatives at different weights. A vertical line shows the weight for the member in the active preference set.

The highest line represents the most preferred alternative (overall) for a given weight on the active member. Thus, in the example above, the "Coyote" alternative is most preferred overall for most weights for the Price measure. It is not until the weight for Price goes below about 10 percent that another alternative (Tiger) becomes preferred.

Sensitivity Table

The sensitivity table option lets you view an overall ranking based on any percentage of weight on a goal or measure.

You can view a sensitivity table by selecting the Results::Sensitivity Table option. When you select the option, Logical Decisions shows you a dialog box with a list of the goals and measures in the analysis. After you select a member, Logical Decisions asks you enter the percent of the total weight to assign it, with the current percentage weight as a default. When you make your selection, Logical Decisions creates a table like the one in Figure 8- 26.

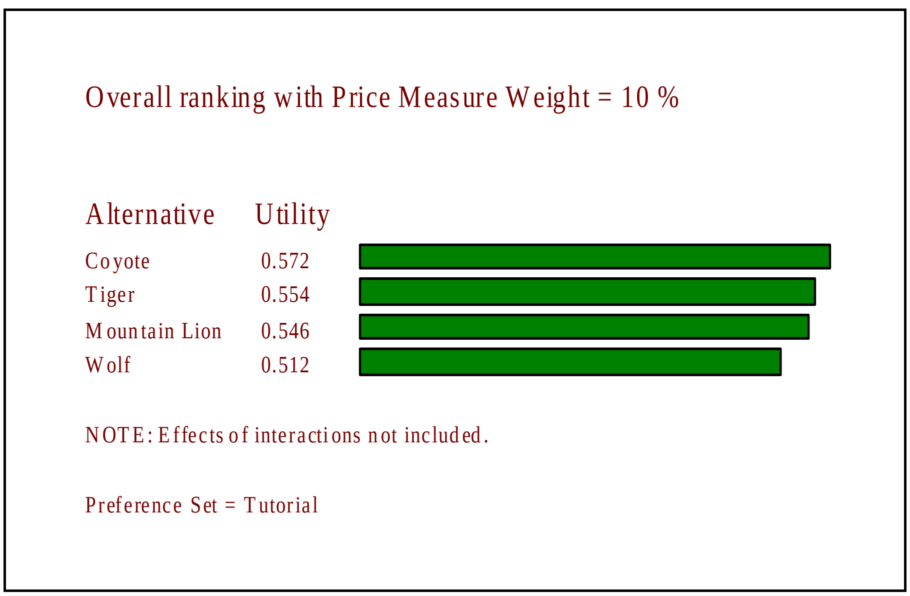


Figure 8- 26.. Example of Results::Sensitivity Table display

Scatter Diagrams

The Results::Scatter Diagrams option lets you compare the performance of the alternatives on any two measures or goals. The comparison is a scatter diagram with one measure or goal on each axis and the alternatives represented by crosses.

When you select this option, Logical Decisions first displays the dialog shown in Figure 8- 27.

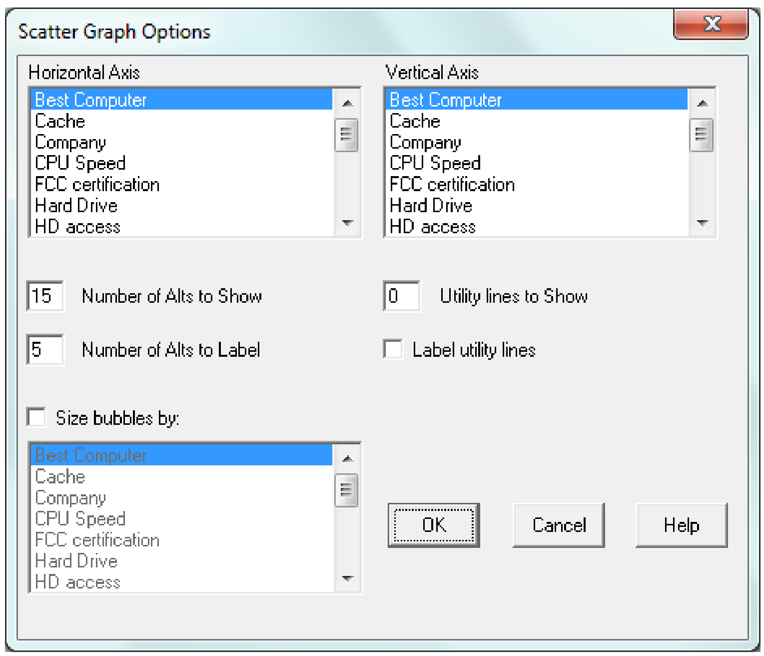


Figure 8- 27. Dialog box for Results::Scatter Diagrams option.

The two lists in the dialog box determine the members that will be shown on the axes of the scatter diagram.

The "Number of Alts to Show" edit tells Logical Decisions how many of the top ranking alternatives to show with crosses.

"The "Number of Alts to Label" edit tells Logical Decisions how

many of the top ranked alternatives to draw in color and to label with the alternative name.
The “Size bubbles” option lets you indicate a third dimension by sizing the bubbles for the alternatives in proportion to their utility on a measure or goal.

The "utility Lines to Show" edit tells Logical Decisions how many utility lines to draw in light gray behind the alternative crosses. This edit may be disabled for pairs of members for which the pairwise utility can’t be computed.

Finally, the "Label Utility Lines" check box tells Logical Decisions whether it should label each line with its utility.

When you click "OK”, Logical Decisions creates a display like the one in Figure 8- 28.

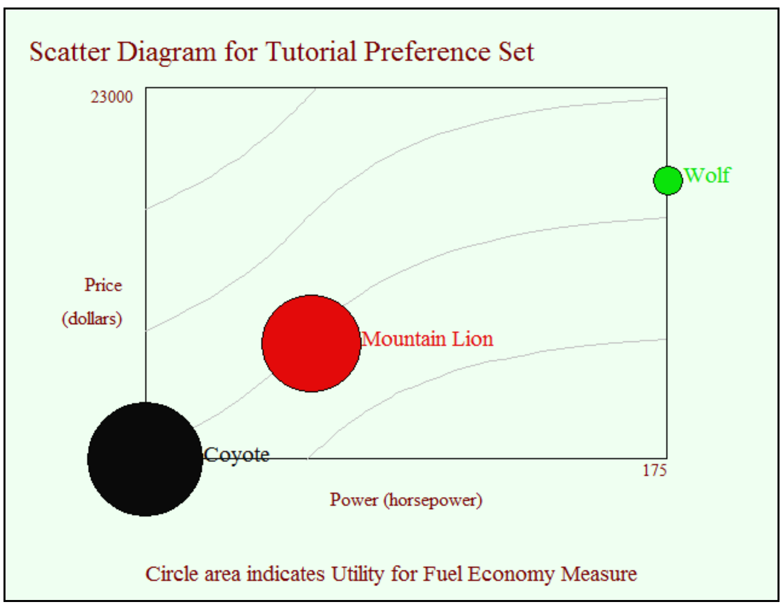


Figure 8- 28. . Example of Results::Scatter Diagram option.

The ranges for the two axes are the nominal range defined in the measure dialog box for measures. For goals, Logical Decisions uses the nominal utility range (usually zero to one). Logical Decisions will expand these ranges to show high ranking alternatives falling outside either range.

If you move your mouse over a point that is not labeled, the label will be shown temporarily. If you click a point the label will be shown permanently. If you click a label it will be hidden.

Efficient Frontier

The Results::Efficient Frontier option lets you identify and order the alternatives with the highest benefit to cost ratio.   The alternatives are ordered on a cumulative "efficient frontier" where the alternative with the highest ratio is drawn first, the one with the second comparison is drawn second and so on.

The cumulative costs and benefits of the alternatives drawn so far are plotted.

When you select this option, Logical Decisions first displays the dialog shown in Figure 8- 29.

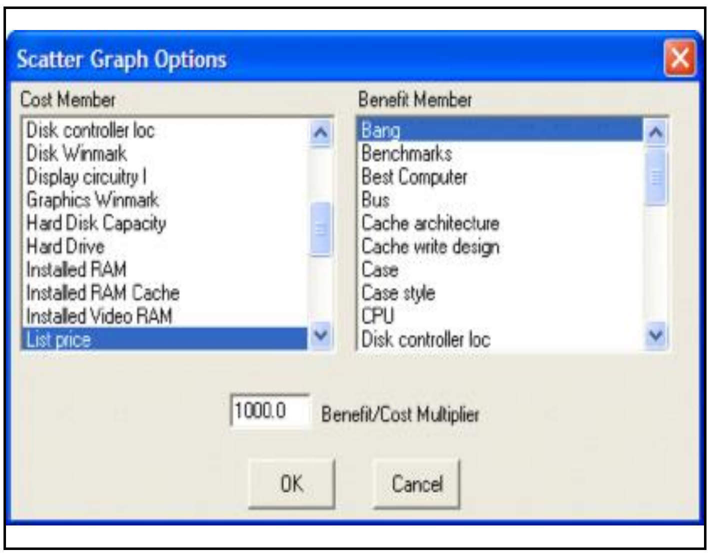


Figure 8- 29. Dialog box for Results::Scatter Diagrams option.

The two lists in the dialog box determine the members that will be shown on the diagram's axes. The cost member is shown on the horizontal axis in nominal units such as dollars. The benefit member is shown on the vertical axis in units of utility. The benefit member is often a goal that aggregates the various measures of benefit.

The “Benefit/Cost Multiplier” edit lets you enter a constant to multiply the benefit cost ratios by, since cost numbers in dollars are usually much larger than benefit numbers in utility.

When you click the "OK”, Logical Decisions creates a display like the one in Figure 8- 30.

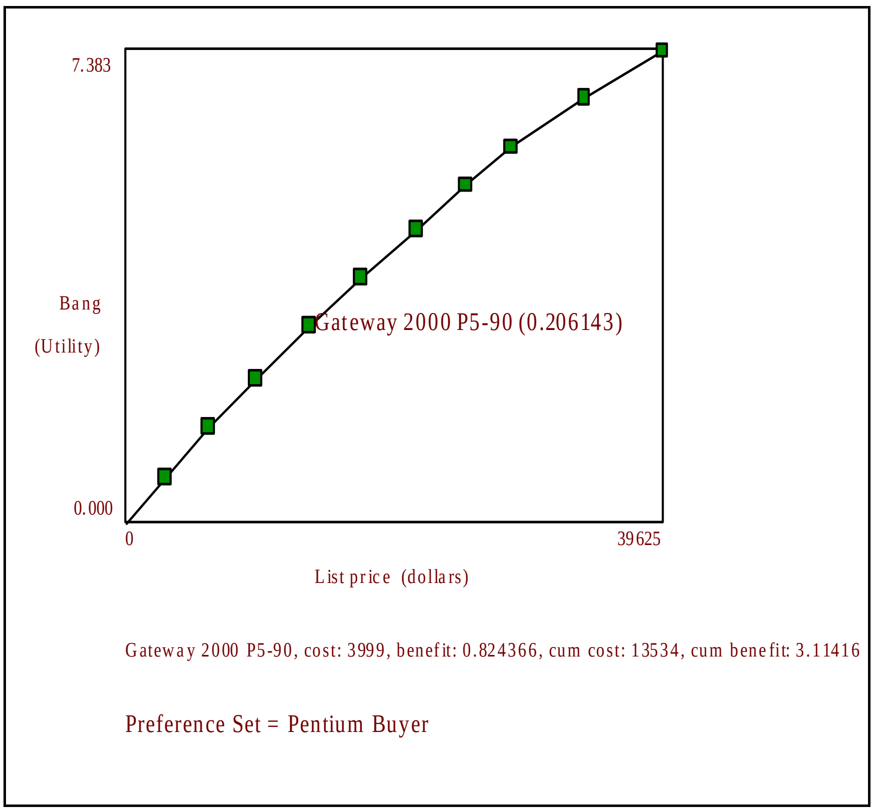


Figure 8- 30. Example of Results::Scatter Diagram option

The ranges for the two axes go from 0.0 to the sums of the costs and benefits for all the alternatives with positive benefits and non-negative costs. The alternatives are shown along a line that starts from the zero cost/zero benefit point in the lower left and adds alternatives along the line in order of decreasing cost benefit.

If you move your mouse over a point, its label will be shown temporarily. The label has the alternative name and the benefit/cost ratio adjusted by the multiplier you entered in the dialog box. Logical Decisions also displays the alternative's cost and benefit levels as well as the cumulative cost and benefit at the bottom of the graph.

If you click on a point the label and details will be shown permanently. If you click on a label it and the details will be hidden.

Interpreting the efficient frontier. If you are selecting multiple alternatives in your analysis, you can think of the efficient frontier as the order in which you should buy them so that you get the most benefit for your costs. You should start at the lower left of the graph and select alternatives along the line. The first alternative in the line will have the highest benefit/cost ratio. The second will have the second highest and so on. You might think of the order of the alternatives as the order in which you would buy them as your budget increases.

Logical Decisions® Portfolio. Many real world situations where you want to select multiple alternatives are much more complicated than this. There may be multiple costs you have to consider and additional constraints that make it inappropriate to select certain combinations of alternatives. For this type of problem, you need a more specialized tool.

Logical Decisions® Portfolio is just such a tool. It is specifically designed to handle complex situations where you want to select sets of alternatives in the presence of budgetary and other constraints. For more information, visit the Logical Decisions web site at www.logicaldecisions.com.

Ranking Results Graph

The Results::Ranking Results Graph option lets you view a graph showing the performance of the alternatives on selected goals and measures. When you select this option, Logical Decisions will display a dialog box like the one in Figure 8- 31.

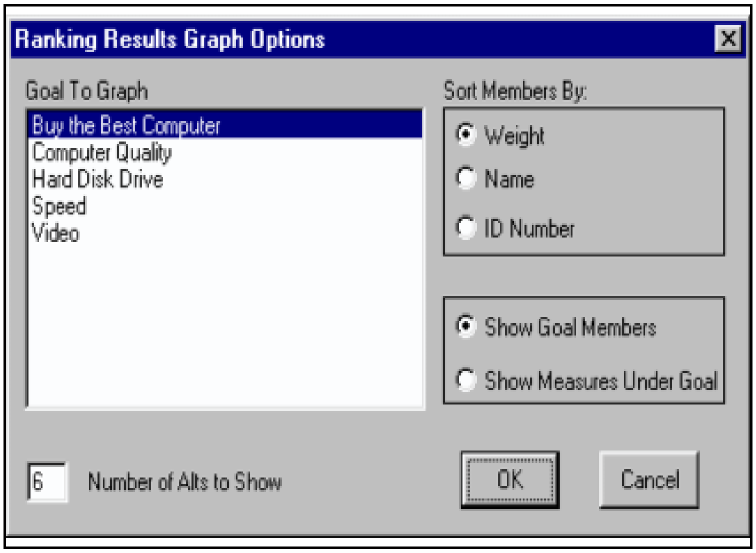


Figure 8- 31. Dialog box for Ranking Results Graph.

In the dialog box, you are asked to select the goal to graph, meaning which goal's results will be displayed at the left of the graph and how that goals members will be sorted. Next you select whether to display the members of the goal (that is, the goals and measures directly underneath the selected goal in the goals hierarchy) or to display all of the measures somewhere under the selected goal in the goals hierarchy. Finally, you select the number of alternatives to display. Logical Decisions will display the top ranking alternatives under the selected goal.

When you click OK, you will see a graph like the one in Figure 8-32.

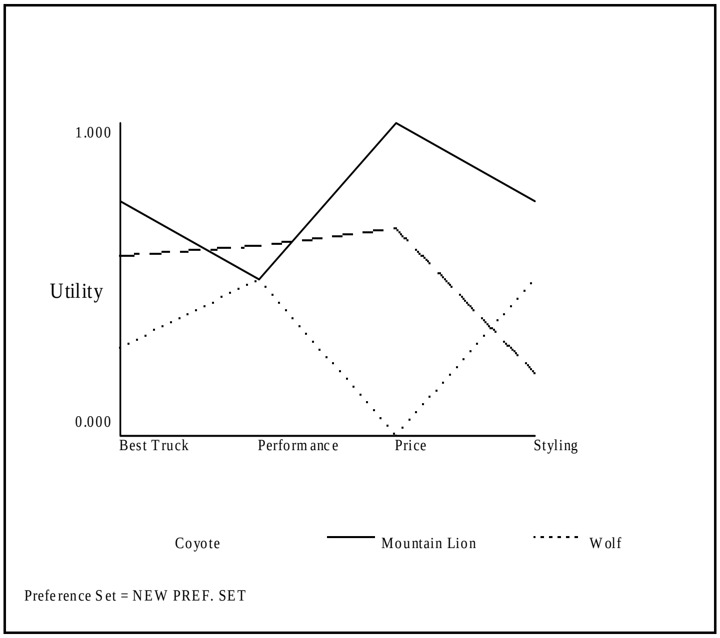


Figure 8- 32.. Example of Results::Ranking Results Graph option.

In the figure, the vertical axis represents utility. The selected goals and measures are displayed along the horizontal axis.

The goal you selected in the dialog box is at the left of the horizontal axis. The alternatives are displayed as horizontal lines. Each alternative's utility for a goal or measure is plotted above that goal or measure.

There is no particular significance to the even spacing of the measures and goals. The lines connecting these points also do not have significance, they just make it easy to track the performance of individual alternatives across different goals and measures.

Ranking Results Matrix

The Results::Ranking Results Matrix option lets you view a matrix of the utility results for all the alternatives on the measures and goals. When you select this option, Logical Decisions will display a matrix like the one in Figure 8- 33.

	Best Computer Goal	Quality Goal	Price Measure	Speed Goal	Video Goal	Hard Drive Goal	Company Measure	Cache Measure
Weight	1	0.287847	0.201203	0.192816	0.139952	0.113633	0.110744	0.100602
Local 1 33 MHZ	0.671	0.391	0.341	1.000	1.000	0.929	0.000	1.000
Local 1 25 MHZ A	0.642	0.391	0.708	0.857	1.000	0.269	0.000	1.000
Local 1 25 MHZ B	0.641	0.391	1.000	0.543	1.000	0.269	0.000	0.400
Local 2 25 MHZ B	0.617	0.391	0.518	0.857	1.000	0.269	0.000	1.000
Local 2 25 MHZ A	0.610	0.391	0.467	0.857	1.000	0.299	0.000	1.000
Mail Order 2 25 MHZ	0.602	1.000	0.018	0.857	1.000	0.052	1.000	1.000
Regional 1 25 MHZ	0.583	0.270	0.245	0.857	1.000	0.765	0.000	1.000
Mail Order 2 20MHZB	0.579	1.000	0.222	0.522	1.000	0.052	1.000	1.000
Regional 1 20 MHZ	0.561	0.270	0.454	0.522	1.000	0.765	0.000	1.000
Local 2 25 MHZ C	0.549	0.391	0.512	0.857	0.520	0.269	0.000	1.000
Mail Order 2 20MHZA	0.539	1.000	0.524	0.000	1.000	0.052	1.000	0.000
Mail Order 1 25 MHZ	0.475	0.429	0.052	0.857	0.400	1.053	0.650	1.000
Mail Order 3 25 MHZ	0.405	0.224	0.060	0.857	1.000	0.204	0.000	1.000
Mail Order 3 20 MHZ	0.380	0.224	0.257	0.522	1.000	0.204	0.000	1.000
Mail Order 1 20 MHZ	0.378	0.429	0.454	0.522	0.400	0.052	0.650	1.000

Figure 8- 33. Example of Results::Ranking Results Matrix option.

In the matrix, the goals and measures are shown at the top, with their weights in the row below them. The alternatives are shown on the left edge of the matrix. Each cell in the body of the matrix represents the utility for the alternative on the goal or measure. The matrix is initially sorted with the highest ranking alternatives towards the top and the most highly weighted goals and measures towards the left.

You can view the dialog box for any goal, measure or alternative by clicking its cell.

Preference Set Summary

The Results::Preference Set Summary option lets you view a summary of the ranking results for all of the preference sets for a single goal or measure. When you select this option, Logical Decisions displays the dialog box shown in Figure 8- 34.

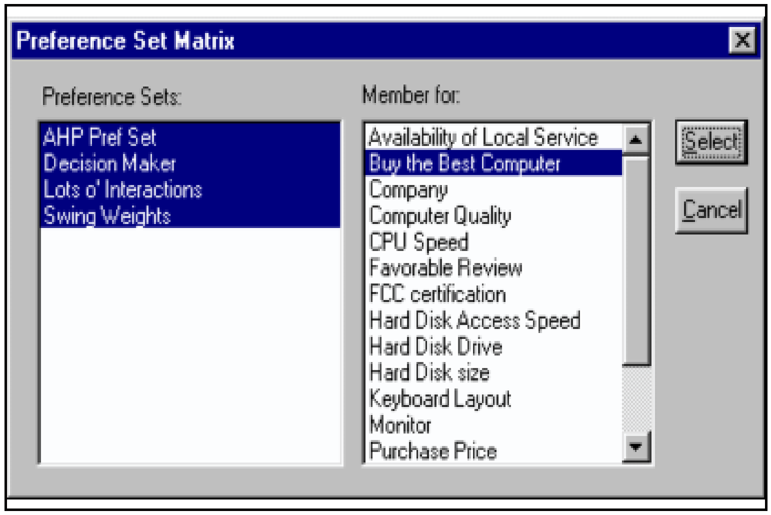


Figure 8- 34. Dialog box for Results::Preference Set Summary option.

In the list at the left you select which preference sets to include in the summary. Just click a preference set to deselect it or reselect it. Select from the list at the right to tell Logical Decisions which member to prepare the summary for. When you click "Select", Logical Decisions will display a matrix like the one in Figure 8- 35.

	AHP Oriented	MAUT Oriented	MAUT, One MUF	Mean	Std. Dev.
Dodge Ram-50	23	71	81	58	31
Ford Ranger	19	51	57	42	20
Toyota	17	46	41	35	16
Mitsubishi	28	57	23	36	18
Dodge Dakota	18	13	16	16	3
Chevy S-10	15	24	3	14	11

Figure 8- 35. Example of Results::Preference Set Summary option

In the figure, the rows represent alternatives and the columns represent preference sets. Each cell represents the utility for the row alternative on the selected measure or goal for the column preference set. The last two columns of the matrix represent the average utility for each alternative and the standard deviations of the utilities.

Cutoff Summary

The Results::Cutoff Summary option lets you view a summary of the alternatives that fail one or more of the measure cutoffs. When you select this option, you will see a table like the one in Figure 8-36.

Alternatives failing one or more cutoffs

ARES Pentium Pro 90 failed 1 cutoff
  240 MB is below the lower cutoff of 500 for Hard Disk Capacity

AST Premmia GX P/90 failed 1 cutoff
  3.25 number is below the lower cutoff of 4 for Bays

AT&T Globalyst 600 failed 2 cutoffs
  180 W is below the lower cutoff of 200 for Power Supply
  3.5 number is below the lower cutoff of 4 for Bays

Aberdeen Super P90 V failed 1 cutoff
  3.5 number is below the lower cutoff of 4 for Bays

CAF Lightning P9 failed 4 cutoffs
  343 MB is below the lower cutoff of 500 for Hard Disk Capacity
  3 number is below the lower cutoff of 4 for Bays
  1 MB is below the lower cutoff of 2 for Max Video RAM
  1 MB is below the lower cutoff of 2 for Installed Video RAM

Dell Dimension XPS P failed 1 cutoff
  3.5 number is below the lower cutoff of 4 for Bays

Diamond DT 586-90 failed 1 cutoff
  345 MB is below the lower cutoff of 500 for Hard Disk Capacity

Figure 8- 36. Example of Results::Cutoff Summary option

Graph an Alternative

The graph an alternative option lets you display a bar graph or "Petal Diagram" showing the performance of a single alternative on the measures or goals. The graphs are unique in that the width of the bar for a measure or goal is proportional to its weight.

You can view the graph alternatives display by selecting the Results::Graph an Alternative option. When you select it, Logical Decisions shows you the dialog box in Figure 8- 37, which helps you customize your graph.

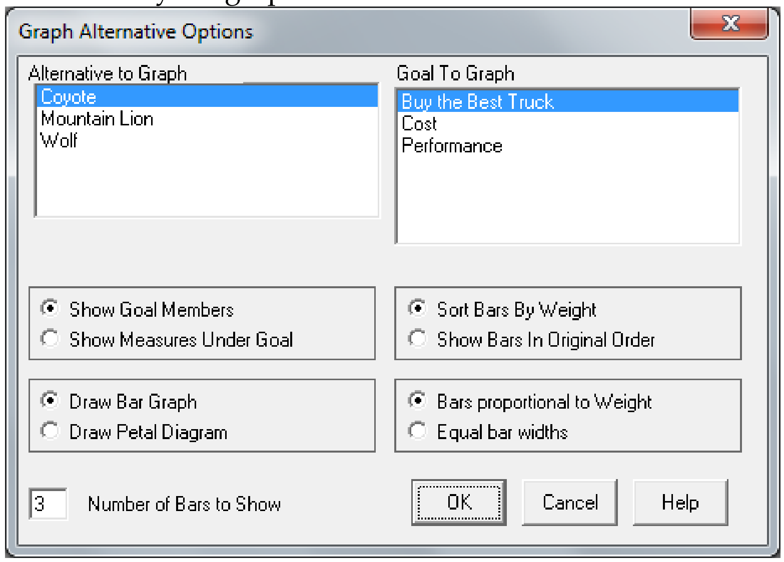


Figure 8- 37. Dialog box for Results::Graph Alternatives option.

This dialog box presents you with a variety of options. The list box on the left contains the alternatives. Click on the alternative you would like to display.

The list box on the right contains the goals. You can click on the "Overall" goal to display bars representing overall results, or click on another goal to display only bars related to that goal. The radio buttons on the upper left determine which bars you will see. If you select the "Show Goal Members" button, Logical Decisions will only show the measures and goals directly under the selected goal. If you select the "Show Measures Under Goal" button, Logical Decisions will show all of the measures under the selected goal.

Logical Decisions will only show the most important (highest weighted) measures or goals, up to the limit selected in the text box labeled "Number of Bars to Show". This box has an upper limit of 15 bars. If you choose a limit less than the number of bars implied by your goal and radio button selections, Logical Decisions will combine the "extra" measures and goals into a bar called "Other".

The radio buttons on the lower left determine the type of graph to be displayed. If you select the “Draw Bar Graph” option a bar graph will be displayed. If you select the “Draw Petal Diagram” button a circular petal diagram will be displayed.

The final pair of radio buttons (on the right) determines the order of the bars. You can sort the bars by relative weight (the most highly weighted -- and widest -- bars will go on the left) or you can show the bars in their original order. Finally, you can select whether the bars' widths will be proportional to their weight.

If you find these options confusing, just experiment a little with different settings. Since nothing you do in the Results menu can change the analysis results, you can't get yourself in trouble.

The example graph alternatives display shown in **Figure 8-38** was created by selecting the "Coyote" alternative from the left list box, the "Buy the Best Truck" goal from the right list box, the "Show Measures Under Goal" button, the "Sort Measures By Weight" button, the "Bars Proportional to Weight" button, the “Draw Bar Graph” button and five as the number of bars to show. **Figure 8-39** was created using the same options but with the “Draw Petal Diagram” option selected.

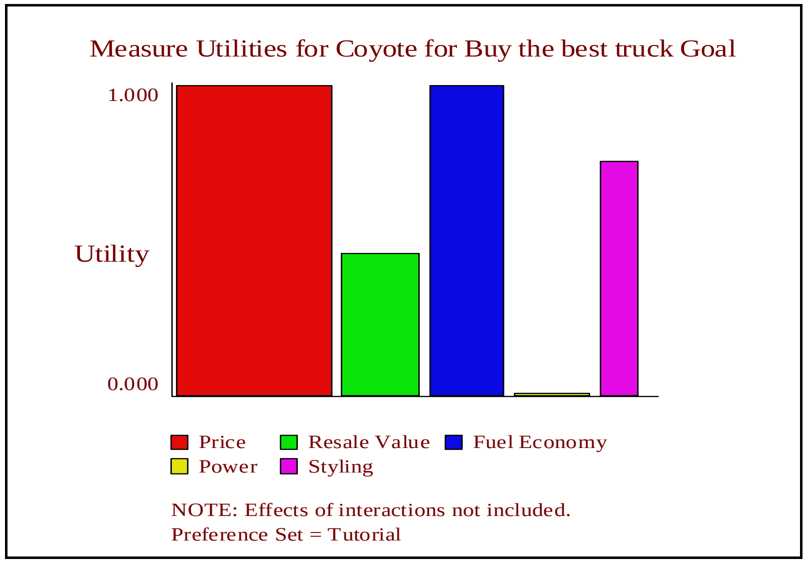


Figure 8- 38. Example of Results::Graph Alternatives display.

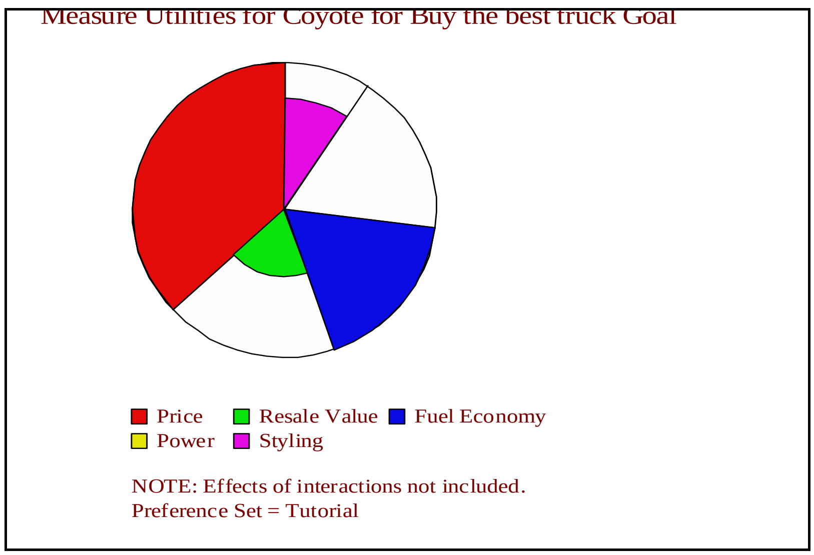


Figure 8- 39. Graph an Alternative option with Petal Diagram selected

Logical Decisions displays utilities greater than one or less than zero as one or zero respectively in the bar graph.

Alternative Uncertainty Graph

The Results::Alternative Uncertainty Graph option lets you view a graph of the uncertainty in a single alternative for a single measure or goal. When you select it, Logical Decisions will display the dialog box shown in Figure 8- 40.

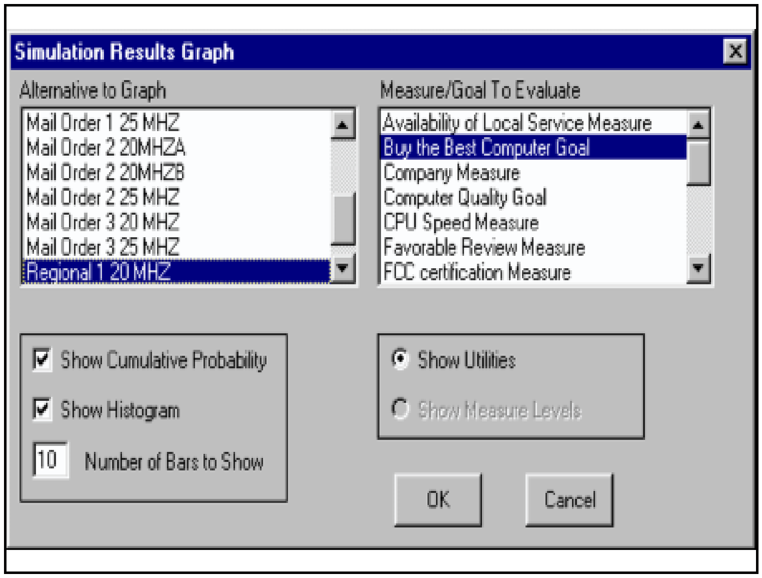


Figure 8- 40. . Dialog box for Results::Alternative Uncertainty Graph option

In the dialog box, you select the alternative to graph from the list on the left and the measure or goal to graph the uncertainties for from the list on the right.

The "Show Cumulative Probability" check box lets you select whether to show a line with the probability that a given simulation trial will be less than or equal to any given level or utility.

The "Show Histogram" check box lets you select whether to show bars with the number of simulation trials that were within a given range.

The "Number of Bars to Show" edit box lets you select how many histogram bars to display.

Finally, the two radio buttons on the right determine whether to draw the graph in terms of utilities or in terms of measure levels. The "Show Measure Levels" button is only enabled if you have selected a measure from the list above it. When you click "OK", Logical Decisions will display a graph like the one shown in Figure 8- 41.

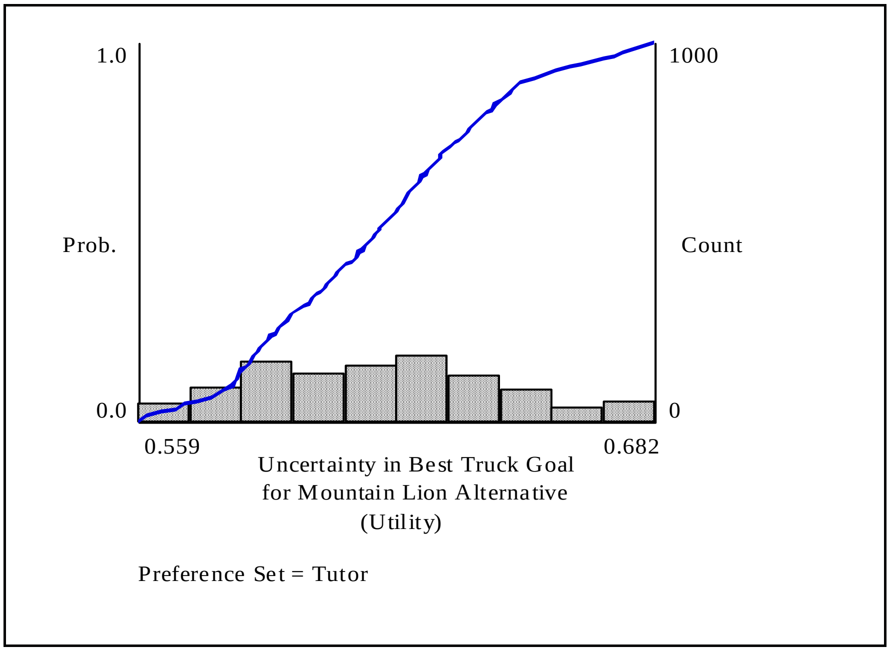


Figure 8- 41. Example of Results::Alternative Uncertainty Graph option.

In the figure, the X-axis represents the range of levels or utilities that were observed in the Monte Carlo simulation for the alternative on the active measure or goal. The scale at the left of the graph is probability and is associated with the blue line. Each point on the line indicates the probability that a simulation trial will be less than or equal to the utility or level below the point.

The scale on the right represents the number of simulation trials that were done. It is associated with the yellow bars at the bottom of the graph. The length of each bar is proportional to the number of simulation trials that resulted in a level or utility within the range spanned by the bar.

Compare Alternatives

The compare alternatives option lets you view a detailed comparison of the differences between two alternatives. You can view an alternatives comparison by selecting the Results::Compare Alternatives option. When you select the option , Logical Decisions shows you the dialog box in Figure 8- 42.

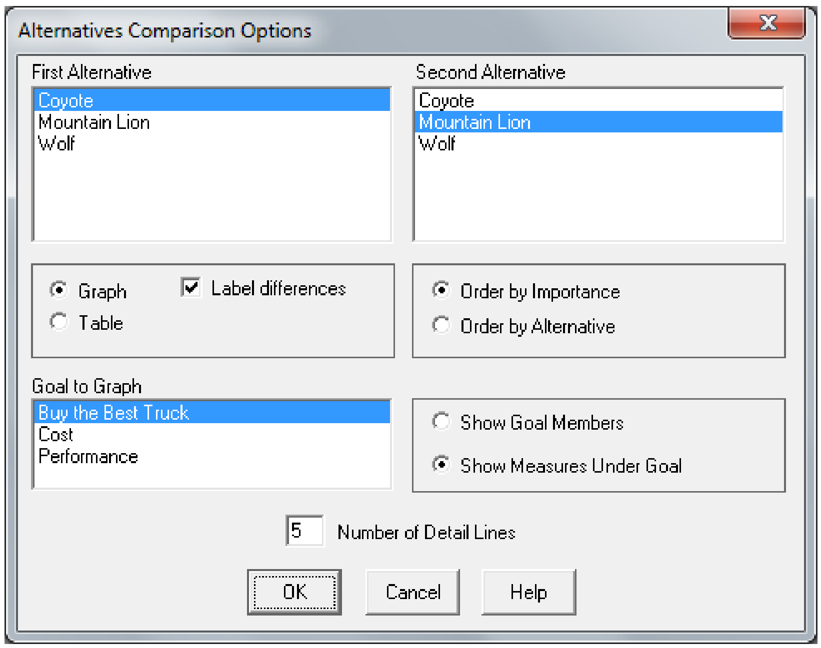


Figure 8- 42. Dialog box for Compare Alternatives option.

In the dialog box, the two lists let you choose the alternatives to compare.

The "Number of Detail Lines" edit box lets you select how many lines comparing the results on single measures to show. The measures not shown in detail lines will be combined in an "Other" line.

The radio buttons on the left tell Logical Decisions what type of comparison to create, a graph or a table. If you select the Graph option, you can check the “Label differences” box to have Logical Decisions print the numeric differences between the alternatives next to the graph’s bars.

The radio buttons on the right let you tell Logical Decisions how to order the detail lines. If you click "Order by Importance”, Logical Decisions will draw the lines showing the most difference between the alternatives first. If you click "Order by Alternative”, Logical Decisions will draw all the lines favoring one alternative first, followed by the lines favoring the other alternative.

The Goal to Graph list lets you select the goal to do the comparison for. You can tell Logical Decisions to show only the members directly under the goal or show all of the measures under the goal by selecting one of the radio buttons on the right.

When you click "OK”, Logical Decisions will create a table like the one in Figure 8- 43 or a graph like the one in Figure 8- 44.

Overall Utility for	Regional 1 20 MHZ	0.561
	Mail Order 2 20MHZA	0.539
	Difference	0.022

Measure	Regional 1 20 MHZ Level	Mail Order 2 20MHZA Level	% Contribution to Difference	Total Contribution
Company	No-Name	First Rate	-502.4	-0.111
gtest	64	0	456.4	0.101
Review	No Review	Best Buy	-292.8	-0.065
Local Service	Yes	No	292.8	0.065
HD size	100	65	289.0	0.064
Keyboard	Fn Keys on Top	Fn Keys on Side	-158.6	-0.035
HD access	22	28	78.7	0.017
Price	3295	3228	-63.1	-0.014

Preference Set = Decision Maker

Figure 8- 43. . Example of Results::Compare Alternatives Table display.

In this table Logical Decisions compares the alternatives by the measures that make the greatest contribution to their difference in overall utility. Each line in the table represents the contribution of a single measure to the ranking results.

Each line has the following information. The Alt1 Level is the level on the measure for the higher ranking alternative.

The Alt2 Level is the level for the lower ranking measure.

The % Contribution to Difference is the percentage of the total difference in overall utility between the two alternatives that is due to the measure. The percentages in this column sum to 100 percent, although individual differences can be greater than 100 percent and can also be negative.

Negative contributions show that the lower ranked "Alt 2" is more preferred on this measure. Logical Decisions displays lines with negative contributions in red and those with positive contributions in blue.

The Total Contribution is the absolute amount of the total difference in overall utility between the two alternatives that is due to the measure. The amounts in this column sum to the number in the difference line at the top of the table. Again, individual contributions can be greater than the total difference and can also be negative. The lines favoring the higher ranked alternative are shown in blue, while the lines favoring the other alternative are shown in red.

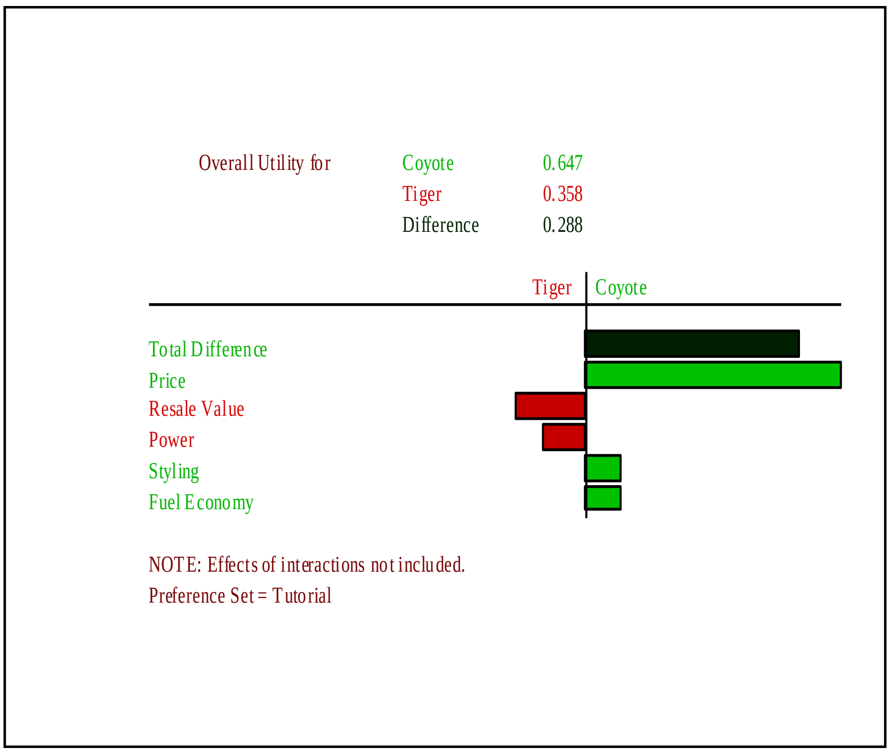


Figure 8- 44. Example of Results::Compare Alternatives Graph display.

In the graph, the bars represent measures that favor one alternative over the other. Longer bars indicate more influence on the overall ranking.

Bars on the left of the graph favor the alternative with the lower overall ranking. Logical Decisions draws these bars in red. Bars on the right of the graph favor the alternative with the higher overall ranking. Logical Decisions draws these bars in green.

The first bar always indicates the difference in overall ranking between the two alternatives. It is always on the right of the graph. Its length can give you an idea of the degree of influence of the various measures compared to the total difference between the alternatives in overall utility.

Printing and Saving Windows

You can print any of the review or results displays, copy them to the clipboard or save them in various file formats. This section describes how to do this.

Printing Graphics

To print a graphic image you should first make sure that the graphic display window is the "active window" with the selected tab on your screen.

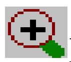
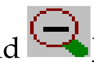
Next select the File::Print option. This begins the printing process.

First, the setup dialog box for the currently selected printer will appear. This dialog box differs from printer to printer and lets you select the proper options for the picture you want to create.

Next a small dialog box appears that says "Printing in Progress”. If you click on the "Cancel" button on this dialog box before it disappears, Logical Decisions will cancel the print job. Otherwise, Logical Decisions sends the graphic image to the Windows Print Manager for printing.

Logical Decisions always prints the full graphic image, regardless of whether it is completely visible on the screen. If the image fits on one page, Logical Decisions will locate it in the upper left of the page. If not, Logical Decisions will print multiple pages until it has printed the entire image.

If you want the image to be a different size, you can use the Window::Zoom option. The size of the image will change according to the zoom percentage you specify.

One hundred percent always returns the image to its original size. The  Window::Zoom In and  Window::Zoom Out option let you quickly zoom in or out by 20%.

You can select the File::Printer Setup option to set the size and layout of the pages you would like to print.

You can use the File::Print Preview option to review what your printed pages will look like.

Copying Graphics Images to the Clipboard

The Windows clipboard lets you transfer graphic images between programs. You can copy any Logical Decisions image to the clipboard simply by making that window active (as described in the "Printing Graphics" section) and selecting the Edit::Copy option. You can check if Logical Decisions has properly copied the image by using the Windows Clipboard Viewer.

Before you copy an image to the clipboard, you should make sure that no graphic objects in the image are selected. If individual objects are selected, Logical Decisions will copy them to the clipboard, rather than the entire image.

An item is selected if it is "marked" by small black squares. To "unselect" objects, just click your mouse in an empty area of the window and any marks will disappear.

Once you have copied a window to the clipboard, you can download the image into many other Windows programs. You can usually do this using the Edit::Paste option. Logical Decisions copies images as "enhanced metafiles" that you can paste directly into a word processor or presentation program for display in reports or slides. There you can manipulate the individual objects in the metafile image in many ways.

Different programs treat clipboard images differently, so there is no guarantee that any particular program can display the image correctly.

Saving Windows to a File

You can save Logical Decisions windows to disk files in several different formats.

To save a window, you should first make sure it is active (as described in the "Printing Graphics" section) and then select the File::Save Window option. You have three options in the sub-menu that appears – Save Graphic, Save Text, and Save Spreadsheet. The options available depend on the type of the active window. When you select an option, Logical Decisions shows you the standard Windows save file dialog box shown in Figure 8- 54.

The dialog box will show you the file formats that are available for the option (graphic, text or spreadsheet) you've selected. The available file formats are:

Graphics file formats: Bitmap (.bmp), JPEG (.jpg), GIF (.gif), PING (.png) and Enhanced Metafile (.emf).

Text file formats: MS Word (.doc), ASCII Text (.txt).

Spreadsheet file formats: Excel 97 (.xls).

When saving a Rank Alternatives window as a text file, Logical Decisions gives you a choice of saving the rankings for all the measures or goals or just the active one to the text file.

Modifying Graphics

Logical Decisions has limited options that let you modify the graphics displays that it creates. These options work on any of the Preference or Results displays described above. While Logical Decisions is not a drawing program, these options should give you enough flexibility to use the Logical Decisions graphics displays directly in your reports and presentations.

If Logical Decisions lacks a modification feature you need, you should use the clipboard or a metafile to copy the display into a drawing or presentation program such as Corel Draw™ or PowerPoint™. Programs such as these provide you a wealth of tools to customize the displays to your needs.

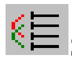
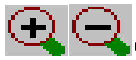
Changing the appearance of windows

Logical Decisions has options that can change how all windows are displayed as well as options that let you change individual windows.

The global options include methods to

- Change the units of a measure,
- Delete all of the alternatives,
- Change the number of trials when doing Monte Carlo simulations,
- Change the names of common Logical Decisions objects,
- Change the display for the common units of utility.
- Change the color scheme for different window types, and
- Change the footnote that appears at the bottom of results windows.

The options for individual windows include methods to

- Sort a window's rows and columns,
- Add text labels, and
- Change the size of the image in a window.

The following paragraphs tell you how to make each of these changes.

Changing Measure Units. The Edit::Change Measure Units option lets you change the units for an measure. For example, you could use this option to change a temperature measure from Fahrenheit to centigrade or miles per gallon measure to kilometers per liter.

The option is useful because it changes the units throughout Logical Decisions, not only in the Matrix display but also in the preference sets, where the units might be used in SUF assessments or in tradeoffs. When you select this option, Logical Decisions will display the dialog box shown in Figure 8- 45.

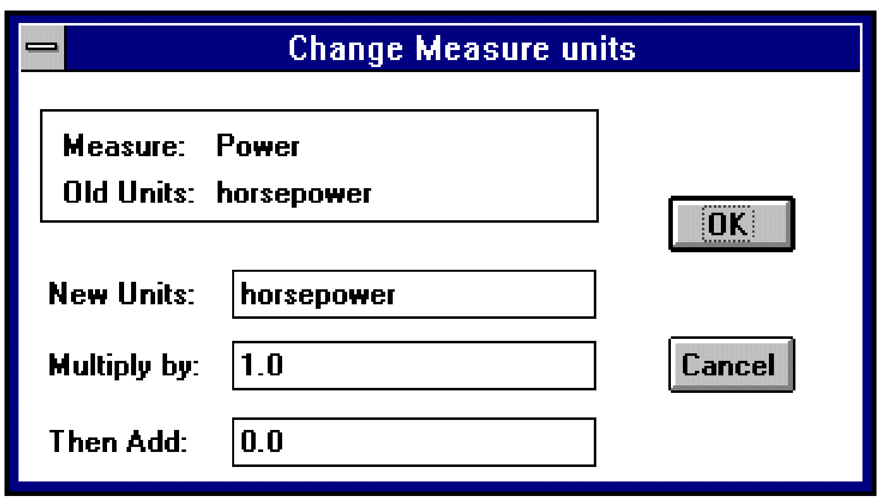


Figure 8- 45. . Dialog box for Edit::Change Measure Units option.

In the dialog box, you enter the new units name in the "New Units" edit. Next you tell Logical Decisions how convert from the old units to the new units. For example, to convert from Fahrenheit to centigrade, you would multiply by .562 and then add -17.98.

Deleting all alternatives. The Edit::Delete All Alternatives option lets you delete all of the alternatives in the analysis. After you select the option and confirm, Logical Decisions deletes the alternatives and adds a single placeholder alternative (Logical Decisions requires there to always be at least one alternative).

Changing Simulation Options. Logical Decisions uses Monte Carlo simulation to estimate the effect of uncertainties in measure levels on uncertainties in the ranking results.

The Preferences::Simulation Preferences option, lets you set the number of simulation trials Logical Decisions should use and also lets you set the initial "seed" number for the simulation. When you select this option, Logical Decisions will display the dialog box shown in Figure 8- 46.

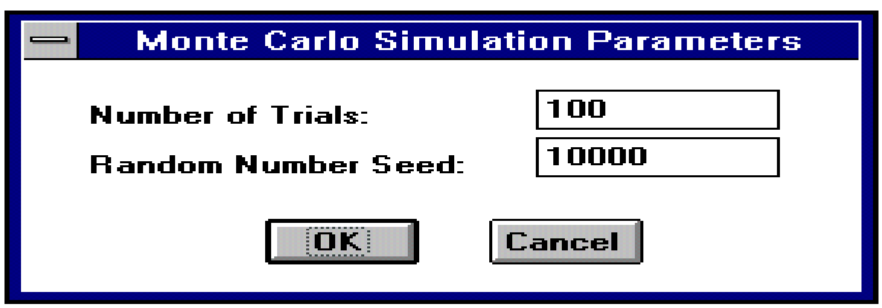


Figure 8- 46. Dialog box for Preferences::Simulation Preferences option

The "Number of Trials" edit box controls how many trials (or iterations) Logical Decisions conducts in each simulation run. The default is 100, and the maximum is 2500.

The "Random Number Seed" option controls the initial starting point for the simulation. Different seeds will lead to slightly different simulation results, but you will seldom have a need to change the default seed.

Changing names. You can change the names of several important object types in Logical Decisions by selecting the Preferences::Name Preferences option. When you select this option, you will see the dialog box in **Figure 8-47**.

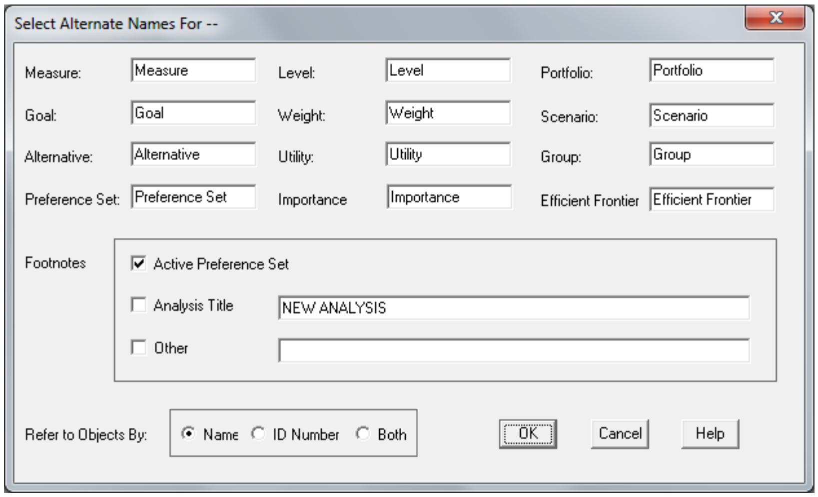


Figure 8- 47. Dialog box for Preferences::Name Preferences option.

Each edit field in this dialog box displays the name for a common Logical Decisions object or idea, like "Measure" or "Utility". By changing the name for the object in this dialog box you change how Logical Decisions refers to it in windows and lists. You generally can't affect how these terms appear in error messages and menus, however. The "Portfolio", "Group", "Scenario", and "Efficient Frontier" names are used in the Portfolio version of Logical Decisions.

You can also change the way Logical Decisions refers to the objects in your analysis by selecting from the radio buttons at the lower left of the dialog box. The objects affected are alternatives, measures, goals and preference sets. The default "Name" button causes Logical Decisions to display only the name of the object in lists and graphic screens. The "ID Number" button causes Logical Decisions to display only the ID number. The "Both" button causes Logical Decisions to display the ID number followed by the name.

Finally, you can change the footnote that appears at the bottom of many Logical Decisions windows. The default is for the footnote to show the name of the active preference set. You can also have the footnote show the title of the analysis and/or another footnote that you enter into the “Other” edit.

Changing the range for utility. You can change the range for the common units of utility with the <u>Preferences::Utility Preferences</u> option. When you select this option, Logical Decisions will display the dialog box shown in Figure 8- 48.

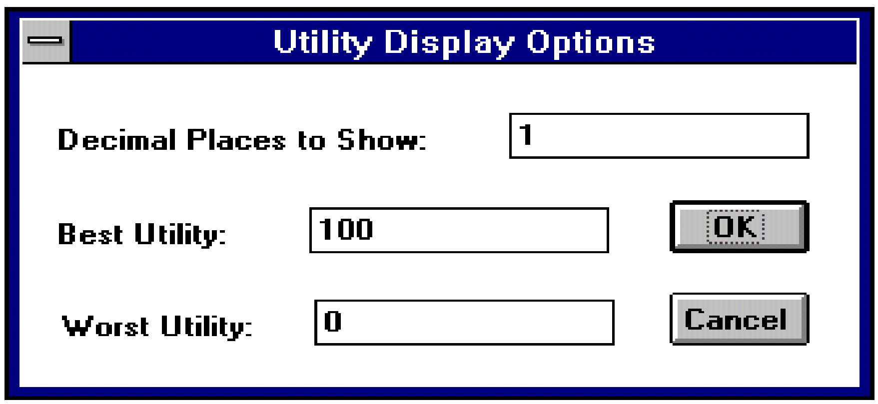
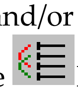


Figure 8- 48. Dialog box for Preferences::Utility Preferences option.

Just enter new values for the most preferred and least preferred utility in the edit boxes at the left of the dialog box. Logical Decisions will adjust the SUF and MUF formulas in your analysis to reflect this new range. It will adjust any assessment, review and results screens that refer to utilities.

You can also tell Logical Decisions the number of decimal places to show when displaying utilities in the "Number of decimal places to show" edit box.

Sorting. You can sort the rows and/or columns of many Logical Decisions displays by selecting the  <u>Preferences::Sort</u> option. When you select this option, Logical Decisions will display one of two dialog boxes. If you can only sort rows or columns, Logical Decisions will display the dialog box shown in Figure 8- 49.

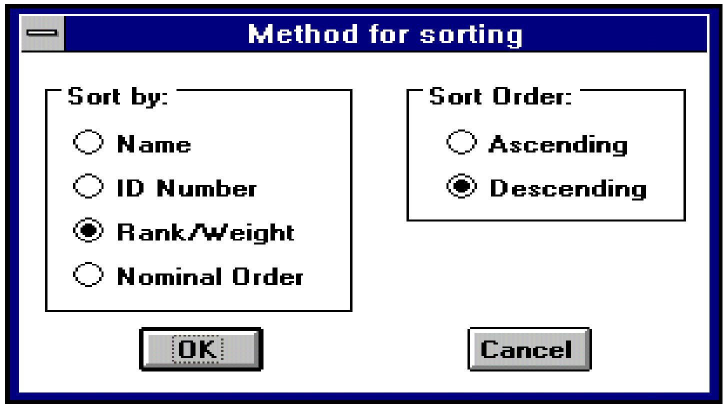


Figure 8- 49. Dialog box for Preferences::Sort option for one direction sort.

The buttons on the left indicate the key to sort on, while the buttons on the right indicate whether the sort should be ascending or descending. The sort options should be self explanatory, except for the "Nominal" order option, which sorts the objects in the order they were entered. If both the rows and columns for a window can be sorted, Logical Decisions displays the dialog box shown in Figure 8- 50.

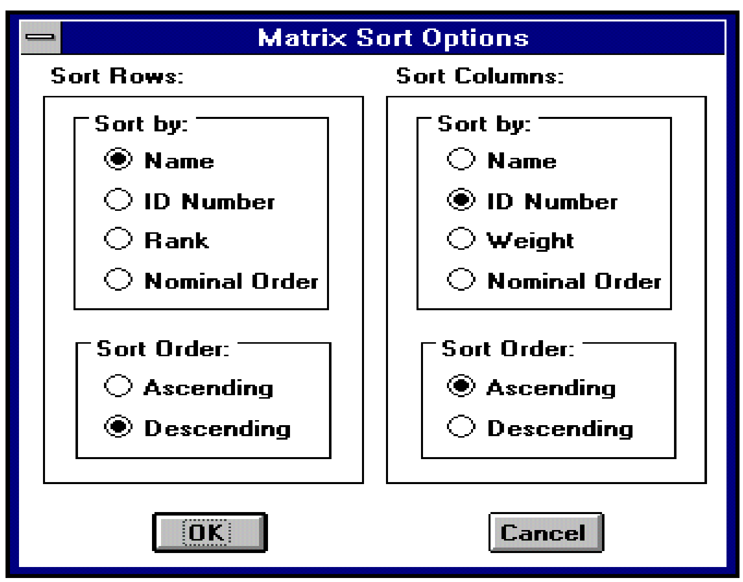


Figure 8- 50. . Dialog box for Preferences::Sort option for two direction sort

This dialog box provides the same options as the one direction sort dialog, but allows you to apply them in two directions.

Adding a Text Label. You can add a text label to a graphic window by selecting the Edit::Graphic Selection::Add Label... option. When you select this option, Logical Decisions asks you to enter the text you want in a text entry dialog box. When you have finished, the text you have entered will appear in the currently active graphics display. You will probably need to move the new label to a new position by dragging it as described in the next section.

Note that any text labels you add are temporary and will be deleted when you close the active window.

Changing the Size of an Image. You can change the size of a graphics image by selecting the Window::Zoom option. This option lets you set a "zoom percentage" that causes Logical Decisions to redraw the active window's image in a different size.

The zoom percentage changes the area of the image in relation to its original area. A zoom percentage of 100 percent will cause Logical Decisions to display the image in its original size. A zoom percentage of less than 100 percent causes the image to be displayed smaller than its original size. Zoom percentages greater than 100 percent cause the image to be displayed larger than its original size.

All changes in zoom percentage are relative to the original size of the image. Thus, you can always go back to the original size by selecting a zoom percentage of 100 percent.

When you select the Window::Zoom option, a text entry dialog box appears, allowing you to enter the desired zoom percentage.

The zoom percentage affects the size of images you print using the File::Print... option, but does not affect the size of images copied to the clipboard or saved as windows metafiles.

The Window::Zoom In and Window::Zoom Out options let you quickly change the size of an image by a fixed percentage. The Zoom In option increases the image' size by 20%, while the Zoom Out option decreases the image's size by 20%.

Changing a window's color scheme. You can change the color scheme for a window by selecting the Preferences::Color Preferences option. When you do this, you will see the dialog box shown in Figure 8- 51

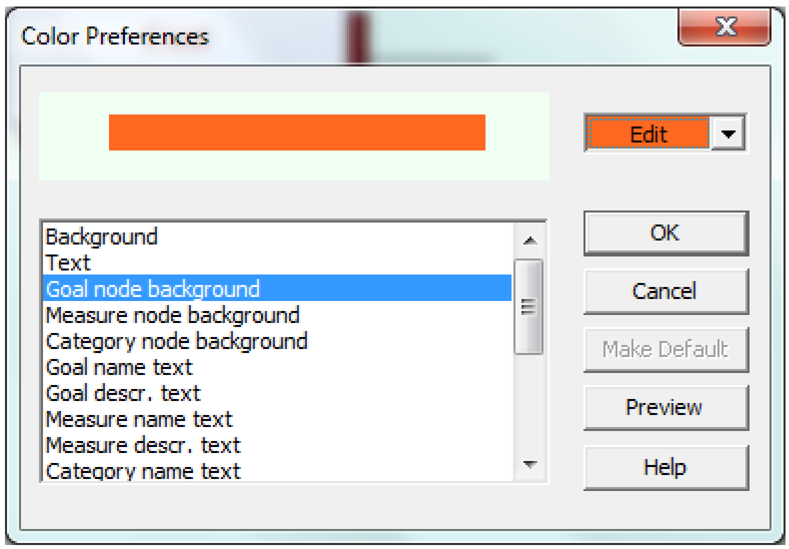


Figure 8- 51. Dialog box for the Preferences::Color Preferences option.

In the dialog box you can select from a list of objects that are shown in the current window type. When you make a selection, the current color for that type of object is shown at the bottom of the dialog box. If you click the "Edit" button, you can change the color in the color selection dialog box shown in Figure 8- 52.

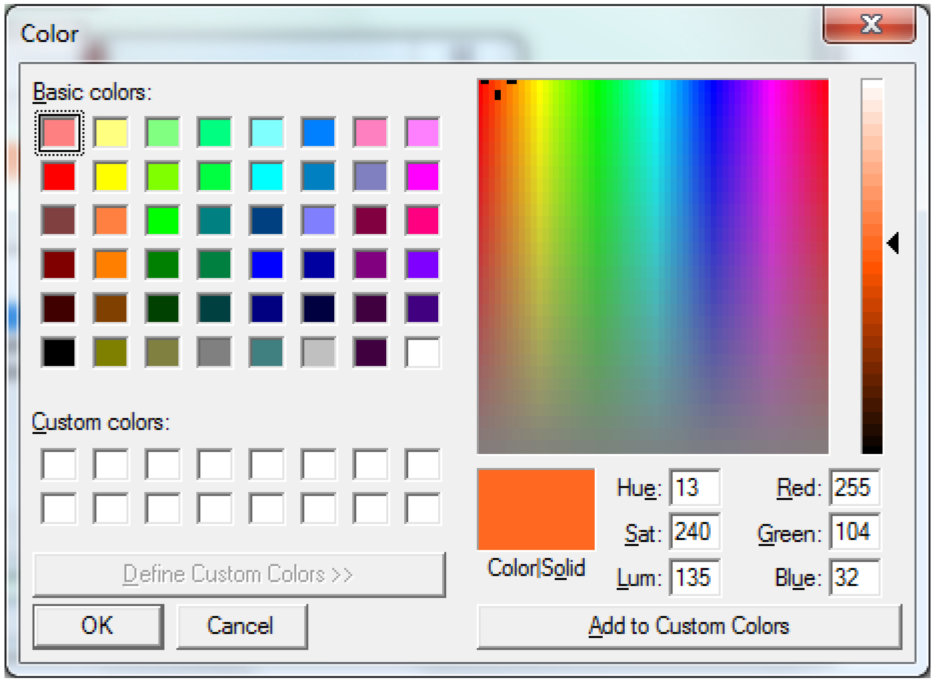


Figure 8- 52. Colors dialog box.

This is a standard Windows dialog box. Just click on a Basic or Custom color, and then click OK. You can see how your changes will look by clicking the "Preview" button.

The first two items in the list, Background and Text are the same for all windows in Logical Decisions. If you change them you are given the option to apply the changes to all Logical Decisions windows. The other items apply to all instances of the type of window that is currently active. For example, if you make a change to a Goals Hierarchy window, the change will apply to all other Goals Hierarchy windows that you create.

Saving and Loading Color Preferences. Logical Decisions saves any color preference changes you have made along with the other data in a .ldw file. You can also save them in a stand alone file that you can load into different Logical Decisions analyses. The Preferences::Save Preferences option lets you save the preferences by showing you a standard file save dialog box.

Logical Decisions Preferences are saved in a file with the extension .ldp.
You load in preferences with the Preferences::Load Preferences option. You will overwrite any color changes you have made if you load a new .ldp file.

Modifying individual graphic objects

Logical Decisions provides tools for you to select individual objects in a graphics window such as a text string or a bar in a graph. After you have selected one or more objects, you can move them, delete them or change their appearance in a variety of ways.

In this section we will first describe how to select objects and then describe how you can modify them.

Note that any changes you make to individual graphic objects are temporary and that they will be lost when you close the window.

Selecting Objects to Modify

Logical Decisions provides several standard tools that let you select objects to modify. The simplest way to select an object is to click on it with your mouse. Logical Decisions will mark the object you have selected with small black squares at the four corners of the object.

You can also select objects by dragging a selecting rectangle around them.

Modifying Selected Objects

Once you have selected the object(s) you want to modify, there are many things you can do to them. You can:

- Move them,
- Delete them,

- Copy them,
- Change their color,
- Change their text, or
- Change their text font.

The following paragraphs tell you how to make each of these changes.

Moving Objects. You can move selected objects by simply positioning your mouse over them and dragging them. Logical Decisions will move the selected objects as a group.

Deleting Objects. You can delete the objects you have selected by using the Edit::Cut option. When you select this option, Logical Decisions copies the selected objects to the clipboard where you can retrieve them using the Edit::Paste option.

Copying Objects. You can copy the objects you have selected using the Edit::Copy option. This option has the same effect as the Edit::Cut option, except that the original objects are not deleted from the window. You can retrieve a copy of the copied objects using the Edit::Paste option.

Changing An Object's Color. Two options let you change the color of an object. You can also change the color of a text object by changing its text font as described below. You can change the color of the outline of an object (or the color of all of a text object) with the Edit::Graphic Selection::Change Pen Color option. When you select this option, Logical Decisions shows you the standard Windows color changing dialog box shown inFigure 8- 52.

You can change the interior of an object such as a bar in a bar graph using the Edit::Graphic Selection::Change Brush Color option. When you select this option, Logical Decisions again shows you the standard dialog box pictured above. When you select a color, the interiors of the selected objects will all change to that color. This option does not affect text or line objects.

Changing Text. If you have selected a single text object, you can change its text with the Edit::Graphic Selection::Edit Text option. When you select the option you will be shown a data entry dialog box where you can make your changes.

Changing Text Fonts. You can change the font of text objects you have selected using the Edit::Change Text Font option. When you select this option, the standard Windows font selection dialog box shown in Figure 8- 53 appears.

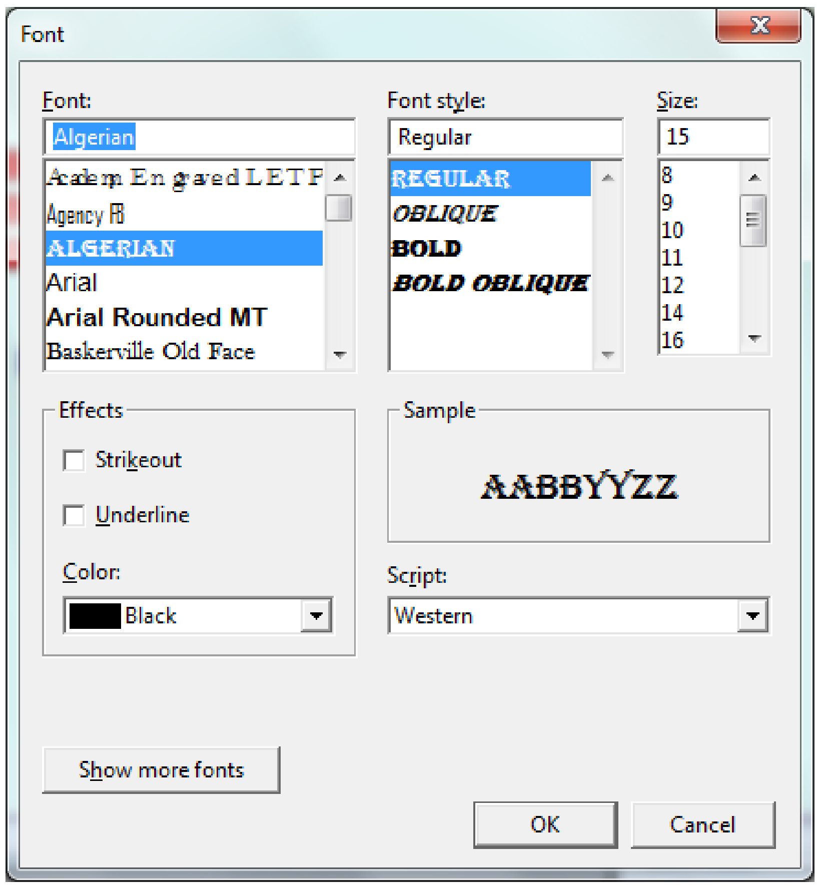


Figure 8- 53.Text font dialog box

This is a standard windows dialog box. Just set the font, style, size, effects, and color options you want and click on the "OK" button. The selected text will be redrawn using the font and options you have selected. Note that fonts you select may not reproduce exactly on the screen or your printer and that every system will likely have a different set of fonts available.

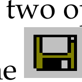
Loading and Saving Logical Decisions Files

The options in the File menu let you load and save your analyses in files called Logical Decisions files. Logical Decisions files contain all of the objects that make up your Logical Decisions analysis, including measures, alternatives, goals and preference sets. Logical Decisions files use a binary file format that is readable only by Logical Decisions. The file menu does, however, provide options to export information to and from other file formats. The remainder of this section describes the options in the File menu for loading and saving Logical Decisions analyses.

Creating a New Logical Decisions analysis

The Files::New option lets you create a new Logical Decisions analysis. When you select this option, Logical Decisions first allows you to save your current analysis if you have not done so. Then Logical Decisions replaces the current analysis with the skeleton analysis that you see when you start Logical Decisions.

Saving a Logical Decisions Analysis

Logical Decisions provides two options for saving your analysis to a Logical Decisions file. The  File::Save and File::Save As are both standard options that appear in many Windows programs. The File::Save option saves your analysis in a file with the most recently used name.

If you have selected “Keep a backup copy when saving” in the

Preferences::Automatic Backup Preferences option, Logical Decisions will save the previous version of the file by changing its extenson to ".BAK”.

The File::Save As option lets you save a Logical Decisions analysis in a file with a new name. When you select this option, Logical Decisions will show you the standard file selection dialog box in Figure 8- 54.

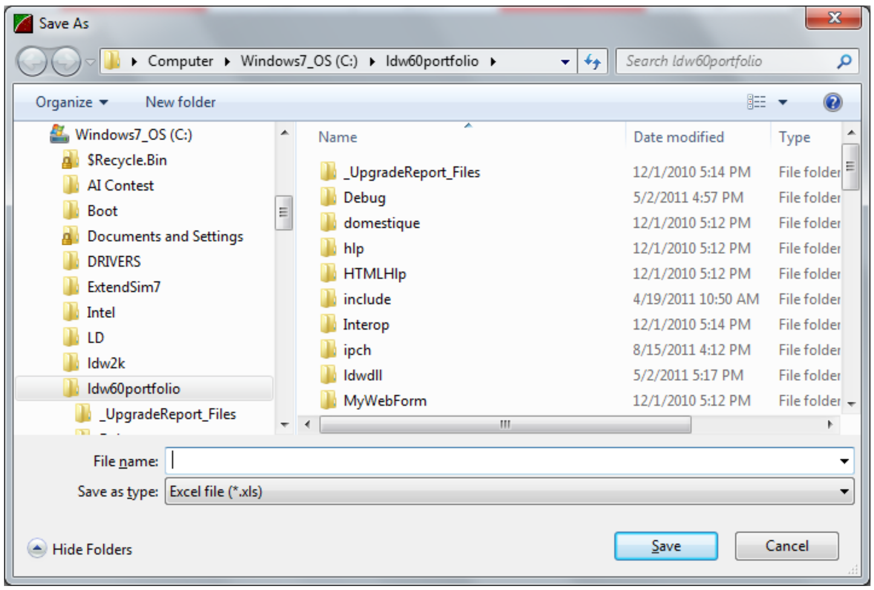


Figure 8- 54. Save File dialog box

Opening a Logical Decisions Analysis

You can open a Logical Decisions analysis by using the  File::Open option. When you select this option, you will see the standard Windows file open dialog box.

If you have made changes in your previous analysis without saving them, Logical Decisions will let you save them before you open the new file. Logical Decisions saves the analysis using the last file name used, as in the  File::Save option.

Importing Data Into Logical Decisions

The File::Import option lets you load data on a set of alternatives from another file format. You can use the Import option to import alternatives data from Microsoft Excel worksheet (.XLS) files and from comma and tab delimited files. You can use the data to create a new Logical Decisions analysis or to update and/or append to the data currently loaded into Logical Decisions. **Note: the easiest way to import for any file format and option is to first export an existing Logical Decisions analysis to that format and then modify the exported file to include your data.**

When you select the Import option, you will see the wizard shown in Figure 8- 55.

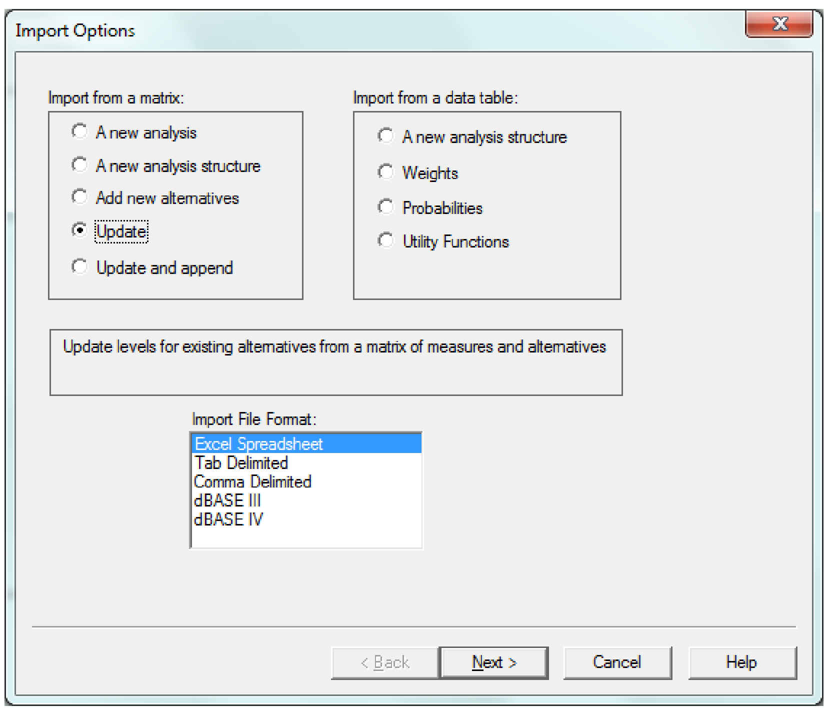


Figure 8- 55. First page of wizard for File::Import Option.

The radio buttons at the top of this wizard let you to select from the following options:

Import from a matrix: These options let you import data from a matrix of alternatives and measures.

- **A new analysis** -- create a new Logical Decisions analysis.

- **A new analysis structure** -- scan a file and create a new Logical Decisions analysis. Import the measures identified in the file, but don't import any alternatives.

- **Add new alternatives** -- add new alternatives to the data currently loaded into Logical Decisions

- **Update** -- modify the measure levels of the current alternatives. The update option assumes that you have already created or loaded an existing data file into the program. Logical Decisions will match the data in the input file with the alternatives and measures in the existing analysis. The previous levels of some or all of the measures will be updated based on the data in the input file.

- **Update and Append** -- both modify the levels of existing alternatives and add new alternatives to the data currently loaded into Logical Decisions.

Import from a data table: These options let you import data a table in an Excel worksheet.

- **A new analysis structure** -- import goals, measures and measure categories, including their organization in a goals hierarchy and the definitions of the measure scales.

- **Weights** – the weights for the goals and measures in the current analysis

- **Probabilities –** probabilistic levels for alternatives on measures or measure categories.

- **Utility Functions –** the single-measure utility functions for the measures in the current analysis.

The list of file formats at the bottom of the wizard lets you tell Logical Decisions the format of the data you will be importing. Just click on the proper format.

The following matrix file formats are currently available:

- **Excel Spreadsheet**-- a file in the Microsoft Excel worksheet (.XLS) format. Currently, Logical Decisions supports the XLS 7.0 (Excel 2003) format only. Logical Decisions will ask you to select a sheet from the workbook.

For the import from a matrix options, the worksheet must have "Number of Alternatives =" in cell A1, the number of alternatives in cell B1, “Number of Measures =” in cell A2 and the number of measures in cell B2.

Rows 3 and 4 can optionally have the analysis title as “Title:” in cell A3 and the title in cell B3 and a note as “Note:” in cell A4 and the note in cell B3.

Column A of the sheet must have alternative names. The next available row (3,4 or 5) of the sheet must have the measure names, starting in column B. Each cell in the matrix of alternatives and measures must be filled with a label, or a number. Formulas are not allowed.

- **Comma Delimited** -- a file in a standard comma delimited format. The file must be a standard DOS text file in a format similar to that shown in Error! Reference source not found..

```
"ALTERNATIVES"
"NAME"“,NUMBER"“,NUMBER"“,LABEL"“,NUMBER"“,LABEL"“,NUMBER"
"NAME"“,Price"“,Power"“,King Cab"“,Miles Per Gallon"“,Luxury"“,Reliability"
"Jeep Comanche",9728,177”,No",17”,Medium",0.75
"Chevy S-10",10073,160”,Yes",16”,Low",0
"Mazda",9865,109”,Yes",20”,Low",0.75
"Toyota",9561,120”,Yes",20”,Medium",1
"Ford Ranger",11147,140”,Yes",18”,Medium",0.5
"Mitsubishi",8480,109”,Yes",21”,Medium",0.8
```

Figure 8- 56. Example of comma delimited file import

The first line has the word "ALTERNATIVES". The second line indicates the type of levels for each measure. Each column has one of three possibilities:

NAME - the column with the alternative names.
NUMBER - the measure will have numeric levels.
LABEL - the measure will have text labels as levels.

The third line has the measure names. The first name must be "NAME". This shows that the first string in each following line will be the name of the alternative. The following strings are the names of the other measures. The measure names must all be on one line, enclosed in quotes and separated by commas. Each line after the measure names line contains the data for a single alternative. First is the name of the alternative, enclosed in quotes, then come the measure levels for the alternative. The measure levels must correspond to the measure names defined in the second line of the file.

- **Tab Delimited** -- a file in a standard tab delimited format. The file must be a standard DOS text file in a format similar to that shown in. Figure 8- 57.

ALTERNATIVES						
NAMENUMBER	NUMBER	NUMBER	NUMBER	NUMBER	LABEL	NUMBER
NAME	Price	Power	King Cab	MPG	Luxury	Reliability
Jeep Comanche	9728	177	No	17	High	0.75
Chevy S-10	10073	160	Yes	16	Medium	0
Mazda	9865	109	Yes	20	Low	0.75
Toyota	9561	120	Yes	20	Low	1
Ford Ranger	11147	140	No	18	Low	0.5
Mitsubishi	8480	109	Yes	21	Low	0.8

. **Figure 8- 57. Example of tab delimited file format**

The first line has the word ALTERNATIVES, with no quotes. The second line indicates the type of levels for each measure as described for comma delimited files.

The third line has the measure names. The first name must be NAME. This shows that the first string in each following line will be the name of the alternative. The following strings are the names of the other measures. The measure names must all be on one line, separated by single tab characters, and not enclosed in quotes.

Each line after the measure names line contains the data for a single alternative. First is the name of the alternative, not enclosed in quotes, then come the measure levels for the alternative, each separated by a single tab character. The measure levels must correspond to the measure names defined in the third line of the file.

When you have selected the correct format and import option, click “Next".

Next Logical Decisions will show you the suggested file name and path. You can change this by clicking “Browse”. Logical Decisions will show a standard Windows "File Open" dialog box. Select the file you want to import and double click it. If you have selected an Excel workbook with more than one sheet, Logical Decisions will ask you to select the sheet with the import data.

If you selected the A New Analysis option in the dialog box, Logical Decisions will automatically create a new analysis using as much data in the import file as possible. Each column in a worksheet or tab or comma delimited file or field in a ".DBF" file, becomes a new measure. Each row in a worksheet, or tab or comma delimited file, or record in a ".DBF" file, becomes a new alternative. Logical Decisions groups all of the new measures under the "Overall" goal. Logical Decisions assumes that the measures are all increasing (more preferred to less) and assigns them nominal ranges equal to their actual ranges for the alternatives in the import file.

If you selected the Import Structure option, Logical Decisions will create a new analysis using the information in the input file as a template. Logical Decisions will create a new measure for each column of the data matrix except the alternative name column.

Logical Decisions will also determine if each measure uses number or text labels.

Then Logical Decisions will scan through the alternative rows to identify the range of each measure found in the alternatives. For numeric measures, Logical Decisions will save the lowest and highest numbers found as the measure's range. For measures with labels, Logical Decisions will save all the different labels it finds for the alternatives in the measure's list of allowable labels. Logical Decisions will not add any alternatives to the analysis.

The idea of the Import Structure option is that you will use it in combination with the Append option in a two pass approach. In the first pass you would select the Import Structure option to identify the measures and their ranges. Then you would massage that information in Logical Decisions, eliminating irrelevant measures, identifying measures where lower levels are preferred, modifying measure ranges, setting cutoffs, etc. At this time, you could also organize the measures into a goals hierarchy and do preference assessments.

Next you would use the Append option to load in the alternatives. You can apply the ranking and cutoffs filters available there to load in only those alternatives that are most promising and that pass all the cutoffs.

If you selected the Update option, Logical Decisions will use the data in the import file to selectively update the alternatives in your analysis.

After you have selected the name of the import file, the wizard asks you to select the measures in your analysis it should update and the fields from the import file that it should use as the source of the updates. You do this using the wizard page shown in Figure 8- 58.

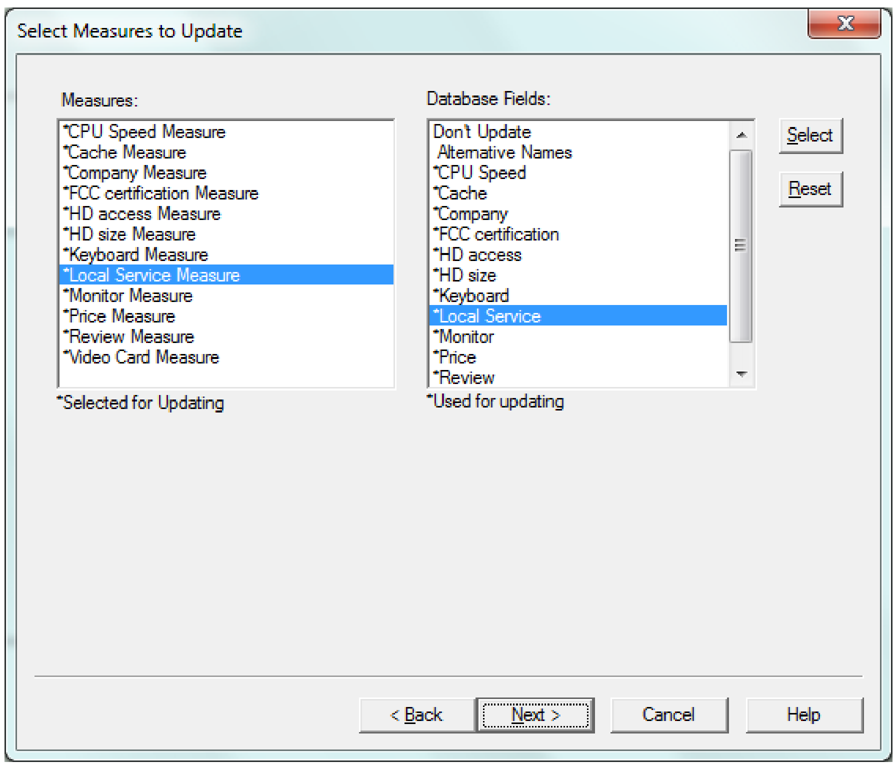


Figure 8- 58. Wizard page for selecting measures to update

In this page, the list on the left contains the measures in your analysis and the list on the right contains the fields in the update file. To select a measure for updating, click its name in the left list and then click the field to use to update it. The wizard will mark both the measure and the field with an asterisk. The wizard marks the measure to show it will be updated, while it marks the field to show it is being used for updating.

Next you will see the update and append options page shown in Figure 8- 59.

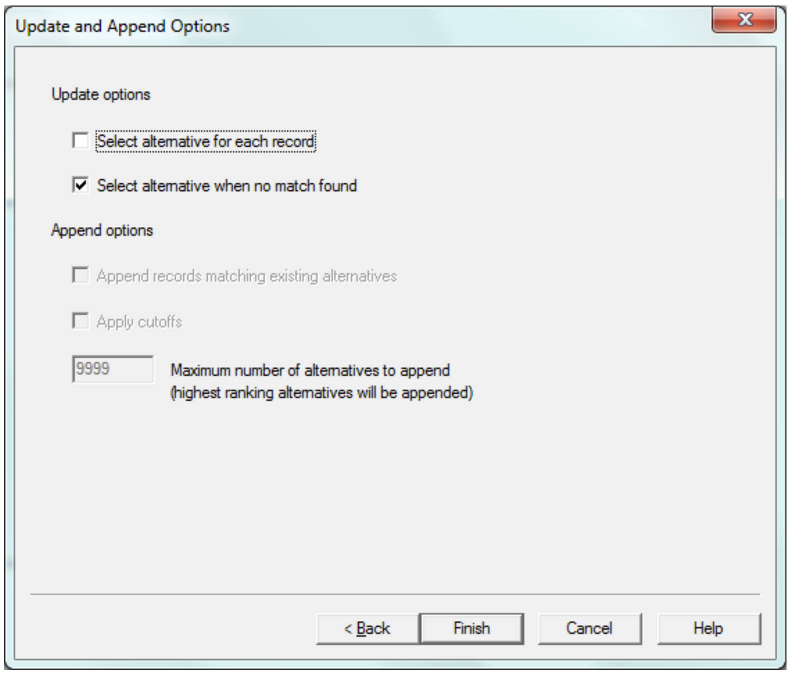


Figure 8- 59. Wizard page for update and append options

- **Select alternative for each record** – the wizard asks you to select which alternative to update for each record of the import file, no matter whether a match exists.

- **Select alternative when no match found** -- Alternatives with exact name matches are updated automatically. If no match is found for a record in the import file, Logical Decisions asks you to select which alternative to update from a list.

The Append option is similar to the Update option, except that new alternatives are added to the current database and Logical Decisions does not modify the existing alternatives. The option proceeds similarly to the Update option.

The wizard gives you a choice of creating a new alternative from each record in the import file or of creating new alternatives only for records that don't match the name of an existing alternative. The wizard also lets you import only those alternatives that meet all of the cutoffs.

The wizard gives you a choice of appending import file records that have the same name as an existing alternative. If you check the box, Logical Decisions will create a new alternative for each record in the import file. Otherwise, the program will check for alternatives with the same name as the record being loaded, and will not append a new alternative if a match is found.

The last two append options determine which alternatives will be kept in the Logical Decisions analysis.

First the wizard asks if it should apply the measure cutoffs to the alternatives. If you check the box, Logical Decisions will not save any alternative that fails a cutoff defined for any of the measures. In addition, when you select this option, Logical Decisions will not append an alternative with a text label that is not on the current list for a measure.

The wizard also asks the maximum number of alternatives that should be imported. If you specify a number less than the number of alternatives in the import file, say 10, Logical Decisions will rank each alternative as it reads it and will only save the top 10 ranked alternatives (it bases its ranking on the active preference set).

This ability -- when combined with the Import Structure option -- provides a powerful way of quickly screening large data files for the most promising alternatives.

When appending, Logical Decisions reads the measure levels for the selected measures from the import file for each alternative. Logical Decisions will assign the other measures their least preferred levels as defined in their properties dialog box.

The Update and Append option in the import dialog box is a combination of the Update and Append options. It lets you simultaneously update existing alternatives and append new records to an existing database using an import file.

Importing data from Excel data tables. Logical Decisions provides options to import data from four types of Excel data tables – Analysis structure, Weights and Probabilities, and Utility Functions.

The analysis structure import option uses the same table structure as the Export Structure option. An example of a structure table is shown in Figure 8- 60.

Logical Decisions Structure							
Title:	NEW ANALYSIS						
Note:							
Type	Name	ID	Comments	Parent	Units	Most Preferred	Least Prefe
Goal	Buy the best truck	1		Buy the best truck	Utility		
Goal	Performance	1.2		Buy the best truck	Utility		
Measure	Power	1.2.1		Performance	horsepower	175.00000	109.000
Measure	Fuel Economy	1.2.2		Performance	miles per gallon	23.00000	16.0000
Category	City	1.2.2.1		Fuel Economy	miles per gallon		
Category	Highway	1.2.2.2		Fuel Economy	miles per gallon		

Figure 8- 60. Data table example for Import/Export structure option.

The table must have “Logical Decisions Structure” in cell A1, and can optionally have the analysis title and a note in cells B2 and B3. The table proper starts in row 6. The first column has the type of the object – Goal, Measure, or Category. The next columns have the Name, ID number, Comments, Parent and Units. The parent of a goal or measure must be a goal that has previously appeared in the table. A category’s parent must be a measure that has previously appeared.

Measures have additional data. The most preferred and least preferred levels of their scales, upper and lower cutoffs, if any, and the number of labels. If the number of labels is zero, the measure will have a continuous scale. If the number of labels is greater than zero, the labels will follow the number of labels in the table.

The Import Weights option lets you import directly entered weights into the preference set for an analysis. The structure must be the same as the currently loaded Logical Decisions analysis. The data table used is the same as for exporting weights and is shown in Figure 8- 61.

Logical Decisions Weights			
Title:	NEW ANALYSIS		
Note:			
Preference Set:	Tutorial		
Goal Name	Num Members	Member Name	Value
Buy the best truck	3		
		Performance	0.35461
		Styling	0.09220
		Cost	0.55319
Performance	2		
		Power	0.35000
		Fuel Economy	0.35000
Cost	2		
		Price	0.66667
		Resale Value	0.33333

Figure 8- 61. Import/Export weights data table example.

The table must have “Logical Decisions Weights” in cell A1, optionally followed by the analysis title and a note in cells B2 and B3.

The preference set name is shown in cell B4. If the preference set exists in the Logical Decisions analysis, you are given the option to overwrite it or copy it to a new preference set before importing. The weights start in row 7 with the name and number of members in the MUF for the overall goal. The next rows have the name and weight for the members of the overall goal.

Logical Decisions assumes that goals appearing in the member list for a goal will in turn have their own MUF. Lower goals with their own MUF can appear in the data table after the member list for the goal it belongs to. For example, the Performance goal's members can appear after the goal appears in the member list for the overall goal.

The Import Probabilities option lets you import probabilistic measure levels. The imported levels will overwrite the existing levels for the alternative and measure. The data tables for importing and exporting are the same and are similar to the example shown in Figure 8- 62.

Logical Decisions Probabilities										
Title:	NEW ANALYSIS									
Note:										
			Normal	Mean	Std.Dev					
			Uniform	Upper	Lower					
			Discrete	Num	P1	L1	etc.			
			PLC	Num	P1	L1	etc.			
			3 Point	Min	Mid	Max				
			Triangle	Min	Mid	Max				
			Label	P1	P2	etc.				
Alternative	Measure	Category	Type	Values						
Coyote	Resale Value		Discrete	3	0.25000	50.00000	0.50000	60.00000	0.25000	65.00000
Mountain Lion	Styling		Label	0.00000	0.00000	0.25000	0.50000	0.25000		
Mountain Lion	Resale Value		Normal	60.00000	5.00000					
Wolf	Resale Value		Uniform	60.00000	70.00000					

Figure 8- 62. Example of Import/Export Probabilities data table.

The table must start with "Logical Decisions Probabilities" in cell A1. This can be followed by the analysis title and a note in cells B2 and B3. The headers in rows 5-11 describe the data that is assumed to be in each column for the different probability distribution types. In the table starting in row 13, each line represents a single probabilistic level. The first column is the alternative name, the second is the measure name and the third column may have a category name. The alternative, measure and category must exist in the currently loaded analysis. The fourth column has the type of the probability distribution using the names shown in the header. The following columns have the data appropriate to each probability distribution.

The Import Utility Functions option lets you import single measure utility functions levels for the measures. The imported functions will overwrite the current utility functions. The data tables for importing and exporting are the same. An example is shown in Figure 8- 63.

Logical Decisions Utility Functions									
Title:	Buying a Computer								
Note:									
Preference Set:	Decision Maker								
	Linear	Least preferred level	Most preferred level						
	SUF	Num ranges							
	SUF Range	Least preferred level	Least preferred utility	Most preferred level	Most preferred utility	Mid-preference level	Mid-preference utility		
	Direct	Num	Label 1	Utility 1	etc.				
	AHP	Adjusted	For Alternatives	AHP SUF	Num Elements				
	AHP Matrix		Element 1	Element 2	etc.				
		Element 1	Ratio 11	Ratio 12	etc.				
Measure name	Type								
CPU Speed	SUF	2							
	1	25.00000	0.70000	33.00000	1.00000	29.00000	0.85000		
	2	20.00000	0.00000	25.00000	0.70000	22.50000	0.35000		
Cache	SUF	2							
	1	32.00000	0.40000	64.00000	1.00000	48.00000	0.70000		
	2	0.00000	0.00000	32.00000	0.40000	16.00000	0.20000		
Company	Direct	No	3	First Rate	1.00000	Second Tier	0.65000	No-Name	0.00000
FCC certification	Direct	No	2	Class B	1.00000	Class A	0.00000		

Figure 8- 63. . Example of Import/Export SUFs data table.

The table must start with "Logical Decisions Utility Functions" in cell A1. This can be followed by the analysis title, a note and the preference set name in cells B2, B3 and B4. The headers in rows 5-12 describe the data that is assumed to be in each column for the different SUF types. In the table starting in row 14, each measure has one or more lines describing the SUF for that measure. The columns have the data appropriate to each SUF type.

Exporting Data From Logical Decisions

The File::Export option lets you save data for the current alternatives to another file format. You can use the Export option to export alternatives data to Microsoft Excel worksheet files, and to comma and tab delimited files.

The exported data can be either the measure levels or the utilities for each measure and goal (for the active preference set) for each alternative. Note that Logical Decisions will export any probabilistic levels as their certainty equivalents. Logical Decisions will also export measure categories automatically.

You can export any of the data tables described above – Structure, Weights, Probabilities or Utility Functions to Excel. You can also export a working version of the utility functions in the active preference set to Excel.

When you select the Export option, Logical Decisions shows you the dialog box in Figure 8- 64.

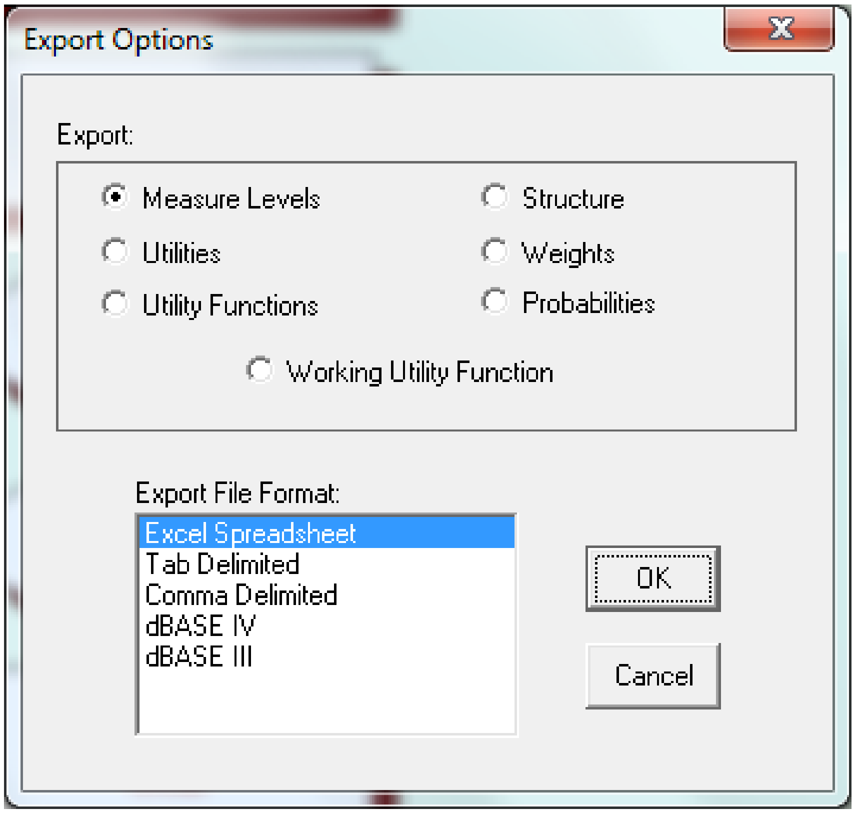


Figure 8- 64. Dialog box for File::Export option.

In this dialog box, the list at the bottom contains the export formats available. These are the same types described for the File::Import option above with the addition of the working utility function option. The radio buttons at the top of the dialog box let you select measure levels, utilities, the utility function, the goals and measures structure, weights, or probability distributions for export. You can only export the utility functions, structure, weights, working utility function and probability distributions to Excel.

When you have selected the type of export you would like, Logical

Decisions shows you the standard Windows "Save As" dialog box to enter the name of the export file to be created. The default name is based on the current Logical Decisions file with an extension appropriate to the file type being created. If you enter the name of an existing file, Logical Decisions asks you to confirm that it should overwrite the file. After you have entered the name, Logical Decisions creates the export file automatically.

With the exception of the "Working Utility Function", the files created for the various formats match the requirements in the File::Import option, so you can modify files you have exported for later import back into Logical Decisions.

Exporting a Working Utility Function. The final export option is to export a utility function. This option lets you export a complete working utility function to an Excel spreadsheet. The utility function exported is the MUF from the active preference set, including all of the single measure utility functions for the measures and the multi-measure utility functions for the goals. The "Working Utility Function" option results in an Excel worksheet that has the utility function for the active preference set embedded as Excel formulas. The top part of the worksheet has rows for the measure names and their associated weights. Row 5 is labeled "Alternative to Evaluate". Here you can enter a level for each evaluation measure and have Excel compute the utility for the alternative for each measure and goal. The overall utility for the alternative is shown in cell B7. By examining the formulas in the worksheet cells, you can see the details of how the utilities are computed.

Logical Decisions also exports a sample alternative for you to rank in the Excel spreadsheet.

Other Options

Several other options are available in Logical Decisions:

- Exit the Program
- Arrange for automatic file backups
- Display the Logical Decisions "About Box"
- Arrange the Program's Child Windows
- Help

Exiting the program. To exit the Logical Decisions program, select the File::Exit option.

Automatic file backups. The Preferences::Automatic Backup Preferences option lets you arrange for timed backups and also to save the previous version of your analysis when you do a File::Save. When you select the option, Logical Decisions displays the dialog box shown in Figure 8-63.

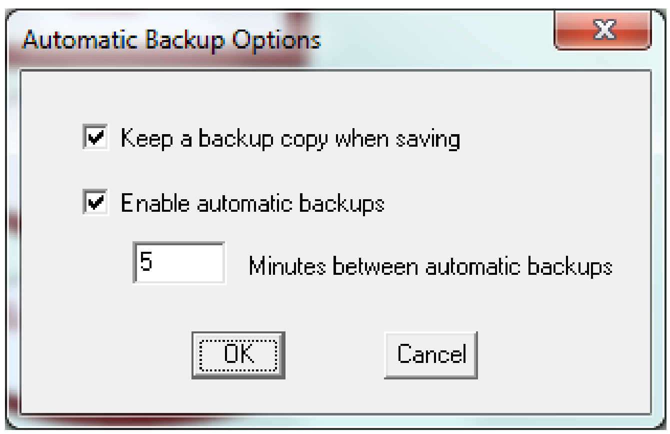


Figure 8- 65. Automatic backup options dialog box

There are two options. You can keep a backup copy of the previous file when saving your analysis. The backup has the same name as the original file with the extension .BAK.

You can also automatically backup your analysis after a specified number of minutes has passed. The backup files are saved with the current file name and the extension .LDS.

Displaying the Logical Decisions About Box. To display the Logical Decisions about box, select the Help::About...

option.

Getting Help. You can get to the Logical Decisions help system through the options in the Help menu:

The Help Index option causes Logical Decisions to display the index for its help system. You can also select this option by pressing the **F1** key.

Entering a new key. Your key controls the features available to you and when your license expires. If you need to enter a new key for your software, you can do so by selecting the Help::Enter Key option.

SECTION

In Depth

9

In Depth

Introduction

This section is a more detailed discussion of how you can use multi-objective decision analysis (MODA) to evaluate difficult real-life decisions. First, we will summarize the steps in the decision analysis approach. We then discuss each step in detail along with how to use Logical Decisions to carry out the steps.

Logical Decisions provides a sophisticated method for prioritizing and ranking alternatives. It lets you use the powerful tools of **decision science** to evaluate complicated alternatives involving uncertainties and seemingly incomparable characteristics. We will call the study of decision making "decision science" and the application of decision science to a particular decision "decision analysis". The particular decision science technique included in Logical Decisions is called "Multi-Objective Decision Analysis" or MODA. The more familiar you become with the principles of decision science and MODA and their use in Logical Decisions, the more insights you can gain into your decisions by using the software.

Decision science was developed in the 1960s and 1970s at Stanford, MIT and other major universities (see Bibliography). It is generally considered a branch of the engineering discipline of Operations Research, but also has links to economics, mathematics and psychology.

The essence of MODA is to break complicated decisions down into small pieces that you can deal with individually and then recombine logically.

A key goal of MODA is to make a clear distinction between the choices that you can make (the **alternatives**), the characteristics of the alternatives (quantified by the **measures**) and the relative desirability of different sets of characteristics (**preferences**). These distinctions let you clearly separate the objective and subjective parts of your decision.

The alternatives and the way they are described using the measures are relatively objective. Even if there are uncertainties in the levels of the measures, it is usually possible to come to an agreement about how to characterize them.

On the other hand, the weights of the different measures, the interactions between them, and your attitudes towards risk are inherently subjective. Reasonable people can have disagreements on these subjects.

You can't generally eliminate these subjective parts of a decision. Logical Decisions provides methods for logically dealing with both the objective and subjective parts of a decision while keeping them well separated.

The types of decisions that you can address using Logical Decisions might best be described as “Choices”. A choice has the following characteristics:

- You will select among a finite set of alternatives.
- All of the choices are “feasible”, meaning that you could actually choose each one if you wanted.
- No evaluation measures have levels that are unacceptable.
- You need to consider at least two evaluation criteria simultaneously.

● You will choose an entire alternative at a single time. That is, you won't choose part of an alternative now and the rest of it later.

Many decisions don't meet one or more of these caveats, meaning that Logical Decisions may not be the best tool to analyze them.

For example, optimization problems such as the best mix of products to produce at an oil refinery have a practically infinite number of possible product mixes (alternatives). These types of problems are often addressed by tools such as linear programming.

Another example is multi-stage decisions, such as a new product introduction. In these problems you might want to make a preliminary decision to do test marketing and then decide later about a full product rollout based on the test results. These types of problems are often analyzed with tools such as decision trees and influence diagrams.

A third example is a portfolio decision, where you will be selecting a set of alternatives subject to budgetary and other constraints. You can analyze these types of problems with Logical Decisions in conjunction with Logical Decisions® Portfolio.

The MODA technique for choices uses the following steps:

1) Identify the alternatives to be ranked.

2) Clarify the goals and objectives that should be met by choosing the top-ranking alternative.

3) Identify measures to quantify how well the alternatives meet the goals and objectives.

4) Quantify the level for each measure for each alternative.

5) Quantify preferences about different levels of the measures.

6) Rank the alternatives by combining information from steps (4) and (5).

7) Do "sensitivity analysis" to see the effects on the results of changes in measure levels or preferences.

Logical Decisions makes it easy to follow these steps and automates the tedious portions of the method. The following sections describe how to do each of the above steps using Logical Decisions. For more information about the details of using Logical Decisions, see sections 6 through 8, Using Logical Decisions; sections 4 and 5, Tutorials; and section 11, Commands Reference. If you have not yet worked through the Tutorial, doing so after you read this section will be helpful.

Identifying and Describing Alternatives

Alternatives are the choices you are ranking. They can be any set of objects or courses of action you must choose between. They can be cars or trucks to buy, colleges to attend, employees to hire, or lifestyles to lead.

Identifying Alternatives

Alternatives are often clearly defined, such as when you have to choose between three different universities. In other cases it may be very difficult for you to identify the alternatives.

If there are many possible alternatives -- such as makes and models of cars (not to mention options and colors) or houses to buy -- you may need to do a preliminary screening to identify a manageable set of alternatives to rank.

In other cases you may need to be very creative to describe alternatives in sufficient detail to allow comparisons.

Composite Alternatives

A more subtle problem in defining alternatives occurs when alternatives are really groups of objects that could be chosen.

For example, suppose you manage the R&D section of a large company and you have some research projects you could fund. If the projects don't interact too much (if selecting one project doesn't affect the desirability of the other projects), you could make each project an alternative. Then you could rank them using Logical Decisions and select the top ranking projects. If the projects do interact, it might better to make your alternatives groups of projects and rank the groups.

Typically, there will be a lot more possible groups of projects than there are individual projects, and you will need to be careful when defining and evaluating ranking measures.

Logical Decisions cannot directly process composite alternatives (by, for example, ranking all possible sets of research projects given data on each individual project). You must define each composite alternative separately. Logical Decisions® Portfolio is a tool that can help you analyze composite alternatives.

Describing Alternatives

In the MODA method, you quantitatively describe your alternatives in terms of variables called **evaluation measures**. Each alternative has a raw score (called a **level**) on each measure. The levels for the measures completely describe an alternative for the purposes of ranking. Thus, it is very important for you to carefully think about how you define the evaluation measures. If you use inappropriate or poorly thought-out measures your ranking results may be non-intuitive and hard to justify. Measures are discussed further on page 302.

Logical Decisions relies on you to gather the measure levels for the alternatives. You should try to be consistent in how you evaluate the different alternatives, so that the same level on a measure always means the same thing. Careful definitions of your measure scales can help.

If you gather data about your alternatives from different sources, you should try to make sure the sources all compute the measure in the same way. For example, if you're pricing washing machines from different stores, make sure the prices you're quoted are really comparable. Do they include sales taxes and delivery charges? Have the costs of the options you want been included? Your results will be incorrect if the prices are based on different assumptions.

The "Analytic Hierarchy Process" provides a method of evaluating your alternatives without explicitly defining their measure levels. In this approach, you directly compare the alternatives' performance as part of the preference assessment process. No scale or units are defined for the measure. This means that when you are using the AHP approach for a measure, you do not need to define any levels for your alternatives on that measure. In fact, Logical Decisions will ignore any levels you have defined for the alternatives.

Because the AHP method does not make use of explicit measure levels, it makes it hard to distinguish between the objective measure levels and the more subjective conversion to common units. In addition, you lose traceability between the level for an alternative on the measure and the utility (common units) assigned the alternative on the measure. For these reasons we recommend that you use the AHP approach infrequently. We feel you should only use it for measures that are very subjective and for which you cannot think of a reasonable quantitative or qualitative scale. The "Analytic Hierarchy Process" method is discussed on page 325.

Identifying and Defining Alternatives in Logical Decisions

Initially, a Logical Decisions alternative is just a name, limited to 255 characters, and optionally an ID number or a comment. The real definition of an alternative is its levels on the evaluation measures.

You define the levels in Logical Decisions' Matrix View. Logical Decisions options let you define measure levels with probabilities or with measure categories. If you have many alternatives you may find it easiest to define them outside Logical Decisions and to use the File::Import option to load them into Logical Decisions.

You can read more about how to define alternatives on page 105. You can read about defining levels with probabilities on page 114 and about defining levels with measure categories on page 126. The File::Import option is discussed on page 273.

Identifying Goals and Objectives

Goals and objectives are the qualitative considerations that influence the desirability of the alternatives. For example, in choosing a car the highest level goal might be "choose the best car". Underneath this broad goal might be dozens of subsidiary concerns, such as "minimize the price of the car", "maximize power", "maximize fuel economy", and "maximize rear seat legroom". Some of these concerns may overlap, some may be conflicting and some may be unimportant when compared to the other concerns. Logical Decisions uses a **Goals Hierarchy** to help you organize the goals and objectives for an analysis.

Developing a Goals Hierarchy

A goals hierarchy is like an organization chart. It starts with the most general goals at the top and breaks these general goals down into more specific sub-goals. In the truck example from the Tutorial, the general goal of "choose the best truck" might be expanded into "minimize cost", "maximize quality", and "maximize features". You might break the "maximize features" objective down further into "maximize performance" and "maximize comfort".

Figure 9- 1 shows how the top portion of a goals hierarchy for buying a truck might look. The process of dividing general goals into more specific goals continues until the objectives are specific enough to measure.

In our example, "minimize cost" might be specific enough to measure although it is near the top of the hierarchy, while we would probably have to break "maximize performance" down further before we could develop meaningful measures. Measures are discussed further on page 302.

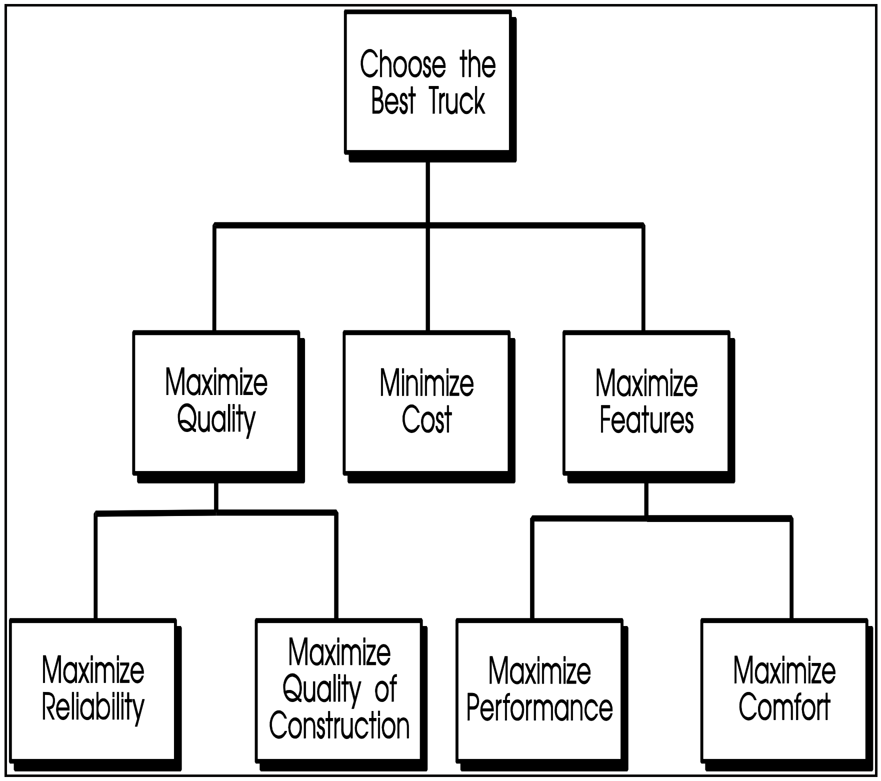


Figure 9- 1. Example goals hierarchy

Goals and Objectives in Logical Decisions

Logical Decisions uses **goals** to organize the measures into a hierarchy. Logical Decisions' goals correspond to those in a goals hierarchy. The lowest level goals serve to aggregate related evaluation measures, while higher level goals can aggregate both measures and other goals.

There is always a highest level goal (initially called "Overall") corresponding to the highest level in the goals hierarchy. Lower level goals can be added and revised using the View::Goals Hierarchy option or the View::Brainstorming option. The measures and other goals that belong to a goal are called its **members**. Logical Decisions requires that the lowest level of the hierarchy be made up of evaluation measures only. This means that at least one goal must be made up of only measures. Since goals may be "measurable" at different levels of the hierarchy, Logical Decisions lets you have both measures and goals as members of a higher level goal. In the truck example, the "choose the best truck" goal might have three members, a measure called Price, a goal called Quality and another goal called Features.

Each goal in Logical Decisions has a name, which can be up to 255 characters, an optional ID number, optional comments, and a nominal utility that Logical Decisions may use in the tradeoff assessment process described on page 344. Each goal also has a set of members, which can be either measures or other goals. The View::Goals Hierarchy option is described on page 96.

Defining Measures

Evaluation measures are the variables used to describe the alternatives. They quantify the lowest level goals in the goals hierarchy described above. The measures completely describe the alternatives for ranking purposes.

Measures must be quantitative or textual and specific enough to let you assign a number, text description or probability distribution for each alternative. Other than that, Logical Decisions puts few restrictions on the form a measure may take. Measures can be natural, such as the cost of a car, or constructed, such as a five-point scale that describes a car's luxuriousness. Each measure consists of units and a range from least preferred to most preferred. The units may be continuous, such as horsepower, or discrete, and there is no requirement that the ranges or units for the different measures be comparable.

Measures whose desirability increases as the level increases (such as miles per gallon, where 30 MPG is preferred to 20 MPG) are called **increasing**. Measures where desirability decreases as the level increases (such as Cost, where $30,000 is less preferred than $20,000) are called **decreasing**. The **most preferred level** of a measure is the highest level for increasing measures and the lowest level for decreasing measures.

An ideal alternative is one with the most preferred level on all of the evaluation measures.

Measures in Logical Decisions

You define measures in Logical Decisions with the measure properties dialog box. Each measure consists of

- A **name**, limited to 255 characters.
- An **ID Number,** limited to 255 characters.
- **Units**, limited to 255 characters.
- A **Goal Above**, defining the goal the measure is a member of.
- A **least preferred level**, in the measure's units.
- A **most preferred level** in the same units, and
- An **upper cutoff level**, above which is unacceptable, also in the same units.
- A **lower cutoff level**, below which is unacceptable, also in the same units.
- **Labels**, optional text strings that make up a set of discrete possible choices for the measure levels.
- **Comments**, an optional text description of the measure.

You can read more about how to define measures on page 109.

Quantifying Measure Levels

To let Logical Decisions rank the alternatives, you must quantify how well each meets your goals and objectives. You do this by defining the level on *each* measure for *each* alternative. You can define measure levels in four ways in Logical Decisions -- with point estimates, labels, probabilities, and measure categories. You can also evaluate alternatives without defining measure levels by using the "Analytic Hierarchy Process" or "Direct Entry" method for computing the common units for the measure.

Point estimates are single numbers that are an alternative's level on a measure.

If the measure levels fall into several natural categories, you can describe the categories with brief text descriptions called labels.

You should use probabilistic levels when you don't know the level of an alternative for a measure with certainty but can describe it with a probability distribution.

You can use measure categories to define a measure's levels as the weighted sum of several sub-measures called categories.
The default is that measure levels are point estimates.

Entering Measure Levels in Logical Decisions

You enter or revise measure levels in Logical Decisions' Matrix view.

When you add a new measure, Logical Decisions initially assigns the least preferred level on that measure to each alternative in your analysis. Similarly, when you add a new alternative Logical Decisions assigns the least preferred level on each measure in your analysis for the alternative. Logical Decisions will **not** automatically adjust default levels if you later change the measure's range.

There are no restrictions on the numbers you can enter as levels. In particular, there is no requirement that the number be within the range you define for a measure in its properties dialog box.

However, if you are using labels, you must select one of the labels defined in the measure's properties dialog box.

By default, the levels you enter in the Matrix view are numerical point estimates. To use labels, select the properties dialog box for the measure and check the "Use Labels" box. Then click the "Labels" tab to define the list of acceptable labels.

To enter a probabilistic level, double click the cell for the level or select the Matrix::Define Probability option. You will then see the probabilities dialog box, where you can define a probability distribution for that level. You can define the level as any of a variety of probability distributions. The choices include Normal, Uniform, and Discrete distributions. If your measure uses labels, you can define a discrete probability distribution over the possible labels.

You can find out more about defining point estimate, label, and probabilistic measure levels on page 113.

Defining Levels With Measure Categories

You can use measure categories to define the levels of a measure as weighted sums or averages of several sub-measures. The measure categories are simplified measures with two differences from regular measures. First, measure categories have no defined range. Second, Logical Decisions does not convert measure categories to common units. Logical Decisions combines the values from all of a measure's categories using a weighted sum. Logical Decisions then converts he computed measure levels to common units using the measure's SUF.

There are two situations where it makes sense to use measure categories.

In the first situation, you want to define a measure as a weighted average of several similar measures. For example, the EPA publishes two different estimates of the fuel economy for cars and trucks -- city mileage and highway mileage. Instead of defining two separate fuel economy measures, you might want to define a single fuel economy measure as the weighted average of the two EPA figures. You could define the multipliers for the categories as the fraction of your total driving that occurs in the city vs. on the highway. The units for the combined measure will still be miles per gallon.

You should base the most preferred and least preferred levels on the range for the alternatives on the combined measure.

The second situation where measure categories are useful is when you want to define a measure as a weighted sum of several sub-measures. A good example is in facility location studies, where several different types of land use may be affected depending on where you locate the facility.

The reservoir location analysis described on page 389 had a measure to describe the number and type of prehistoric sites that would be affected at different locations. The prehistoric sites measure used the following five categories:

- "Residential Bases with Interpretive Value"
- "Residential Bases"
- "Processing Sites"
- "Isolated Rock Art"
- "Prehistoric Isolates"

Each category level for a reservoir alternative was the number of sites of the category type found at the reservoir location.

The multiplier for each category was based on the relative importance of affecting sites of that type. The "Residential Bases With Interpretive Value" category was selected as a "currency" category. It was assigned a multiplier of 1.0. The multipliers for the other categories were defined as the fraction of the impact of one currency site represented by affecting one of the other categories' sites. For example, the experts in the study said that affecting ten "Processing Sites" would have about the same impact as affecting just one "Residential Base with Interpretive Value". Thus each processing site represented about one tenth the impact of one site in the "currency" category and the "Processing Sites" category was assigned a multiplier of 0.1.

To compute the measure level for each alternative, the number of sites in each category was multiplied by its category multiplier and summed.

The resulting measure level for each alternative could be interpreted as the "equivalent" number of sites of the "currency" category affected at each reservoir location. The units for the prehistoric sites measure were thus defined as "equivalent residential base sites with interpretive value”.

The measure levels for particular alternatives were non-integer numbers of residential base sites. A level of 2.5 on the prehistoric sites measure means that the mix of sites in all the different categories represents an impact halfway between two and three residential base sites alone.

The advantage of combining the different types of prehistoric sites in this way is that the preferences of higher level decision makers can be assessed on a single simple but specific prehistoric sites measure -- the number of residential base sites affected. In addition, the level for each alternative reflects all of the various types of prehistoric impact for that alternative.

See page 126 for a discussion of how to define and enter measure category levels.

Quantifying Preferences

The most powerful and sophisticated parts of Logical Decisions are the methods used to quantify preferences. Logical Decisions lets you select from several different methods to make the individual measures comparable and to identify the relative importances of the measures. These two steps are done separately and are discussed separately in this section. The third preference assessment step -- defining multipliers for measure categories -- was discussed in the previous section.

Converting the Measures to Common Units

Since Logical Decisions allows so much flexibility in defining the scales and units for the measures, you cannot directly combine the measures into an overall score. For example, there is no direct way to combine the price of a car with its horsepower. To combine the measures, we must first convert them to a common scale.

The common scale used in decision analysis is called **utility**, which has units called **utils** (generally pronounced "you-tills"). Utility is a measure of desirability. The idea is that *more utility is preferred to less* and that each util represents the same amount of "increased desirability”.

The default utility scale for each measure has a range from zero to one, with one being the most preferred.

Logical Decisions assigns a utility of zero to alternatives having the least preferred level for a measure. Logical Decisions assigns a utility of one to alternatives having the most preferred level.

Alternatives having intermediate levels for a measure have a utility between zero and one on the measure's utility scale. Logical Decisions provides seven methods for computing the common units for a measure:

- Single Measure Utility Functions (SUFs),
- the Balance Beam method,
- the Analytic Hierarchy Process,
- Adjusted AHP,
- Ideal AHP,
- AHP SUFs, and
- Direct Entry.

Two of these methods -- SUFs and AHP SUFs -- use a continuous function to convert levels on a measure's nominal scale (say horsepower) to utility. The balance beam and direct entry methods associate utilities directly with labels or alternatives. The other three methods are based on the "Analytic Hierarchy Process". They define the utility for the alternatives by having you directly compare their performance on a measure without defining an explicit scale for the measure.

The Analytic Hierarchy Process, Ideal AHP and adjusted AHP methods don't use explicit measure levels. Thus, they don't allow the distinction that the decision analysis method usually makes between the objective measure levels and the more subjective conversion to common units. We recommend that you use the AHP approach infrequently, and only for measures that are very subjective and for which you cannot think of a reasonable quantitative scale.

Each method for computing common units is discussed further below.

Single Measure Utility Functions

Utility functions -- or more specifically **single-measure utility functions**, or **SUFs** -- are formulas that convert the levels for a measure to utils. You develop a SUF for a measure by interviewing (**eliciting**) the person making the decision (who we will call the **decision maker**).

There is no right or wrong SUF for any measure. The shape of the SUF should depend on the problem and on the decision maker's personal preferences.

This is where the separation of objective and subjective elements in Logical Decisions comes in. Identifying the measure levels for an alternative is a relatively objective process, while converting levels to utility is inherently subjective.

Straight line SUFs. The simplest type of SUF is a **linear SUF**. A linear SUF assigns a utility of zero to the least preferred level of a measure and one to the most preferred level. It assigns intermediate levels utilities that delineate a straight line between the two end levels. An example of a linear SUF is shown in Figure 9- 2, for a measure of Power. Straight line SUFs are the most commonly used type of SUF and they are the default used by Logical Decisions.

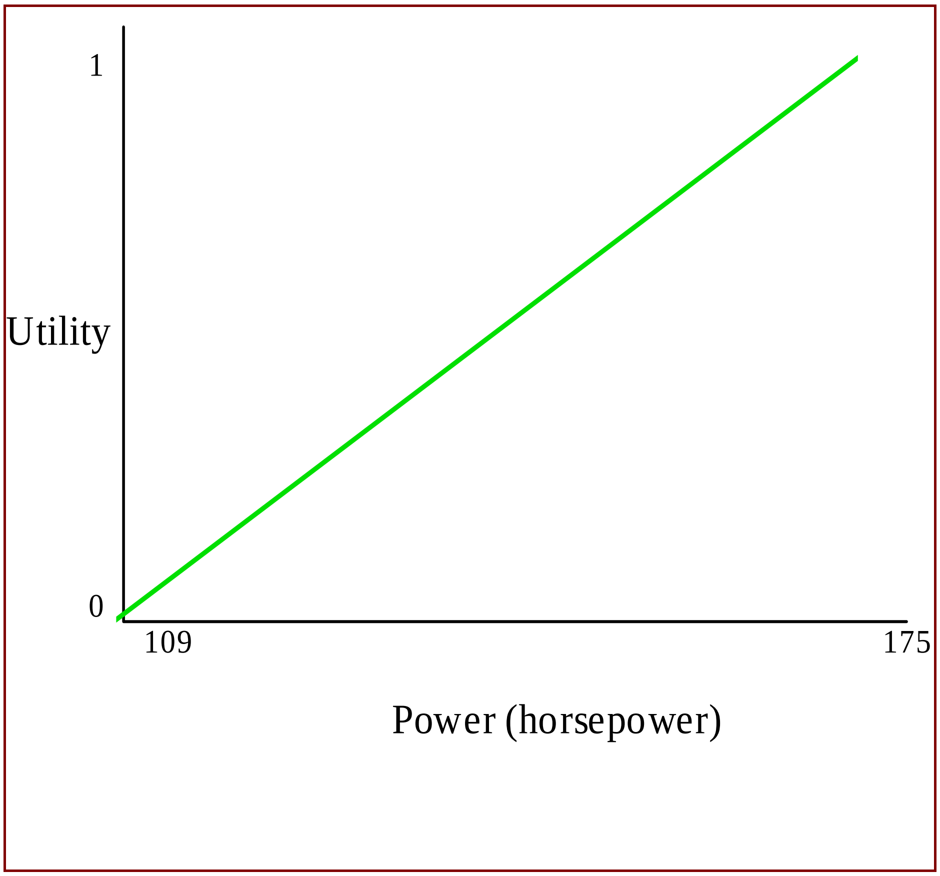


Figure 9- 2. Example of linear (straight line) SUF

Non-Linear SUFs. Straight line SUFs can't describe many common preferences. For example, suppose that in our truck example you feel that you want a powerful truck, but that after a certain level the usefulness of additional horsepower begins to drop off.

Suppose there is a range of from, say, 80 to 180 horsepower in the trucks you are comparing. You might feel that an increase from 80 to 90 hp was much more important than an increase from 170 to 180 even though the increase is 10 hp in both cases. To capture these preferences you must make the utility change from 80 to 90 HP greater than the change from 170 to 180.

The idea that the increase in desirability per unit decreases with increasing levels is related to the idea from economics of **decreasing marginal returns**, although here we are talking about decreasing returns of utils rather than dollars. The idea is also related to the decision science concept of **risk aversion**.

Eliciting SUFs. The process of establishing the proper shape for the SUF for each measure is called **SUF assessment**. Since there is no intrinsically correct shape for a SUF, the assessment process must be subjective. There are two commonly used methods for assessing a SUF -- **mid-level splitting** and assessments using **probabilities**. These approaches have different theoretical foundations that are mostly of academic interest. If you know the differences, you will know which technique you will want to use. If not, use the technique you feel most comfortable with.

SUF Assessment using Mid-Level Splitting. The mid-level splitting procedure seeks to identify the level that is exactly mid-way (half-way) in preference between a low level and a high level for a measure. The SUF::Assess Value option implements the mid-level splitting procedure in Logical Decisions. Remember that this **mid-preference level** could well be different from the average of the two ends of the range.

You define the mid-preference level by asking the decision maker questions about changes in the measure. Specifically the mid-preference level (call it L) is where you prefer a *change* from the least preferred level (call it L0) to L and a *change* from L to the most preferred level (call it L1) equally. In other words, you want to find the level L that divides the range from L0 to L1 into two pieces, *each representing an equal change in utility*.

In more mathematical terms, if U(x) represents the SUF for the measure, we want to find the point where

$$U(L) - U(L0) = U(L1) - U(L).$$

Remember that you should always prefer L to L0 and you should always prefer L1 to L. However, you still may feel that the *change* from L0 to L is more significant or important than the *change* from L to L1. You may feel this even though the result of the second change (L1) is the most preferred level overall.

Assume when asking these questions about one measure that the levels of all of the other measures remain constant. You should think of the questions of in terms of simplified hypothetical alternatives, even if the levels in the questions are similar to those for the real alternatives.

If the decision maker cannot answer the questions without knowing a specific level of *another* measure, there may be a preferential dependence between the two measures. Modeling preference dependencies is beyond the current abilities of Logical Decisions.
For an example of the mid-level splitting approach, consider the truck example used in the Tutorial. Suppose that the range of available horsepowers in the different trucks being considered is 80 to 160. To establish the mid-preference point you might ask the following series of questions (illustrated in Figure 9- 3):

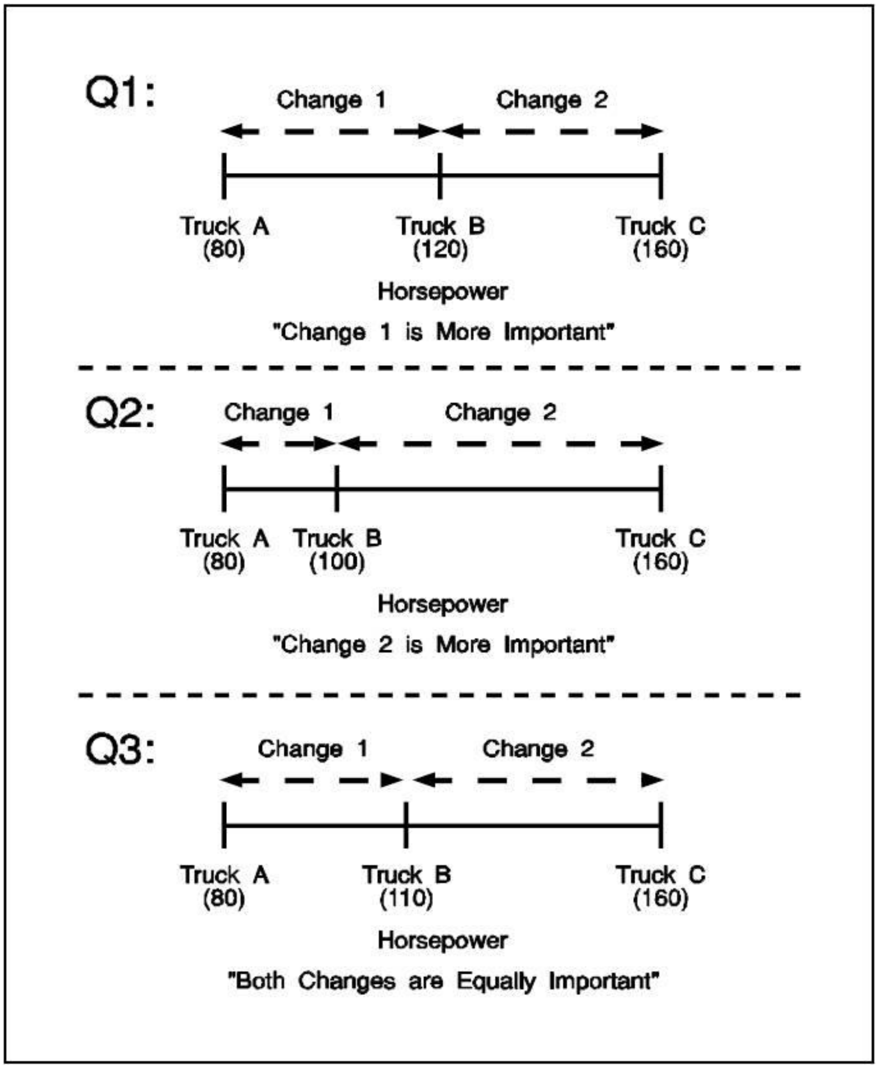


Figure 9- 3. . Example of SUF assessment process

Q1: The range on power is from 80 hp to 160 hp. Suppose you are thinking of buying a truck with the best levels on all of the other measures, including price, but with only 80 hp. Call this truck **A**. Now suppose I tell you that I have found another truck that has 120 hp but still has the same levels on the other measures, including cost. Call this truck **B**, and call the change from truck **A** to truck **B** change 1. Suppose in addition that tomorrow I find another truck that has 160 hp and the same levels on the other measures as trucks **A** and **B**. Call this truck

C. Call the change from truck **B** to truck **C** change 2.

Since all the other measures are equal, you should like truck **C** better than truck **B** better than truck **A**. But I want you to tell me which *change* is more important: change 1 where horsepower improves from 80 to 120 or change 2, where horsepower improves from 120 to 160?

A: Well, 120 is halfway between 80 and 160, so I suppose I should feel that the changes are equally important, but I think that 120 hp is pretty adequate for the type of driving I do and that 80 hp is just barely acceptable, so even though I'd like the 160 hp truck, I think that change 1 is the most important.

Q2: OK, that makes sense. Now let me change the question a little bit. Let's change the horsepower on truck **B** from 120 to 100 while keeping everything else the same. This means that change 1 is from 80 to 100 hp and change 2 is from 100 to 160. Now which change is more important?

A: With truck B at 100 hp, it's not that much better than truck A, so now I think that change 2, where I can improve all the way from 100 to 160 is more important.

Q3: Good. You can see that I'm trying to find a horsepower for truck **B** that makes it so that change 1 and change 2 are equally important. Now, how would you feel if I change truck **B**'s hp to 105?

A: I still think that change 2 is more important if the midpoint is 105, but if you made it 110, I'd have a hard time choosing.

The decision maker has discovered that 110 hp represents her mid-preference level in the range from 80 to 160 hp.

Since U(L0) = U(80) = 0 and U(L1) = U(160) = 1 by definition, we can use the equation above to see that U(L) = U(110) = 0.5. In other words, the mid-preference level is halfway in preferences between the most and least preferred levels. Thus it should get the utility that is half way in terms of utils between 0 and 1 -- 0.5.

Defining a SUF from the Mid-preference Level. Once you have established the mid-preference level, you still need to define the SUF function for the evaluation measure. There are several ways to go. The simplest method is to draw a smooth curve that passes through the three points -- (level = 80 hp, Utility = 0.0), (110, 0.5) and (160, 1.0). Logical Decisions does this by estimating the parameters for an exponential curve of the form:

$$U(x) = a + be^{(-cx)}$$

where a, b and c are scaling constants and e is the mathematical constant 2.718... whose natural logarithm is 1. The particular curve that would result from the example is

$$U(x) = 1.543 - 4.384e^{(-0.01305x)}$$

Since Logical Decisions computes this curve automatically, understanding the details of the mathematics is not important. A graph of the resulting curve is shown in Figure 9- 4.

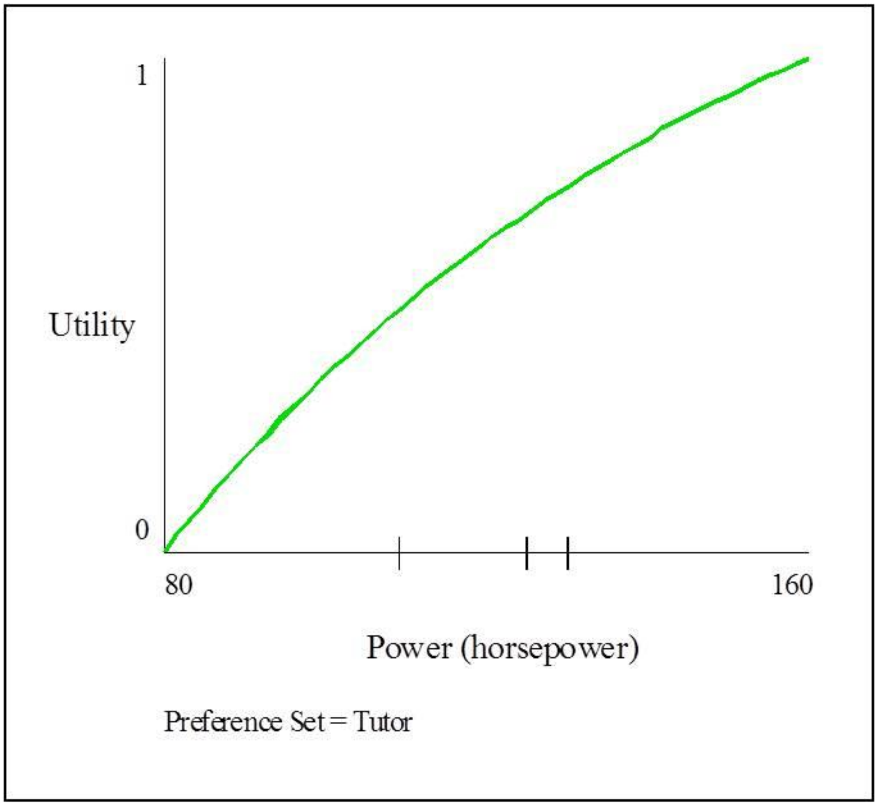


Figure 9- 4. SUF curve resulting from a mid-preference level of 110 for a range of 80 to 160 hp.

If you think that the smooth curve doesn't adequately model the decision maker's preferences, you can subdivide the range for the measure into multiple parts. For example, you could split the range at 110 hp and assess new midpoints for the range from 80 to 110 and for the range from 110 to 160 hp. This allows you to define multiple smooth curves for different parts of the SUF, and can result in a complicated but more true-to-life SUF curve.

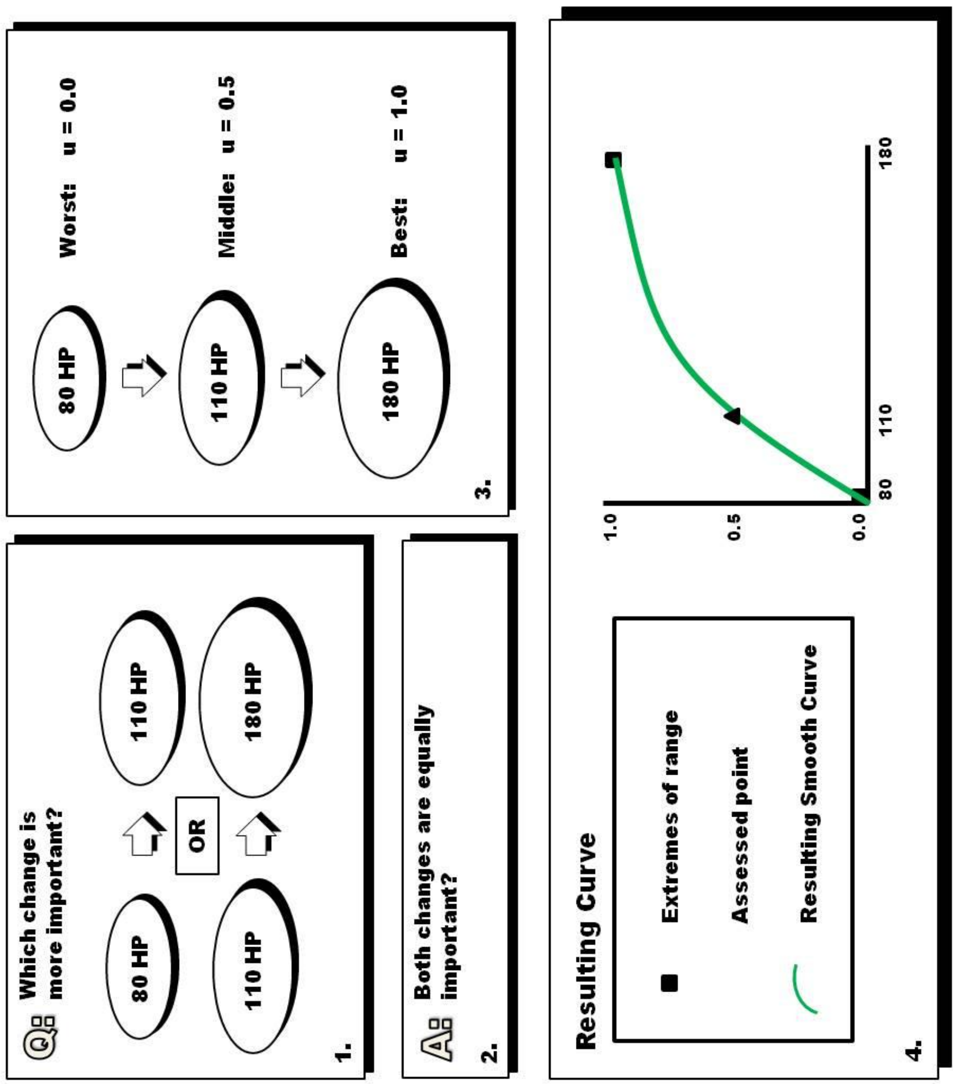


Figure 9- 5. Summary of SUF assessment process using mid-level splitting method.

Figure 9- 5 summarizes the process of SUF assessment using the mid-level splitting method. In box 1, the decision maker is asked which change is preferred, one from 80 to 110 hp or one from 110 to 180 hp.

In box 2, the decision maker answers that the changes are equally preferred. This implies that 110 is the mid-preference level for the range from 80 to 180 hp.

In box 3, we assign utilities to the three levels. The least preferred level of 80 hp is assigned U = 0 by definition. The most preferred level 180 is assigned U = 1, also by definition. The mid-preference level of 110 is assigned the average of the two other utilities or U = 0.5.

In box 4, a graph of utility vs. horsepower is shown with a smooth curve fit between the three known points. This curve defines a SUF for horsepower for the range 80 to 160 hp.

Note that technically a preference function assessed using the mid-level splitting technique should be called a **measurable value function** rather than a utility function.

Disadvantages of the Mid-level Splitting Method. The mid-level splitting method is difficult to use if your measure scale is not continuous. For example, if a measure consists of, say, five specially defined scale points, it may not be the case that one point is the mid-preference level between two others. In addition, the requirement of using changes in levels rather than the levels directly is difficult for some decision makers. If either of these problems arises it may be easier to use the probability method described below.

SUF Assessment Using Probabilities. The second approach for assessing SUFs involves asking questions that involve uncertain levels of the measure for some hypothetical alternatives. The probability assessment method is implemented in Logical Decisions as the SUF::Assess Utility option.

The general idea is to find an alternative with a certain (point estimate) level on a measure that is equally preferred to an alternative with well-defined probabilities of having two different levels, each of whose utilities is known.

As an example, we will use the resale value of the truck after three years (as a percentage of its purchase price). We could describe two alternatives: **A**, which is a truck with a single known resale value and **B**, which is a truck with a well-defined probability of getting one of two resale values.

The dialogue for assessing the mid-preference level for resale value using the probability approach might go as follows (illustrated in **Figure 9-6**):

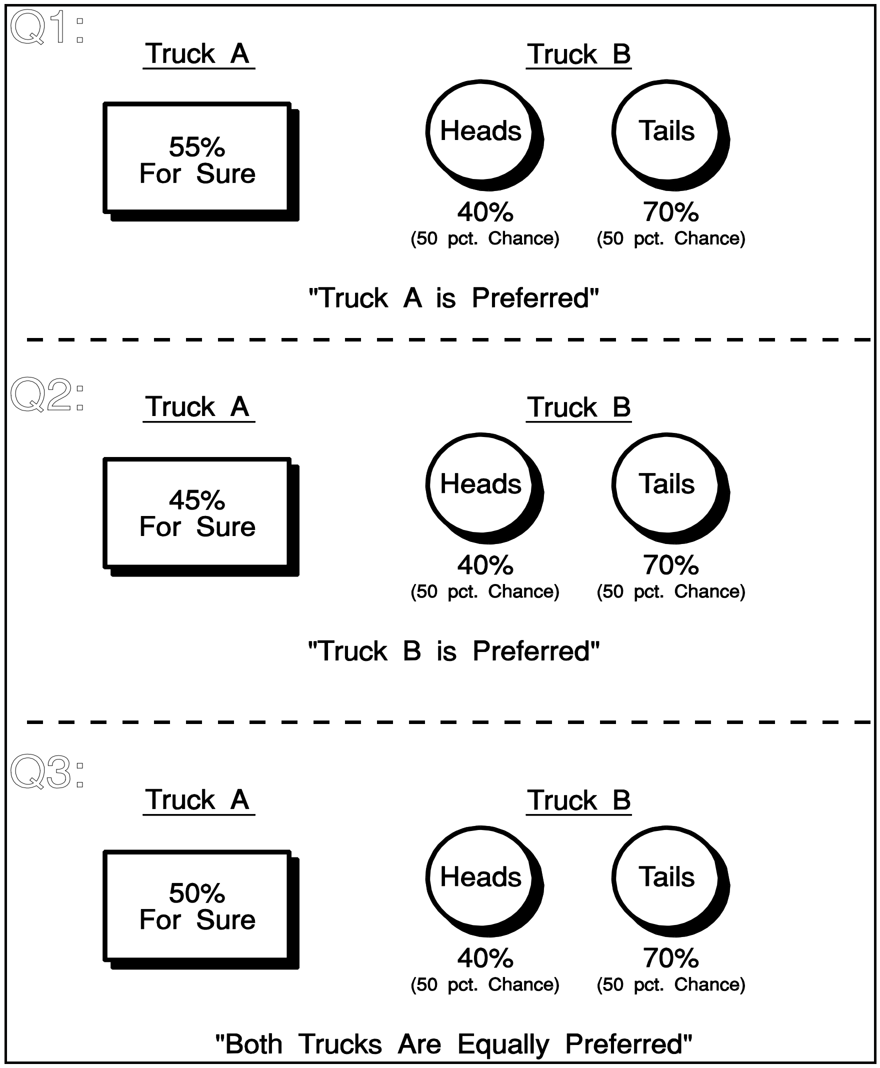


Figure 9- 6. Example of SUF assessment using probability approach

Q1: The resale value range is from 40 to 70 percent of purchase price. Suppose you were thinking of buying a truck with the best levels on all of the other measures, including cost, and with 55 percent. Call this truck **A**. Now suppose I offer you another truck, identical to **A** *except* for resale value. Truck **B** has a 50% chance of having a 40 percent resale value and a 50% chance of having a 70 percent resale value.

Which of the two choices would you prefer, the sure thing **A** or the uncertain alternative **B**?

A: Well, 55 percent is halfway between 40 and 70, so I suppose I should feel that the two choices are about equal, but I think that 55 percent is a pretty adequate return and that 40 percent is just barely acceptable, so even though I'd like the 70 percent resale, I wouldn't be willing to risk the chance of getting the 40 percent resale, so I'd pick A.

Q2: OK, that makes sense. Now let me change the question a little bit. Lets change the resale value on truck **A** from 55 to 45 percent while keeping everything else the same. Now which choice would you prefer?

A: With truck A at 45 percent resale value its not that much better than truck B with 40 percent resale value, so now I think that I might be willing to gamble on getting the 70 percent resale value. I guess this means I pick B.

Q3: Good. You can see that I'm trying to find a resale value for truck **A** that makes it so choices **A** and **B** are *equally desirable*. How about if I change truck **A**'s resale value to 50 percent?

A: Well, I think I'd have a hard time choosing.

Defining a SUF with the Probability Question. The rules of decision science tell us that if alternatives **A** and **B** are equally preferred, then the utility of alternative **A** is equal to the **expected utility** of alternative **B**. The expected utility of **B** is the sum of the utilities of the resale values multiplied by their probabilities ($P_1U(RV_1) + P_2U(RV_2)$).

The decision maker has told us that she prefers 50 percent for sure and a **lottery** (the decision science term for this type of gamble) with equal chances of 40 and 70 percent equally. This means that U(50) should equal 0.5 since that is the expected utility of the lottery. You can compute the expected value of the lottery by remembering that U(40) = 0 and U(70) = 1 and by using the formula above that says that

$$
\begin{aligned}
U(\text{lottery}) &= (P_1U(RV_1) + P_2U(RV_2)) \\
&= 0.5U(40) + 0.5U(70) \\
&= 0.5(0.0) + 0.5(1.0) \\
&= 0.5.
\end{aligned}
$$

If you have a measure with non-continuous scale points, you can use a variation of the probability method.

In this variation, you keep the levels of the three alternatives constant and vary the probability of getting the most preferred alternative in the lottery. You adjust the probability until the lottery and certain alternative are equally preferred. Note again that you do not have to worry about the details of the arithmetic. Logical Decisions handles all of the calculations.

Since the probability method results in a mid-preference level (the level of alternative **A** of 60 percent is the mid-preference level), you can use the probability method *interchangeably* with the mid-level splitting method.

Risk Premiums and Risk Aversion. Two parameters are useful in understanding the utility assessment results.

The first number, the **risk premium** indicates how much you would pay to avoid the uncertainty in the lottery. It is the difference in the expected value of the lottery **B** and the certain level L.

If the risk premium is positive and higher levels of the measure are preferred, then you would be willing to accept less of the measure (in terms of expected value) in order to avoid uncertainty. This type of preference is called **risk-averse**.

The converse is when the risk premium is negative and you would have to have a higher expected value in the certain alternative before it is equally preferred to the lottery. This type of preference is called **risk-seeking**.

The second parameter, **local risk aversion** (r) is a somewhat less intuitive number. It is defined as the ratio $r = -u''(x)/u'(x)$, where $u'(x)$ is the first derivative and $u'(x)$ is the second derivative of the utility function. In the case of the exponential utility functions used in Logical Decisions this complicated function has a simple result. It is equal to the constant c in the exponential formula $u(x) = a + be^{-cx}$. If r is positive you are locally risk-averse (for measures where higher levels are preferred). If r is negative, you are locally risk-seeking. Both of these parameters are displayed when you do an assessment in Logical Decisions with the SUF::Assess Utility option.

Assessing SUFs with Logical Decisions. You assess SUFs in Logical Decisions with the Assess::Common Units option. You must define SUFs over the nominal utility range (usually from zero to one, with the least preferred level of the measure assigned the utility zero and the most preferred level assigned one).

Each measure starts with a straight line (linear) SUF. Logical Decisions automatically returns a measure's SUF to a straight line if you change its range. If you want to keep the default straight line SUF, you can skip the SUF assessment process entirely for that measure.

During the SUF assessment process, Logical Decisions lets you use the mid-level splitting method or probability method to assess a point or the SUF or one of its sub-ranges. You do this by selecting the SUF::Assess Value or SUF::Assess Utility option. These options will only be available when they are appropriate for the selected active point. When you complete your assessment using one of these options, Logical Decisions will update the current SUF to reflect the assessed point.

Other options related to SUFs let you display SUF curves (the Review::Common Units option) and formulas (the Review::Weights::SUF Formulas option), and compute the utility corresponding to a given level, or the level corresponding to a given utility (the Review::Compute Utilities option). SUF assessment is discussed further on page 138.

Assessing Common Units with the Balance Beam Method

The balance beam method works by comparing the level of a single (more preferred) alternative with the combined levels of several (less preferred) other alternatives. If you prefer the single alternative equally to the bundle of alternatives, the balance beam method sets the utility of the more preferred alternative equal to the sum of the utilities of the alternatives in the bundle.

When the Balance Beam method is Suitable. The Balance Beam method is most appropriate for measures that are somewhat abstract. For example, some decision analysts use the Balance Beam method for direct comparisons of alternatives' overall benefits. Other possibilities are measures like Severity of Impacts or Costs (assuming that cost information isn't available explicitly). Using the Balance Beam method for measures such as Styling or Fuel Economy isn't generally appropriate, since you would be asking whether the Styling of car A is preferred to the Styling of car B and C combined, which doesn't make much sense.

The Balance Beam method tends to result in a wide range of scores for the alternatives, potentially covering several orders of magnitude. This can be very useful when you are doing benefit/cost or portfolio analysis, since the costs of the alternatives also frequently cover very wide ranges and it makes sense for the benefits to have a similar range of variation to the costs.

When you use the Balance Beam method, any levels you have entered for the measure will be ignored. At the end of the Balance Beam process, Logical Decisions will give you the option of converting the balance beam scores to levels. Otherwise the scores are adjusted so that the highest score equals 1.0 and are retained as utilities.

The mechanics of the balance beam process are discussed on Page 149.

Computing Common Units with the Analytic Hierarchy Process

The "Analytic Hierarchy Process" defines the utilities of a set of alternatives by having you directly compare their performance on an evaluation measure. You do this comparison intuitively, without defining an explicit scale for the measure.

In the original formulation of the AHP method, the same procedure is used for computing the common units (utilities) for the alternatives on the measures and for computing the relative weights of the measures or goals. In the first case comparisons are done between pairs of alternatives and in the second case comparisons are done between pairs of measures or goals.

In both cases the result is a number associated with each alternative or measure that you can interpret as a utility or as a weight, respectively.

The AHP numbers are normalized to sum to one. This may be useful if the measure represents some quantity or function that is being divided up between the alternatives.

Note that many decision analysts would object to using the term "utility" for the numbers that result from an AHP assessment. We will call them utilities here simply to avoid having to introduce a new term.

Logical Decisions lets you use the AHP method for all or just part of your analysis. You can use it to assess utilities for only one or two measures and use the SUF method described above for other measures. You could also assess measure utilities using AHP and assess the weights for the measures using another method or vice versa.

Several weight assessment methods expect utilities to range from zero to one instead of being normalized to sum to one as they do in the AHP method. Therefore, Logical Decisions has an option that lets you use the AHP assessment process to obtain utilities that range from zero to one. This is called the Adjusted AHP Option in Logical Decisions' Assess::Common Units option. A second option, introduced by the developers of the AHP approach is called the Ideal method. This method adjusts the highest ranking alternative to have a utility of 1.0, but does not adjust the lower end of the scale. This is done by multiplying the utility of each alternative by one over the utility of the highest ranking alternative. The final option -- where the utilities for the alternatives sum to one -- is simply called the Analytic Hierarchy Process option.

You should use the Analytic Hierarchy Process option if you want to follow the traditional AHP approach and use the AHP weight assessment method. You should use the Adjusted AHP method in combination with any other weight assessment method.

When you assess utilities with the AHP approach, you will be making direct comparisons between the performances of two alternatives. To help you do this, Logical Decisions displays a matrix whose rows and columns both represent alternatives. That is, the matrix has one row and one column for each alternative in your analysis.

Each cell in the matrix represents the ratio of the row alternative's performance on the measure to the column alternative's performance.

You complete the AHP assessment process by entering performance ratios into the proper cells. You will be done when each cell has the correct performance ratio.

Your task is not quite as daunting as it seems. Since the cells on the diagonal of the matrix compare the performance of each alternative to itself, the performance ratios in those cells must all be one.

You don't have to enter these obvious ratios. Logical Decisions uses the diagonal cells to show the computed utilities for the alternatives instead of the forced 1.0 ratios.

In addition, the ratio of a row to a column alternative must be the inverse of the ratio of the column alternative to the row alternative. For example, suppose alternative **A** is in row and column 1 of the matrix and alternative **B** is in row and column 2. If **A**'s performance on the measure is twice as good as **B**'s then the cell for row 1 and column 2 should have the ratio 2.0. Similarly, the cell for row 2 and column 1 should have the ratio 0.5, since it is the ratio of **B**'s performance to **A**'s.

These ratios are linked, so when you enter the ratio for one cell, Logical Decisions automatically enters its inverse in the corresponding cell on the other side of the matrix.

This means you only have to enter as many ratios as there are cells above the diagonal row in the matrix to complete your assessment.

Each time you enter a ratio, Logical Decisions marks the cell in blue and updates the level in the corresponding cell on the other side of the diagonal. Logical Decisions also marks this cell in blue. You will have completed your assessment when all the cells in the matrix are marked in blue.

The developers of the AHP method have provided some cues to help you set the performance ratios. They have defined the following five terms along with a corresponding performance ratio:

Ratio	Term	Explanation
1	Equal Importance	Two activities contribute equally to the objective.
3	Moderate Importance	Experience and judgment slightly favor one activity over another.
5	Essential or Strong Importance	Experience and judgment strongly favor one activity over another.
7	Demonstrated Importance	An activity is strongly Favored and its dominance is demonstrated in practice.
9	Extreme Importance	The evidence favoring one activity over another is of the highest possible order of affirmation.

In the traditional AHP approach, you can only enter one of these ratios or one of the intermediate ratios 2, 4, 6, or 8. Logical Decisions does not impose these restrictions. You can enter any ratio you want. However, if you use the AHP dialog box to select a ratio, you are restricted to one of these nine ratios.

To compute the utilities for the alternatives from the ratios, the AHP method uses computations based on linear algebra. This method results in consistent utilities if you have entered completely consistent ratios and results in "best fit" utilities if your ratios are not completely consistent.

The utility for each alternative is generally very close to the geometric mean of the ratios in its matrix row. The geometric mean is the nth root of the product of the ratios, where n is the number of alternatives. The utilities are computed for each row and the means are then normalized to sum to one.

Instead of waiting till you have entered all the needed ratios, Logical Decisions computes the utilities for the alternatives each time you enter a new ratio. (You can turn off this computation by unchecking the AHP::Estimate Ratios option.) Logical Decisions uses all the ratios you have entered so far as the basis for its estimates.

Logical Decisions uses a simple iterative procedure to estimate the ratios you haven't entered yet based on those you have. Thus, there is always a complete set of utilities available. If you don't want to enter all the ratios required by the AHP process (and sometimes quite a lot of ratios are required), you can stop any time the computed utilities seem reasonable.

Estimates of Consistency in AHP

The AHP process asks you to enter more performance ratios than are strictly necessary to compute a set of utilities for the alternatives. Because of this, your performance ratios are likely to be inconsistent.

To provide guidance on how consistent you are, the developers of the AHP method suggest using a statistic called the "consistency ratio (CR)". The CI compares your matrix to a random matrix of the same size. The higher the CR, the more inconsistent you are. The developers of AHP suggest that if the CR for your matrix is greater than 0.1 you should adjust your ratios to make them more consistent.

Two intermediate statistics are used to compute the CR. The first, called "λ max" is the principal eigenvalue of your AHP matrix. λ max is the matrix product of your AHP matrix and the vector of the (unadjusted) utilities for the alternatives. (Don't worry if this is unclear. You won't be tested on it.) The second intermediate statistic is called the "consistency index (CI)". The CI is an absolute measure of consistency. It's computed from λ max as

$$CI = (\lambda \max - n)/(n - 1),$$

where n is the number of alternatives. The consistency ratio CR is computed by dividing the CI for your matrix by the CI for a "random" matrix of the same size.

The discussion on page 156 tells you how to assess common units with the Analytic Hierarchy Process in Logical Decisions.

Computing Common Units with AHP SUFs

Logical Decisions lets you combine the AHP and SUF methods for computing common units in a method called AHP SUFs. In this method, you will still define a scale and range for your measure and levels for your alternatives on the measure. However, instead of using the normal SUF assessment process, you will use an AHP matrix to define a SUF for the measure.

You begin the process by selecting a subset of your alternatives to use in the AHP matrix. These alternatives must have levels within the range for the measure defined in its measure dialog box.

After you select your alternatives, you continue with the AHP assessment process as described above. When you are done, each alternative will have an associated utility as computed from the AHP matrix.

Since the alternatives also have levels, we can compare the levels and utilities and use them to define a SUF. This is done in one of two ways depending on the alternatives you selected.

If you selected alternatives that cover only part of the measure's range, Logical Decisions uses the unadjusted AHP utilities to define the utility for each alternative's level. Logical Decisions assigns the measure's least preferred level a utility of zero and its most preferred level a utility of one. These endpoints are connected to the utilities computed using AHP matrix with straight lines.

If you selected alternatives that cover the measure's entire range, a slightly different process is used. The AHP utilities are first adjusted to range from zero to one (as in the Adjusted AHP Measure Levels method) and are then associated with the measure levels. The utilities are then connected with straight lines to form a complete SUF.

Establishing the Importance of Each Measure

After you have made the measures comparable by converting them to common units, the next step is to define how to combine the utilities for individual measures into utilities for the goals. Logical Decisions also quantifies an alternative's performance on a goal in units of utility.

A goal's utility is computed using a function that combines the utilities of a goal's active members into a utility for the goal. The formula used to combine the utilities is a **Multiple-measure Utility Function** or **MUF** (pronounced "muff"). Higher level goals can have a MUF that combines utilities for not only measures but also utilities for lower level goals computed using their own MUFs.

The utility of an alternative on the "Overall" goal is its **overall utility**. *The alternative with the highest overall utility is the most preferred.*

Deciding which Goals Should Have a MUF

Logical Decisions includes each measure in your analysis in the MUF for exactly one goal. In addition, Logical Decisions includes goals that have their own MUF in the MUF for exactly one higher level goal. Logical Decisions does not explicitly include goals that do not have their own MUF in any other MUF.

Logical Decisions lets you decide which goals should have their own MUF. A goal that has its own MUF will combine the utilities for the measures and goals directly below it in the goals hierarchy into a utility for the goal.

The exception is that the MUF for a goal will not include the utility for a goal directly below it that does not have its own MUF. Call the goal having the MUF the MUF-Goal and the goal below it without a MUF the NONMUF-Goal. Logical Decisions includes the utilities for each of the NONMUF-Goal's members in the MUF-Goal's MUF.

If you request a ranking of the alternatives on the NONMUF-Goal Logical Decisions will compute a temporary MUF for it. The MUF will combine the utilities of the goal's members based on their weights in the MUF-Goal MUF. The only goal required to have its own MUF is the "Overall" goal.

Figure 9- 7 shows how you might combine the members and goals in a goals hierarchy into MUFs.

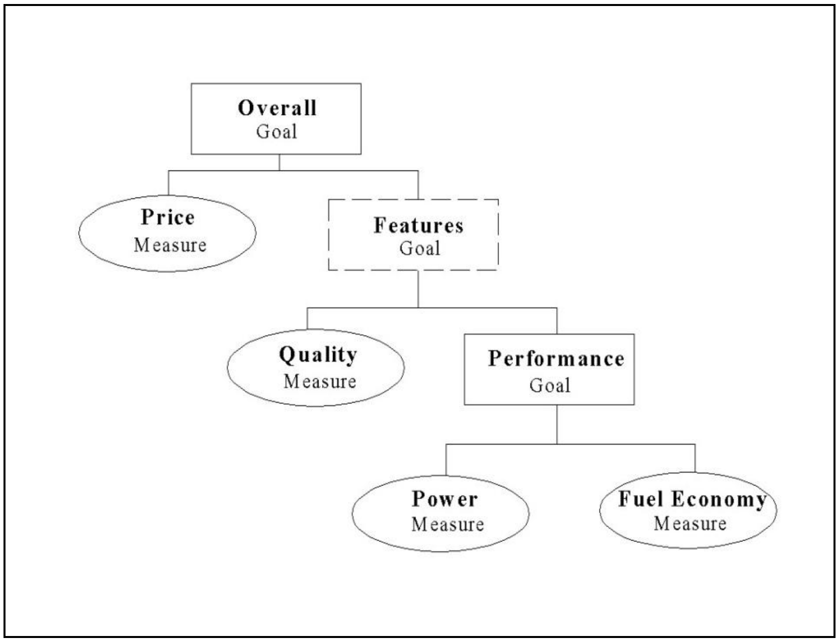


Figure 9- 7. Effects of goals with and without their own MUFs.

In **Figure 9- 7**, the "Overall" and "Performance" goals have their own MUFs while the "Features" goal does not. In this situation, the MUF for the "Performance" goal will combine the utilities of the "Power" and "Fuel Economy" measures. The MUF for the "Overall" goal will combine the utilities for the "Price" measure, the "Quality" measure and the "Performance" goal.

The "Features" goal will not have its own MUF. If you request a ranking on the "Features" goal, Logical Decisions will compute a temporary MUF that combines the utilities for the "Quality" measure and the "Performance" goal.

You can view which goals have MUFs in the Logical Decisions Goals Hierarchy view by selecting the Hierarchy::Show Assessment Status option. You can also view this in the Assess::Weights dialog box.

There are two general strategies for deciding which goals should have a MUF. The first strategy is to only have a MUF for the "Overall" goal and not for any of the sub-goals. Then, Logical

Decisions will combine all of the measures in your analysis in a single overall MUF. The preference assessments will only involve measures and Logical Decisions will compute the utilities for sub-goals using temporary MUFs. This strategy is the default.

The other strategy is to have a MUF for all of the goals in your analysis. This lets you do your preference assessments for only the members directly underneath each goal.

Different preference assessment methods have different traditions for deciding which goals should have a MUF. The Smart, Smarter and Balance Beam methods often use a single overall MUF. The AHP approach generally has a MUF for each goal. The tradeoff and pairwise weight ratio methods can use either approach.

Interactions apply to all the members of a MUF. If you want to have only a few particular members interact, you must include them in their own MUF. You should include members that interact under their own goal and make sure that that goal has its own MUF.

In the discussions below we will call the members of a goal's MUF the "active members" for the goal.

Representatives for Goals With a MUF. Logical Decisions will include goals that have their own MUF in the MUF for a higher level goal. Often it is difficult to answer preference assessment questions involving a goal because it is hard to interpret the meaning of different levels of utility for a goal. It may also be hard to remember the measures and sub-goals that are its active members and their importances.

Therefore Logical Decisions allows you to select a representative for the goal in several weight assessment methods. The representative can be any measure below the goal in the goals hierarchy. It can also be any sub-goal with its own MUF below the goal in the goals hierarchy.

The representative replaces the goal in the preference assessment questions for the MUF the goal is a member of. Logical Decisions computes the goal's weight based on the representative's weight in the MUF for the goal and the representative's weight in the MUF the goal is a member of.

Here is an example. In the tutorial example, a "Performance" goal includes "Power" and "Fuel Economy" measures. The "Performance" goal and a "Price" measure make up the "Overall" goal (we'll assume that the "Styling" measure has been deleted).

Suppose "Power" and "Fuel Economy" are assessed equal weights of 0.5 in the "Performance" goal's MUF. Now suppose that "Power" is selected as the representative for the "Performance" goal in the "Overall" goal's preference assessment. Suppose the "Power" and "Price" measures are also assessed equal weights of 0.5. Then the weight assigned to "Performance" will be 0.5 divided by the weight for "Power" in its MUF, which is also 0.5.

This means that in the "Overall" goal's MUF, "Price" will have a weight of 0.5 and "Performance" will have a weight of 1.0. After Logical Decisions has adjusted these weights to sum to one, "Price" will have a weight of 0.33 and "Performance" will have a weight of 0.67.

Note that Logical Decisions does not include the representative in the MUF instead of the goal it represents. The representative is just a tool that helps you define the weight that Logical Decisions should assign to the goal in the MUF it is a member of.

For Logical Decisions to compute a goal's utility when only its representative's level has been defined, it must make an assumption about the utilities of the goal's other members. Therefore, when you define a goal Logical Decisions asks you to specify a **nominal utility**. Logical Decisions temporarily assigns this nominal utility to all of the goal's members, *except* its representative, when doing tradeoffs.

This allows Logical Decisions to estimate the goal's utility as follows:

$$U_g(X_r = x) = k_r U_r(x) + k_1 U_{nom} + \ldots + k_n U_{nom}$$

$$= k_r U_r(x) + (1 - k_r) U_{nom}$$

where

$U_g(X_r = x)$ = goal g's utility when its representative r has level x and the other members have the nominal utility,

k_r = the small **k** for the representative measure,

$U_r(x)$ = the utility of level x for the representative measure,

U_{nom} = the nominal utility assigned to other members of the goal.

Logical Decisions applies this formula recursively if the goal's representative is a member of a goal below it in the hierarchy. The formula is similar but more complicated if the goal has a multiplicative MUF formula.

You can use representatives in all the weight assessment methods except the smarter method and the direct entry method. The AHP method has a tradition of not using representatives, while representatives are often used in the tradeoff and pairwise weight ratios methods.

Formulas for MUFs

The simplest MUFs compute an alternative's utility for a goal using a weighted average. These are called **additive MUFs**, since the weighted utilities for each active member are added to obtain the goal utility. Logical Decisions allows you to define more complicated MUF formulas that allow interactions if necessary. MUFs with interactions will be discussed on page 359.

Approaches for Assessing MUFs

To define an additive MUF, you must define a scaling constant (or weight) for each measure. Four general approaches have been developed for doing this.

The first approach is to have the decision maker directly provide the scaling constants.

The second approach is to have the decision maker order the active members from most to least important.

The third approach is to have the decision maker provide "importance ratios" that imply the ratios of the weights for two or more active members.

The fourth approach is to compute the scaling constants using pairs of simplified alternatives or bundles of alternatives that the decision maker prefers equally. Because the decision maker prefers the alternatives equally, they should have equal overall utilities. If you define enough pairs, Logical Decisions can identify a unique set of weights -- the weights that result in all the pairs having equal overall utilities.

Logical Decisions provides six different assessment methods that let you carry out these approaches:

- You can **directly enter** the scaling constants,
- You can use the "**Smarter Method**" to have Logical Decisions compute weights based on your ordering of the importances of the active members,
- You can use the "**Smart Method**" to have Logical Decisions

compute the weights on "swing weights”,

- You can define "**Tradeoffs**" between pairs of active members that Logical Decisions helps you select,

- You use the "**Balance Beam Method**" to identify equally preferred bundles of member levels,

- You can define the "**Weight Ratios**" between pairs of active members, or

- You can use the "**Analytic Hierarchy Process”.**

The smarter method uses the importance ordering approach. The smart, weight ratios and analytic hierarchy process methods use the importance ratios approach. The tradeoff method uses the comparisons of alternatives approach.

The direct entry method, of course, carries out the direct entry approach. However, you can also interpret the directly entered scaling constants as probabilities that partially define pairs of equally preferred alternatives. This interpretation is discussed further below.

The importance ordering, importance ratios and alternative comparisons approaches are all discussed in more detail below.

Assessing Weights Using Importance Orderings

The "Smarter" method lets you define the weights for the active members using a simple ordering of their relative importances. The method is very easy for decision makers to use and results in a fairly robust set of weights. The Smarter method is often a good starting point before using a more sophisticated method.

When using the smarter method, you can encourage the decision maker to think about the member's ranges by providing the following scenario:

> Suppose you had an alternative that had the least preferred level on all of the active members. And further suppose that you could improve just one active member from its least preferred to its most preferred level. Which active member would you choose to improve?

The first member to be improved is given an importance ordering of one. Then you repeat the question with the caveat that the decision maker must choose a member other than the first one. You can continue in this way until the decision maker has ordered all of the active members.

Logical Decisions computes weights from the ordering using an average of the extremes of the possible weights. The following example with two members illustrates the approach:

> Suppose the "Performance" goal has two members -- "Power" and "Fuel Economy", and suppose that the decision maker orders "Power" first and "Fuel Economy" second.
>
> If we put as much weight as possible on "Power", it will have a weight of 1.0 and "Fuel Economy" will have a weight of 0.0. If we put as much weight as possible on "Fuel Economy", it will have a weight of 0.5. "Power" will also have a weight of 0.5, since its weight must be greater than or equal to Fuel Economy's if Power is more important.
>
> These two possibilities define the extremes of the possible weights. If we average the weights assigned to the two members under the two scenarios we get the following:

Scenario	Power Weight	Fuel Econ. Weight
1	1.0	0.0
2	0.5	0.5
Average	0.75	0.25

These weights -- 0.75 for "Power" and 0.25 for "Fuel Economy" are the weights assigned by Logical Decisions using the smarter method. Note that any case where two members are involved will result in the same weights. The extension to more members is easy. Each new member adds another extreme case. If a third member was added to the example a new extreme case of 1/3, 1/3, 1/3 would be added to the average.

The weight for the member with the highest order number drops sharply as more members are added. Therefore, Logical Decisions lets you specify a minimum weight to assign to each member. Logical Decisions allocates this weight before computing the weights as above. This results in all of the members having weights at least slightly above the minimum weight.

Logical Decisions also lets you have ties (members with the same order number) and lets you assign a zero to a member to show no importance at all.

Because of the relatively crude approach the smarter method uses to compute the weights, Logical Decisions does not let you use representatives when using this method.

Note that Logical Decisions does not adjust the ordering of the members if you modify a member's definition or range. Thus, if you make significant changes to a member you should remember to go back and review any importance orderings you have entered using the smarter method.

Assessing Weights Using Importance Ratios

Logical Decisions provides three methods to assess weights using importance ratios -- the "Smart" method, the pairwise weight ratios method, and the "Analytic Hierarchy Process". An importance ratio is a directly specified ratio between the weights for two or more members.

The "Smart" method is a "global" method for assigning weight ratios. That is, you assign the ratios all at once instead of for pairs of members as in the other two ratio methods. The smart method is sometimes called the "swing weights" method.

When using the smart method, you can encourage the decision maker to think about the members' ranges by providing the following scenario:

> Suppose you had an alternative that had the least preferred level on all of the active members. And further suppose that you could improve just one active member from its least preferred to most preferred level. Which active member would you improve?

You should give the first member the decision maker asks to improve a "swing weight" of one hundred. Then, for each other active member, you ask the decision maker the relative importance of "swinging" it over its range compared with "swinging" the first member over its range. Thus you ask the decision maker to state importance as a percentage of the first member's one hundred point swing weight. If the decision maker thought that swinging a member was half as important as swinging the first member she would give it a swing weight of fifty.

You can continue in this way until the decision maker has assigned a swing weight to all of the members.

The idea of the relative importances of swinging members through their ranges is rather abstract. However, studies and experience have shown that decision makers are willing to provide this information and often feel very comfortable doing so.

To compute the absolute weights for the members from their swing weights, Logical Decisions simply adjusts the swing weights so they sum to one.

The other two importance ratio methods -- pairwise weight ratios and the analytic hierarchy process -- ask the decision maker to specify ratios between pairs of members.

In the pairwise weight ratios method, Logical Decisions helps you identify pairs of members for which to define weight ratios. When you have entered enough ratios to define a complete set of weights, the process is complete.

To compute a complete set of weights, you must define ratios that include each active member at least once. This means that if there are n active members, you need to enter n - 1 ratios. Logical Decisions uses this information and any information on interactions to compute the absolute weight for each active member.

The Analytic Hierarchy Process is like the pairwise weight ratios method. However, instead of entering ratios for selected pairs of members, you enter ratios for *all possible pairs*. This means that if there are n active members, you need to enter n*(n - 1)/2 importance ratios. Since this is more than the minimum needed to compute the weights (n - 1), there may be inconsistencies in your answers. See page 159 for a discussion of the consistency measures used in the AHP method.

The weight for each active member is computed using a matrix algebra approach that is generally very close to the geometric mean of the ratios in its matrix row. The geometric mean is the nth root of the product of the ratios, where n is the number of alternatives.

Instead of waiting till you have entered all the needed ratios, Logical Decisions computes the active member's weights each time you enter a new ratio. Logical Decisions uses all the ratios you have entered so far as the basis for its estimates. Logical Decisions uses a simple iterative procedure to estimate the ratios you haven't entered yet based on those you have. Thus, there is always a complete set of weights available. If you don't want to enter all the ratios required by the AHP process, you can stop any time the computed weights seem reasonable to you.

Note that, if you want to use the "complete" AHP method, you should use the "Analytic Hierarchy Process" method when converting the measures to common units.

Both pairwise weight assessment methods focus on the members' names rather than their ranges. Of course, it is possible to take the ranges into consideration when assigning weight ratios. For example, you could think of each ratio as a "mini-swing weight", and think of the relative importance of changing each member from its most preferred to least preferred level. The "complete" AHP method compounds this problem by not even using explicit measure levels. Here you will need to think about the best and worst performances for the members for the alternatives in your analysis.

You should be considering the ranges for the members when assigning weight ratios using the methods described above. If the ranges or definitions of the members change, their weight ratios should change. Logical Decisions does not automatically adjust any weight ratios if you change a member. Thus, when you make changes you should review any weight ratios you have assessed to see if you should make any changes.

Assessing Weights by Comparing Pairs of Alternatives

The tradeoff and balance beam methods in Logical Decisions take an indirect approach to establishing the weights of the measures. These approaches use the idea that *equally preferred alternatives should have equal utilities*.

Logical Decisions exploits this idea by having the decision maker identify pairs of equally preferred alternatives that differ on two of the active members. Logical Decisions uses these differences to identify the *implied* relative importance of the two measures.

It should be easier for a decision maker to say when she prefers two alternatives equally (if their differences are easy enough to understand) than to consistently specify weights. The tradeoff and balance beam methods are discussed separately below.

The Tradeoff Method

The key element of the tradeoff method is, not surprisingly, a **tradeoff**. A tradeoff is a pair of equally preferred simplified alternatives that differ in their levels on *exactly two* of the active members.

Figure 9- 8 shows how a tradeoff can be used to compute the relative importance of two measures. In box 1, the decision maker is asked to choose which alternative is preferred: a car having 110 hp and costing $7,000 or a car having 180 hp and costing $12,000. In box 2, the decision maker replies that she prefers the two alternatives equally.

Since she prefers the alternatives equally, they should have equal utilities. Since a MUF is (usually) a weighted average of the utilities of the active members, this means that the two weighted averages must be equal. When comparing the weighted average for the two simplified alternatives, we see that the terms for the members other than the ones in the tradeoff drop out. This is because the levels on all members not explicitly mentioned in the tradeoff are assumed to be equal.

Thus, the weight for horsepower times the utility for horsepower plus the weight for cost times the utility for cost must be equal for the two alternatives in the tradeoff. This implies in turn that the change in utility for horsepower times the weight for horsepower must equal the change in utility for cost times the weight for cost.

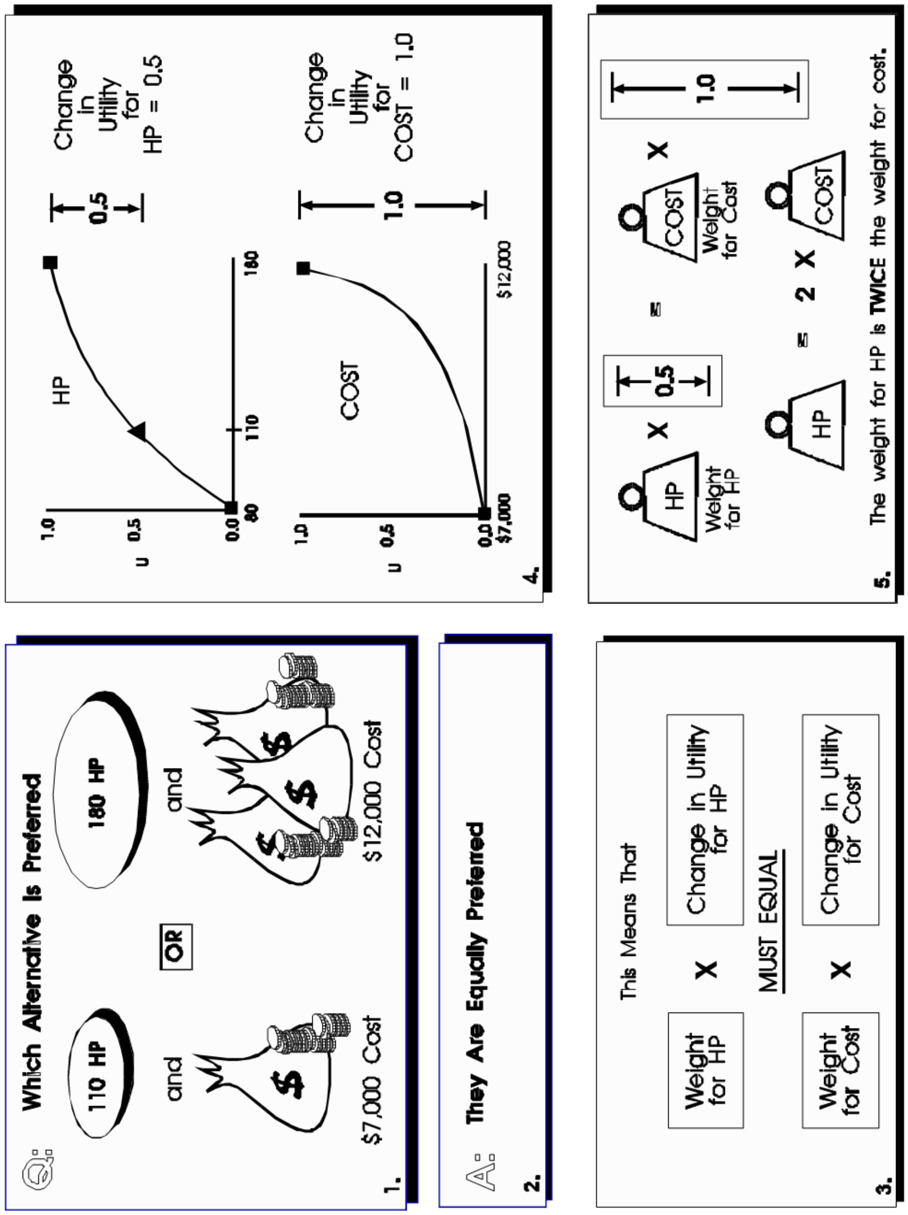


Figure 9- 8. Summary of estimating the relative importance of two measures from a tradeoff.

The two changes must just compensate for each other in order for the alternatives to have equal overall utilities. This is shown in box 3. In box 4, we use the previously assessed SUFs to identify the change inutility for horsepower and cost for the two alternatives.

In box 5, we see that the change in utility for horsepower is only half the change for cost. Thus, the weight for horsepower must be twice the weight for cost. The mathematics of this process are described in the Appendix on page 443.

An advantage of the tradeoff approach is that the weight computation method automatically takes the ranges and SUF curves of the measures into account when Logical Decisions computes the weights. You don't have to consult the decision maker again if you change the ranges or SUFs for the measures. This idea of computing the relative importance of the measures using equally preferred alternatives is discussed further below.

Establishing Tradeoffs. All of the computations needed to convert tradeoffs to relative weights are done automatically by Logical Decisions. The only thing the decision maker has to do is establish the tradeoff pairs of equally preferred alternatives.

Typically, tradeoffs are assessed with the help of a graph that has one member on the horizontal axis and of the other on the vertical axis. Each point on the graph represents a possible alternative. These simplified alternatives are assumed to have identical levels on all of the other evaluation measures and goals.

In the tradeoff assessment process, Logical Decisions highlights two points on the graph and asks the decision maker which she prefers. Based on the decision maker's response, Logical Decisions helps her modify one alternative until she prefers it *equally* to the other.

Logical Decisions starts the process by showing one alternative having the most preferred level on the first member and the least preferred level on the other. The other alternative has the least preferred level on the first member and the most preferred level on the second. Logical Decisions represents these two alternatives by points at opposite corners of the graph.

If the decision maker prefers the two alternatives equally, Logical Decisions will assign the two members equal weights. A decrease in the first member of its entire range just compensates for an increase in the second member over its range.

If, however, the decision maker prefers the first alternative, the improvement in the second measure does not compensate for the change in the first. To make the second alternative more attractive, we improve its level on the first member.

If we improved the first member all the way to its most preferred level, the decision maker would have to prefer the second alternative to the first. It would have the same level (the most preferred) on the first member and a better level on the second (the most preferred level vs. the least preferred level).

This means that we can find a level for the first member on the second alternative that makes the second alternative equally preferred to the first. A series of questions posed to the decision maker will allow us to zero in on that level.

For example, suppose that again we want to establish a tradeoff between Cost and Power for use in selecting trucks. We might do this by going through the following dialogue with the decision maker:

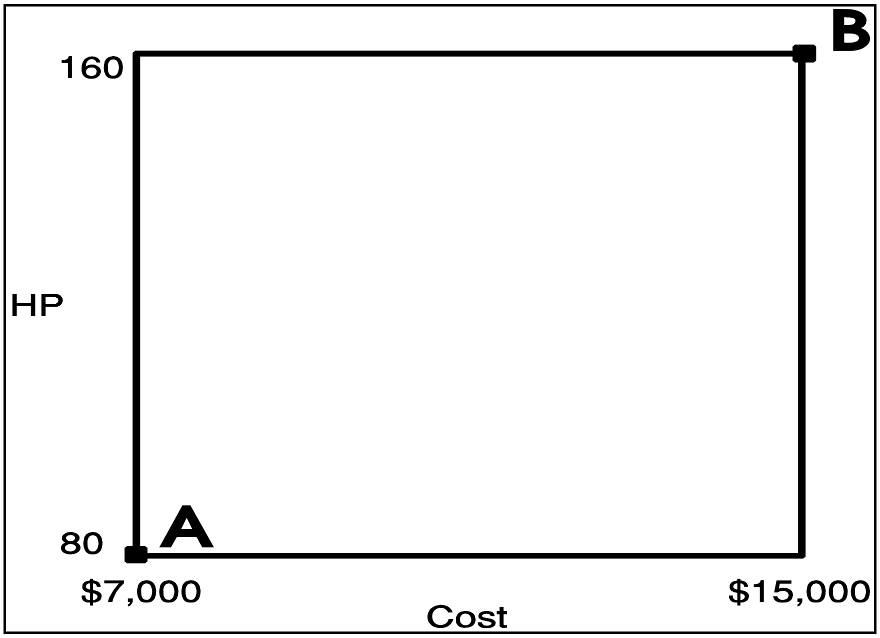


Figure 9- 9. . Example graph for tradeoff assessment

Q: Look at the graph in Figure 9- 9. The two labeled points represent trucks that you might like to buy. Assume that all of the other measures are at their most preferred levels. Alternative **A** has cost at its best level of $7000 but only has 80 horsepower, while alternative **B** has a cost of $15,000 but has the best horsepower at 160. If you had to choose between **A** and **B**, which one would you pick?

A: Well, I don't really like either of these alternatives too much, but I'm on a pretty tight budget, so if I had to choose I guess I'd choose A because it's so much cheaper.

Q: That makes sense. If I want you to choose **B**, I'll have to make **B** look better. How about if I keep **B**'s horsepower at 160 but make it so that it only costs $7100? I'll label this new alternative **B**' (see Figure 9- 10).

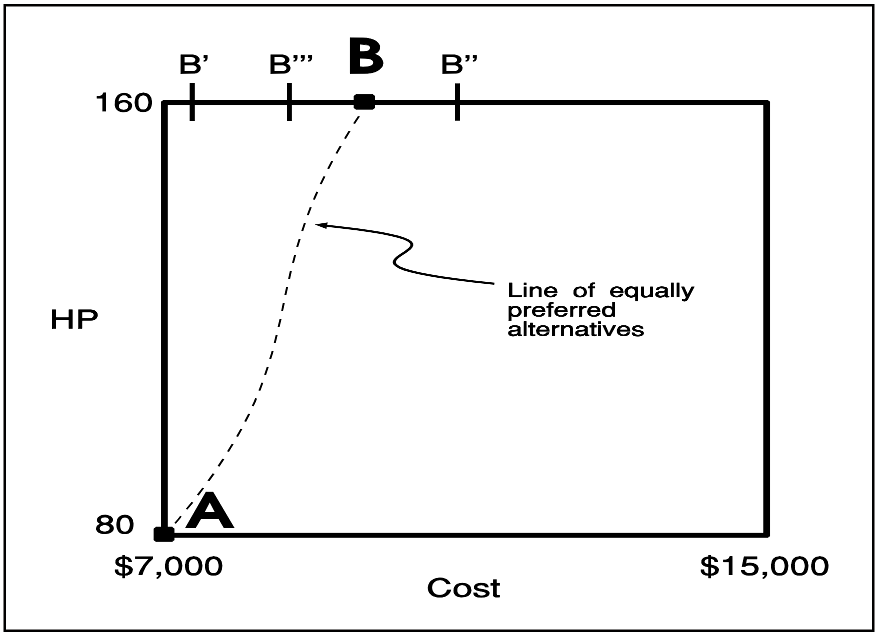


Figure 9- 10. MUF assessment figure 2

A: That's easy! I'd definitely take B' if I'd only have to pay $100 more to get all that extra horsepower.

Q: OK, now I'll make it a little harder. Suppose I change **B** so that its cost is $10,000. I've marked this **B**''?

A: Now it's starting to get close, but I think $3000 is too much to pay for more horsepower if everything else is the same, so I'd pick A.

Q: How about if I make **B**'s cost $8500, as in point **B**'''?

A: In that case I'd pick B''', but if you increase B to $9000 I'd have a hard time choosing.

Q: You mean that if the price for **B** was a little bit below $9000 you'd pick **B** but if it was a little bit above $9000 you'd pick **A**?

A: That seems like you're trying to put too fine a point on it, but I guess that around $9000 is where I'd start switching between A

and B.

This dialogue let us establish a tradeoff between cost and power by identifying two alternatives that differ only in those measures and that the decision maker prefers equally. The two equally preferred alternatives are:

> Alternative **A**: cost = $7000, power = 80 hp, and
> Alternative **B**: cost = $9000, power = 160 hp.

Logical Decisions can now compute the relative weight for the two measures (if the SUFs for the two measures have been assessed). Logical Decisions does this automatically. You and the decision maker don't have to do any computations. All you have to do is tell Logical Decisions when you prefer two simple alternatives equally.

Assessing Tradeoffs with Logical Decisions. Logical Decisions simplifies the tradeoff assessment process by keeping track of which measures you have assessed. Initially Logical Decisions lets you select any two active members to trade against one another. Once you have done one or more tradeoffs, the program gives you a reduced range of choices. In this way Logical Decisions ensures that you don't assess any unneeded tradeoffs.

To compute a complete set of weights for a MUF, you must have at least one tradeoff that includes each active member. If there are n members you must assess n-1 tradeoffs.

The Balance Beam Method

The balance beam method works by comparing an alternative with the best level of a single (more important) alternative and the worst levels on all the other measures with an alternative with the best level on several (less important) other measures. If you prefer the two alternatives equally, the balance beam method sets the weight of the more important measure equal to the sum of the weights of the measures in the bundle.

When the Balance Beam method is Suitable. The Balance Beam method is most appropriate for problems with a relatively large number of measures. A large number of measures should make it easier to find bundles of measures whose weight equals that of a more important measure.

The Balance Beam method tends to result in a wide range of weights for the measures, potentially covering several orders of magnitude. This is also a characteristic of the tradeoff method also and seems to be a better reflection of true decision maker preferences than the more equal weights often obtained with other methods.

The scores from the balance beam process are adjusted so that they sum to 1.0 and are retained as weights.

The mechanics of the balance beam process are discussed on page 149.

Interpreting Directly Entered Weights

You can interpret directly entered weights as defining a pair of equally preferred alternatives. In this interpretation, think of an alternative that has the least preferred level on each of the active members except one -- the member whose weight you are assessing, which has the most preferred level. This is the first simplified alternative in the pair. Call it the "one member for sure" alternative.

Next think of an alternative with well-defined uncertainties. This alternative has a probability P of having all of the active members at their most preferred levels (including the one you are assessing) and a probability of 1 - P of having all of the active members at their least preferred levels. This is the second simplified alternative (well, maybe its not so simple). Call it the "all or nothing" alternative.

Now think of adjusting P so that the decision maker prefers the

two alternatives equally. Then you can compute the scaling constant for the member being assessed as follows.
The utility for the "one member for sure" alternative is 1.0 for the member being assessed and 0.0 for the other active members from the way we defined the alternative. Thus, its utility as computed by the MUF is the weight for the member being assessed times one plus the weights for the other active members times zero. Thus, the "one member for sure" alternative's utility for the active goal is equal to the weight for the member being assessed. Let's call this **w**.

We can also compute the utility for the "all or nothing" alternative. We know that the utility in a MUF is 1.0 if all active members are at their most preferred level. We also know that, if all active members are at their least preferred levels, the utility is 0.0. Decision theory also tells us that the utility of an alternative with uncertainties is the expected utility for the alternative. The expected utility for the "all or nothing" alternative is P times 1.0 and (1 - P) times 0.0. This is equal to P itself.

Since the decision maker said she prefers the two simplified alternatives equally they must have equal utilities. Thus **w** must equal P.

Thus, you can assess weights for direct entry by assessing the **w** for each active member by defining a "one member for sure" alternative where only it has its most preferred level and assessing the P for which the decision maker prefers it equally to the "all or nothing" alternative. **W** for each member is equal to the P that makes the two alternatives equal.

Note that if you use this method, the **w**s won't generally sum to one. As described on page 359, **w**s that don't sum to one define a multiplicative MUF that includes interactions between the active members. This probabilistic method for assessing weights can also be used to simultaneously assess interactions.

It is not clear how to compute weights using representatives when there are also interactions. Thus, Logical Decisions does not let you use representatives for sub-goals in the direct entry method.

Changing Weight Assessment Methods

Logical Decisions makes it easy to change the weight assessment method for a goal. Just select a new method from the list in the weight assessment dialog box. Logical Decisions will warn you that you might lose some preference information if you have already done assessments with the old method. When you change between methods, Logical Decisions tries to assign parameters in the new method that result in the same weights as in the old method. Thus, if you change from the "Smarter" to the "Smart" method, Logical Decisions computes and saves a set of swing weights that result in the same weights as the smarter importance ordering. If you then change to the tradeoff method, Logical Decisions computes and saves a set of tradeoffs (against the most important member) that result in the same weights as the swing weights. This lets you get an initial assessment using an "easy" method and still check your results using a more "difficult" method.

The Relationship Between Measure Ranges and Weights

One of the most misunderstood concepts in multi-objective decision analysis is the relationship between measure ranges and weights.

The common misconception is that there is **no** relationship and that measure weights can be assessed based on the names of the measures alone. This is incorrect. There is a strong relationship between measure ranges and weights.

- **As the range for a measure gets wider, its weight should increase.**

Weights in Logical Decisions are computed based on the most and least preferred levels for each measure established in the measure's properties dialog box. This range is also used in the conversion to common units step.

Establishing a measure's range. There are several approaches to establishing a measure's range.

One approach is the use the exact range of the alternatives. This may cause problems due to the more or less random numbers that will define the range. Also the range may have to be changed frequently as alternatives are added and deleted.

Another approach is to use the range of the alternatives, but expand it somewhat to nearby round numbers. For example if the range for alternative trucks for horsepower is 109 hp to 177 hp, you might consider defining the range in Logical Decisions as 100 hp to 180 hp or 100 hp to 200 hp. This will make the assessment questions easier to think about and will reduce the need for adjustments as alternatives are modified.

This is the approach recommended for Logical Decisions.
Two other approaches for establishing ranges are not recommended. The first is to establish the widest range possible, regardless of the alternatives, such as 75 hp to 350 hp for the truck example. This approach has several drawbacks, including having no well defined method for establishing the range and potentially forcing consideration of unacceptable measure levels when assessing weights.

The final method, used in the Analytic Hierarchy Process is to not specify a range at all. This can lead to large disagreements in the weight assessments due to different implicit ranges. It also may force decision makers to consider unacceptable measure levels during the weight assessment. It also makes it impossible to meaningfully adjust the weights as alternatives are modified.

Understanding the Relationship Between Ranges and Weights. To understand the relationship between ranges and weights intuitively, let's look at an extreme example. Figure 9- 11 shows two possible car buying scenarios.

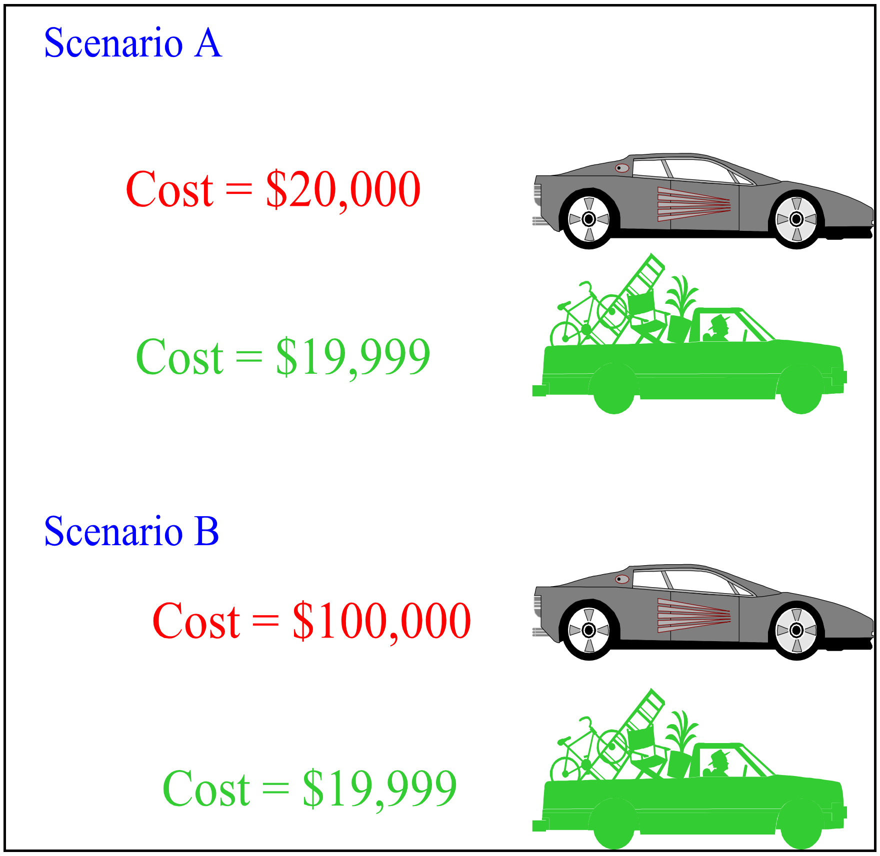


Figure 9- 11. Extreme example of the relationship between range and weight

In Scenario A, the cars are very different, but the price difference is only $1. It seems reasonable to assume that in this scenario the price would be a very minor factor in the decision. If the range for price in Logical Decisions was the same as for the alternatives a very low weight for price would be appropriate.

In Scenario B, the alternatives are the same, but the price difference is now $81,000. In this scenario, price is likely to be a major factor in the choice and thus should be assigned a relatively large weight in the analysis.

Here is another more quantitative example. Figure 9- 12 shows a situation where two cars differ on price and performance but are equally preferred.

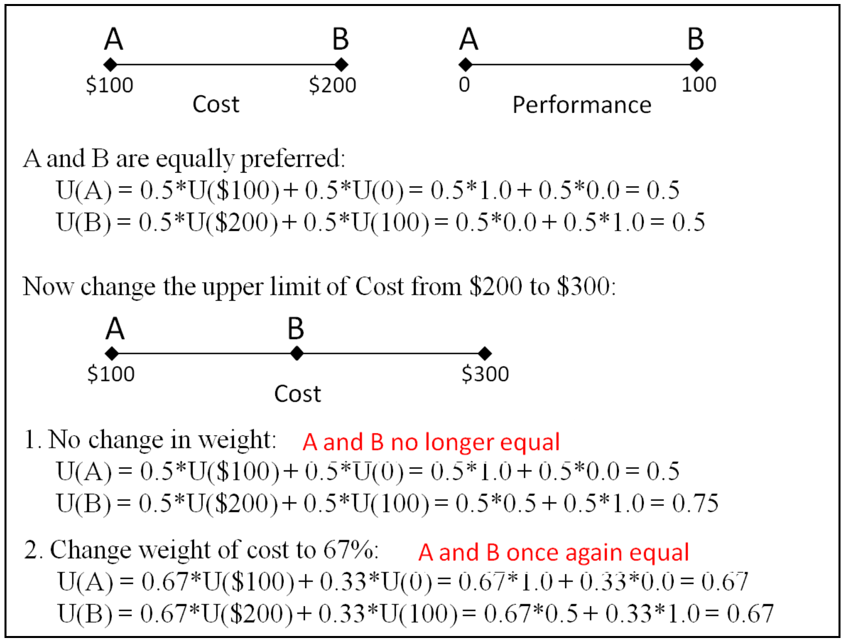


Figure 9- 12. Quantitative range vs. weight example

The difference in cost between A and B is just matched by the improvement in performance from A to B. Based on this tradeoff, equal weights are assessed for the Cost and Performance measures. The resulting MUF results in equal utilities for A and B as they should have.

Now suppose the range for Cost is increased from $100 to $300 instead of $100 to $200. If there is no change in weights, the computed utility for B changes, because it is no longer at the least preferred level for Cost. The utilities for A and B are no longer equal, even though we still find them equally desirable.

The way to bring things back into sync is to change the relative weights for Cost and Performance. In particular, since the range for Cost has doubled it should get twice as much weight as before.

This means that Cost will have twice the weight of Performance.

When we make the weights sum to 1.0, this means that Cost will have a weight of 0.67 and Performance will have a weight of 0.33. When we compute the utilities of A and B, we find that with the new weights they are once again have equal utilities.

Thus, proportionally increasing the weight for Cost as we increase its range correctly compensates for the change and keeps equally preferred alternatives equally ranked.

Top Down Vs. Bottom Up. An issue related to ranges and weights is whether preferences in a goals hierarchy should be assessed from the top down or the bottom up.

The top down approach is to assess the relative weights of the highest level goal first and then to do lower level assessments to allocate each goal's weight among its members. The bottom up approach is to first assess the relative weights of the lowest level measures within each lowest level goal and then to do higher level assessments to establish the relative weights of higher level goals.

While both approaches are possible in Logical Decisions, the bottom up approach is preferred. This is because the top down approach makes it difficult to think about the measures below a goal when assessing its relative weight.

When assessing the weight for a high level goal, it is tempting to think about the global significance of the goal's name rather than the specific measures (and associated ranges) included under the goal. This can lead to too much weight assigned to a measure with a very narrow range or too little weight assigned to a measure with a wide range.

In the bottom up approach, the decision makers will have thought about the measures under a goal before assessing the weight of the goal itself. This should lead to more reasonable weight assessments for the higher level goals.

An even better approach is to use representatives (page 334) to assess each goal's weight indirectly. It's easier to think about the range and importance of a single measure than to think about the whole set of measures represented by a goal.

Ranges and Weights in Logical Decisions. The tradeoff method is the only weight assessment method in Logical Decisions that automatically compensates for changes in measure ranges. This is because the tradeoff method uses pairs of equally preferred alternatives and computes weights based on the measure ranges to make their utilities come out equal.

If a measure's range changes, Logical Decisions automatically recalculates the weights to compensate and keep the tradeoff pairs equal. The tradeoff computation is described in Appendix A. For the other methods, the weights should be manually adjusted or reassessed after a change is made in a measure range.

Assessing Interactions Between Measures

The discussion of MUFs so far has assumed that the active members don't interact with one another. Each active member makes its own contribution to the MUF formula as determined by its weight, and that contribution does not depend on the levels of the other active members.

However, this may not be an adequate model of people's preferences. For example, a decision maker might want balanced performance in a truck. That could mean that a desirable truck should have both high horsepower and good gas mileage. Thus, she would prefer a truck with medium levels of these two measures to one with the best level on one measure and the worst level on the other.

Or, she could feel exactly the opposite, that if either horsepower or gas mileage is outstanding, the level of the other measure doesn't really matter.

Logical Decisions can model these types of preference interactions by using a **multiplicative MUF formula**. Like the additive MUF formula, each measure in a multiplicative MUF has an associated scaling constant (weight). However, the multiplicative formula requires an additional scaling constant, traditionally called "Big **K**". Big K defines the type and degree of interaction between the measures.

The multiplicative MUF formula is written as follows:
$U(X) = ((1+Kk_1U_1(X))x(1+Kk_2U_2(X))x...x(1+Kk_nU_n(X))- 1)/K$

where

$U(X)$	= the overall utility of alternative X,
k_i	= the scaling constant **small k** for measure i,
$U_i(X)$	= the SUF utility on member i for alternative X,
K	= the interaction scaling constant **big K**

The level of big **K** can result in several types of interaction between evaluation measures:

Value of big **K**	Sum of small k_i	Type of interaction
$-1 < K < 0$	> 1	**constructive:** high utility on one measure means high utility overall
$K = 0$	= 1	**neutral:** use additive MUF formula
$K > 0$	< 1	**destructive:** low

utility on one
measure means low
utility overall

Figure 9- 13 is an example of the overall utilities that result from two measures having equal weights and neutral interactions. The two measures range from 0 to 1, and have straight line SUFs. You can see that the overall utility here is simply the average of the two individual SUF utilities.

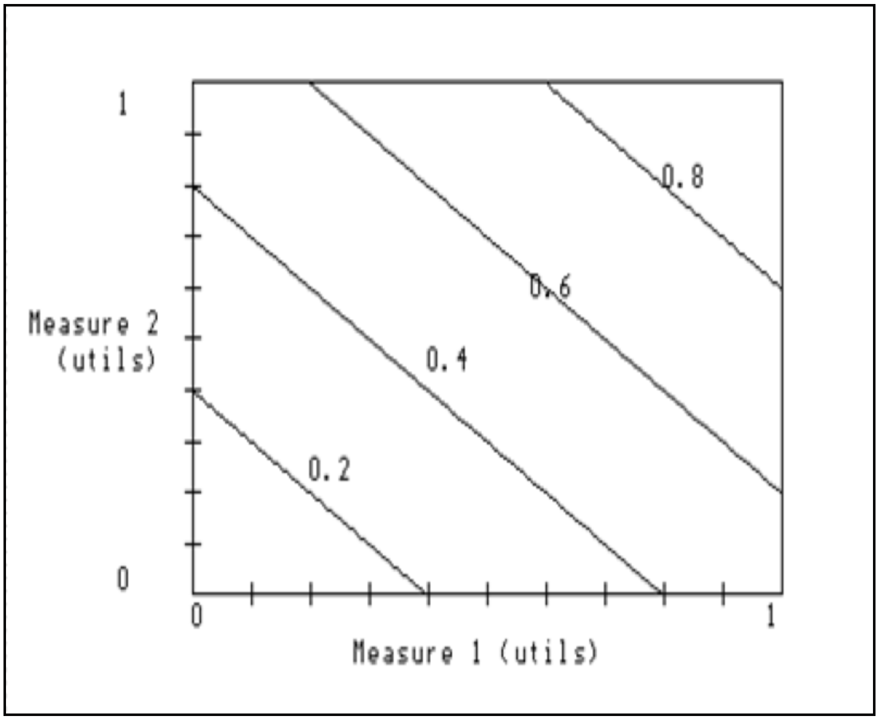


Figure 9- 13. Overall utilities for a pair of measures with neutral interaction.

Figure 9- 14 is an example of the overall utilities that result from the same two measures but with destructive interaction. Both measures were assigned a small **k** of 0.1, resulting in a big **K** for the two measure MUF of 80, indicating strong destructive interaction.

You can see that the overall utility curves have moved toward the upper right-hand corner of the graph. This shows that higher levels on the two measures are required to obtain a given overall utility than with neutral interaction. The concave shape of the curves shows that alternatives with balanced utilities on the two measures will get generally higher overall utilities than alternatives with more skewed utilities.

For example, an alternative with a 0.5 level on both measures has an overall utility of about 0.3, while an alternative with 1.0 on one measure and 0.0 on the other has an overall utility less than 0.2.

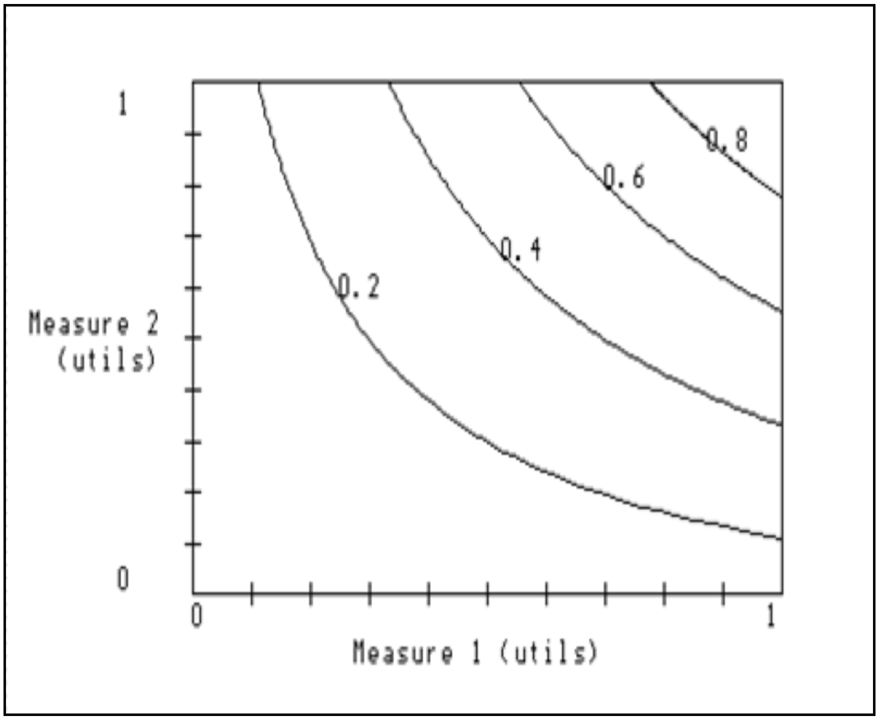


Figure 9- 14. Overall utilities for a pair of measures with destructive interaction

Figure 9- 15 is an example of the overall utilities that result from the same two measures with constructive interaction. Both measures were assigned a small **k** of 0.9, resulting in a big **K** for the two measure MUF of -0.987, indicating strong constructive interaction. The overall utility curves have now moved toward the lower left-hand corner of the graph, showing that much lower levels on the two measures are required to obtain a given overall utility than with neutral or destructive interaction. The convex

shape of the curves shows that alternatives with balanced utilities on the two measures will now get lower overall utilities than alternatives with more skewed utilities.

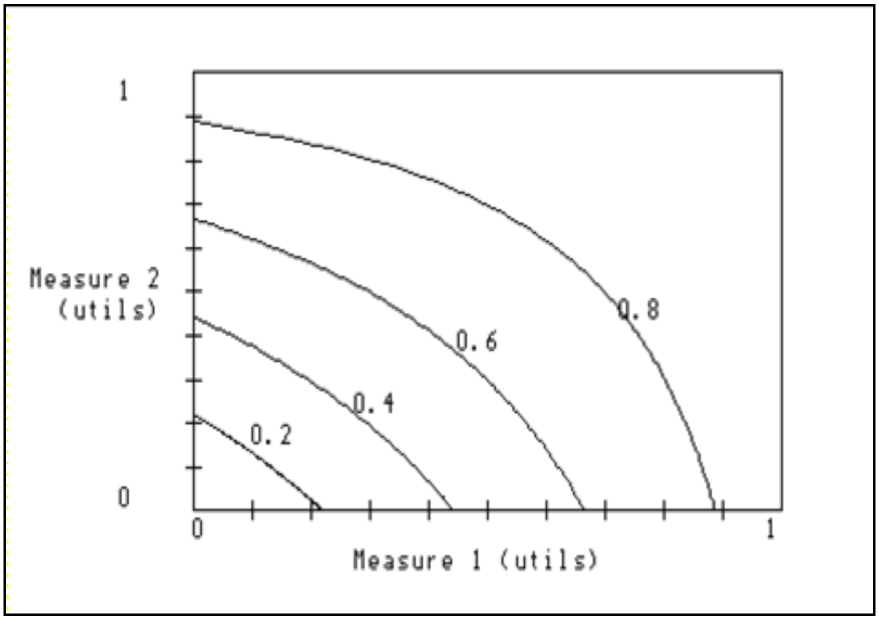


Figure 9- 15. Overall utilities for a pair of measures with constructive interaction.

An alternative with a 0.5 level on both measures now has an overall utility of about 0.7, while an alternative with 1.0 on one measure and 0.0 on the other has an overall utility greater than 0.8.

Note that interactions affect all of the active members in a MUF. In the examples above either of the members could pull the overall score up or down (depending on whether the interaction was constructive or destructive).

If you only want one or two members to have this ability, you should simply give those members a high weight. Also, the interactions tend to work in one direction only. With constructive interaction, a single member can have a large effect in increasing the overall utility, but can only have a small effect in the other direction.

Similarly, a single member can have a large effect in reducing the overall utility if there is destructive interaction, but can only have a small effect in increasing the overall utility.

Defining Interactions Between Measures. Determining a multiplicative MUF formula requires one more piece of preference information than an additive MUF formula. The additional information lets Logical Decisions compute the multiplicative MUF formula's interaction scaling constant, big **K**.

The additional piece of information can be:

- a second tradeoff between two members that were already involved in a tradeoff,
- a response to a probabilistic question that gives additional information about two members already involved in a tradeoff, or
- defining the exact value of one scaling (weighting) constant.

You usually define a **second tradeoff** between two active members by comparing an alternative where they are at extreme levels to one where they are at intermediate levels. It helps if the two members are nearly equally weighted.

For example, suppose that we have done a tradeoff between power and fuel economy and found that the decision maker feels that they are equally important. Now we define a second tradeoff between the two measures with a dialogue that might go as follows:

Q: We already talked about the tradeoff between power and fuel economy. Now I want to look at those measures again to define their interaction. Suppose a truck has 175 hp (the most preferred level) but only gets 16 mpg (the least preferred level). Call this alternative **A**. Now suppose a second truck is the same as the first but has 130 hp (already defined as the mid-preference level) and gets 20 mpg (also the mid-preference level). Call this alternative **B**. Which of these two alternatives would you prefer?

A: I could see where some people might think these were equally desirable, especially given what I've said before about these two measures, but I really think a truck should have balanced performance. I don't think I'd like to give up so much fuel economy to get really good power. So, I'd pick the balanced alternative B.

Q: Good, that's the type of interaction I'm trying to get at here. Suppose I make alternative **B** less desirable. If I define **B**' as having 110 hp and getting 18 mpg, would you still prefer it to alternative **A**?

A: No, now I think I'd prefer alternative A. I think I'd have trouble deciding if alternative B had 125 hp and got 19 mpg.

Logical Decisions can combine this second tradeoff between power and fuel economy with the first one and the tradeoffs for the other members to compute the scaling constants for a multiplicative MUF formula. The algebra is somewhat complicated and won't be described here. The computations are all done automatically by Logical Decisions.

You can make some qualitative checks on the computations, however. Since alternative **B** had levels that were less than the mid-preference levels, this means that the decision maker felt that the low level on MPG for alternative **A** had a relatively large effect on the overall utility. This corresponds to the third case in the table above (destructive interaction), where big **K** is greater than 0 and the small $\mathbf{k}_i$ sum to less than 1.

The response to a probabilistic question can also define the degree of interaction between two measures. Here Logical Decisions asks the decision maker to choose between two uncertain outcomes.

This is the most difficult type of preference question used in Logical Decisions. You might pose the question as follows:

Q: We already talked about the tradeoff between power and fuel economy. Now I want to look at those measures again to see if they have any interaction. Suppose a truck has uncertainties for some reason -- maybe it has an option package the dealer doesn't have the details for. Anyway, if you can imagine it, suppose the truck has a 50 percent chance having 160 hp (the most preferred level) and 30 mpg (also the most preferred level) and a 50 percent chance of having 80 hp and 16 mpg (the least preferred levels). In other words, it's an all or nothing gamble, either the most preferred level on both measures or the least preferred levels, both with an equal chance of occurring. Call this alternative **A**. Now suppose a second truck is the same as the first but has a 50 percent chance of having 160 hp and 16 mpg and a 50 percent chance of having 80 hp and 30 mpg. It's still uncertain. You're guaranteed to get either good horsepower or good gas mileage, but not both. Call this alternative **B**. I know these are complicated so I've drawn them in Figure 9- 16. Which of **A** or **B** would you prefer?

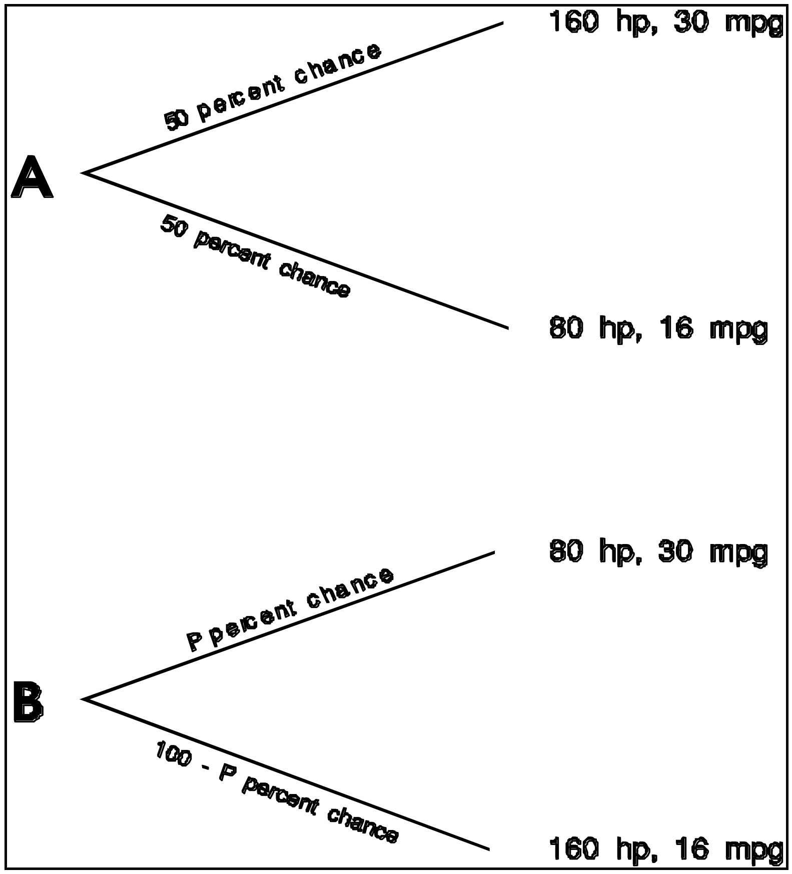


Figure 9- 16. Example of assessment question for interactions

A: Wow, that's pretty complicated. It's also hard to see where I'd really be presented with alternatives like this, but I guess I can imagine it. I don't like either of the choices in B very much because I really think a truck should have balanced performance. I don't think I would like to give up so much fuel economy to get really good power or vice versa. So, I'd pick alternative A, where at least I have a chance of getting everything I want.

Q: Good, that's the type of interaction I'm trying to get at here. Suppose I make alternative **A** less desirable. I'll keep everything the same but change the probabilities for **A**. Suppose the probability of getting the most preferred levels on power and fuel economy was only 25 percent. Would you still prefer alternative **A** to alternative **B**?

A: No, now I think I'd prefer alternative B in that case. I think I'd have trouble deciding if the probability of getting the most preferred levels was 40 percent.

Logical Decisions can combine this probabilistic tradeoff between power and fuel economy with the original tradeoffs to compute the scaling constants for a multiplicative MUF formula. Again, the arithmetic is somewhat complicated and won't be described here.

Qualitative checks can still be done. The overall utility of alternative **A** is equal to its expected utility. If there were only two measures, power and fuel economy, the top possibility, with the most preferred level on both measures, would have an overall utility of 1. The lower possibility would have a utility of 0.

The expected utility of the lottery is
(40 percent)x1 + (60 percent)x0 = 0.4. Both of the possibilities in alternative **B** would have overall utilities of 0.5 if the two measures were equally important (which we are assuming) and there were no interactions. This would make the overall utility of alternative **B** also equal to 0.5. However, since **A** and **B** were equally preferred, they must have the same overall utility, so interaction must make the overall utility of **B** less than 0.5.

A probability of less than 0.5 for the more preferred possibility of alternative **A** corresponds to the third case in the table above, where big **K** is greater than 0 and the small $\mathbf{k}_i$ sum to less than 1. Here, a low utility on any one measure leads to a low overall utility (destructive interaction).

Defining Interactions in Logical Decisions. Logical Decisions lets you define interactions in several ways --

- By using an additive MUF formula (no interactions).

- By assessing a second tradeoff.
- By assessing a probabilistic tradeoff.
- By directly entering the small **k** for one measure.
- By directly entering the small **k** for all measures.

Generally, you define interactions *after* the weights have been assessed. If you define the MUF formula to have no interactions, you don't need to enter any additional information. This is the default.

To assess a second tradeoff between two measures, Logical Decisions displays a list of the existing tradeoffs and asks you to select one. Then Logical Decisions asks you to directly define the second tradeoff using the "free float" tradeoff assessment option.

If you have used a weight assessment method other than tradeoffs, Logical Decisions will let you select any two active members and define a tradeoff between them.

To assess a probabilistic tradeoff, Logical Decisions again asks you to select an existing tradeoff. Logical Decisions then constructs a probabilistic tradeoff question for the members in the original tradeoff and asks you to enter the probability that makes the two alternatives equally preferred. Again for other assessment methods you can select any two active members to use in the question.

Directly entering the small **k** for one active member lets Logical Decisions compute the complete MUF formula. Usually you will compute the small **k**s using an additive MUF formula first and then select an adjustment. If you enter a small **k** smaller than the one computed for the additive formula, you will have a big **K** greater than zero, indicating destructive interaction.

If you enter a small **k** greater than the original one, Logical

Decisions will compute a big **K** less then zero, showing constructive interaction. You must enter a small **k** between zero and one. Sometimes it is possible to enter a small **k** that is inconsistent with the assessed tradeoffs. Here, Logical Decisions will adjust the small **k** until it achieves consistency.

Defining interactions with the direct entry method. Finally, if you are using the direct entry weight assessment method, you can define interactions when you define the weights for the active members. The small **k**s you enter must be between zero and one. The sum of the small **k**s defines the type of interaction:

- Small **k**s that sum to one imply an additive MUF formula.
- Small **k**s that sum to less than one imply a multiplicative MUF formula with destructive interaction.
- Small **k**s that sum to more than one imply a multiplicative MUF formula with constructive interaction.

Note that if you want to use the direct entry weight assessment method to define interactions, you must have the "Interactions Computed Directly" interaction assessment method selected.

Ranking Alternatives

A ranking of the alternatives is the primary result of an analysis done with Logical Decisions. You can display a ranking of the alternatives can for *any* measure or goal. You get the *overall* ranking by doing a ranking for the Overall goal.

You can do a ranking at any time. If you have not assessed a SUF for a measure, Logical Decisions assumes a linear (straight line) SUF. If you have not assessed any weights, Logical Decisions assumes that all measures are equally important (have equal weights).

Figure 8- 18 on page 227 shows an example of the ranking of alternatives.

Interpreting the Ranking Results

Logical Decisions' ranking results are presented in terms of utilities. You should be careful when interpreting these utilities.

Most importantly, the absolute size of the utility numbers is not meaningful. Thus, an alternative with a utility of .98 in one analysis is not inherently better than an alternative with a utility of .75 in another analysis.

You should only compare the utilities from a particular analysis with each other.

It is easy to change the sizes of the utility numbers by changing the measures' ranges. However, these types of changes *will not* change the alternatives' rank ordering if you adjust the weights properly.

Utilities can be adjusted by adding a constant to all of the utilities or by multiplying all of the utilities by a constant. In mathematical terms, utilities are unique up to a **linear transformation**. Scales like utility with this property are called **interval scales**.

One type of comparison that is possible between alternatives is *changes* in utilities. If alternative **A** has a utility of 0.5, alternative **B** has a utility of 0.6 and alternative **C** has a utility of 0.8, not only can you say that alternative **C** is preferred to alternatives **A** and **B**, you can also say that the increase in desirability from **B** to **C** is greater than the increase from **A** to **B**.

Although utilities generally range from zero to one, occasionally an alternative will have a ranking outside this range, either negative or greater than one. There is nothing wrong with this. It just means that the alternative has one or more levels outside the ranges of the measures, and that Logical Decisions has extrapolated the utilities for these measures

SECTION

Examples

10

Examples

Introduction

This section provides three examples of how Logical Decisions (LDW) has been used on real problems. The first example involves selecting a personal computer system -- a problem faced by small businesses. The second example involves buying a home. The final example is finding the best location for a reservoir -- a large engineering problem of the type faced by many public agencies. These examples are actual case studies that used the LDW software, although the details have been changed to protect clients' anonymity

These examples should give you a better idea of how LDW you can use in practice and of the types of insights you can gain by using LDW. Each example has an associated LDW data file that is installed with the LDW software. These files will let you review the SUFs and tradeoffs developed for each analysis. You can gain an understanding of how to use the results displays by trying the different options with these example data sets.

Buying a Computer

The first example is a small business in the process of upgrading its personal computer system. The company wanted a powerful computer but naturally wanted to minimize its cost. In reviewing the advertisements and reviews in local and national publications, the decision maker found a myriad of systems with many available options and configurations. Each manufacturer used different components with differing performances. The different configurations all resulted in different prices and made it difficult to see which system represented the best value. Note that this analysis was done in 1990 and reflects the computer technology and prices of that time.

After a careful review of the current advertisements the decision maker could narrow the manufacturers down to a preliminary list of six companies. For each company, the decision maker identified the computer system that seemed to best fit his needs. If more than one system seemed promising, they were both included as alternatives. This process was done informally, with the idea that other manufactures and system alternatives could be added later if necessary. All of the candidate computers were IBM PC "Clones" with 80386 Intel CPUs, hard drives, two floppy disk drives, and VGA color monitors and graphics cards.

After the decision maker had identified the preliminary alternatives, the next step was to refine the overall goal of "choose the best computer." The decision maker initially came up with five sub-goals under the overall goal. These were:

- Minimize Price,
- Maximize Quality,
- Maximize Speed,
- Maximize Hard Drive Performance, and
- Maximize Video Quality.

The decision maker then refined these sub-goals until he could quantify them. The price goal was straightforward and could be quantified directly as a measure -- the total price of the system (including any applicable taxes and shipping). Two of the goals -- Speed and Hard Drive Performance could be measured using standard measures included in all of the ads. Speed was mainly a function of the CPU clock speed and the presence and size of a memory cache. The decision maker created measures to capture these two considerations. Similarly, the decision maker could characterize hard drive performance by the size of the drive (in megabytes) and the disk access time (measured in ms). Video performance was more difficult to measure, but could be divided into qualitative measures related to the monitor and the video card.

The most difficult goal to measure was the quality goal. After some thought, the decision maker felt that quality should reflect the reputation (if any) of the manufacturer, and favorable reviews of the computer in national or local publications. In addition, the decision maker included two other more specific concerns under this goal -- the quality of the computer's keyboard and its FCC certification type.

As the analysis progressed, the decision maker realized that he was worried about buying a mail order computer because of possible difficulties in obtaining service. A measure was added to reflect this concern.

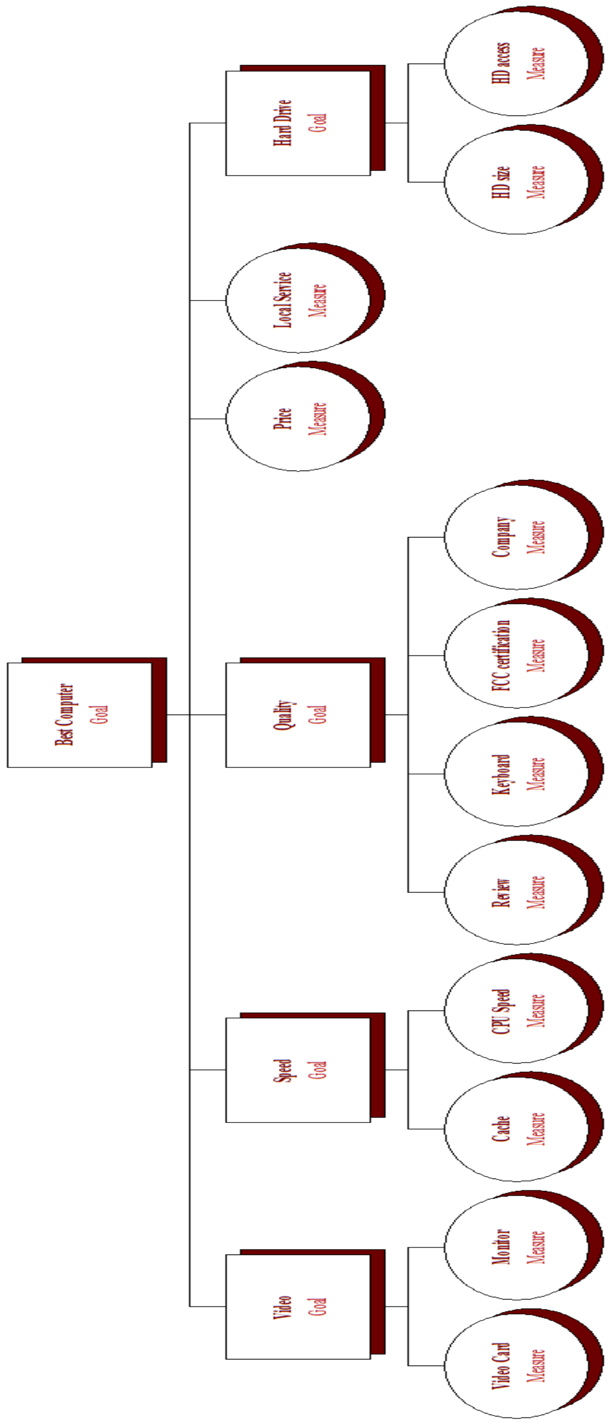


Figure 10- 1. Goals hierarchy for computer selection decision.

The completed goals hierarchy is shown in Figure 10- 1.

After the goals hierarchy had been completed, the next step was to complete the definitions of the measures. In particular, it was necessary to define the scale points in the constructed (non-numeric) scales. It is not sufficient to use 1 - 10 or similar scales, since it is not clear what the different scale points mean. This makes it difficult to consistently rank the alternatives or to assess tradeoffs concerning the measure. **Figure 10-2** shows some constructed scales for the computer selection example.

Video Monitor Quality

Best	1. A brand name multi-sync monitor comes with the system.
	2. An unknown brand multi-sync monitor comes with the system.
	3. A brand-name VGA monitor comes with the system.
Worst	4. An unknown brand VGA monitor comes with the system.

Video Card Quality

Best	1. A brand-name 16 bit SVGA card comes with the system.
	2. An unknown brand 16 bit SVGA card comes with the system.
	3. SVGA card comes with the system.
Worst	4. A VGA only card comes with the system.

Company Quality

Best	1. A first rate, well established company.
	2. A "second tier" but still well known company.
Worst	3. A "no-name" clone maker.

Reviews

Best	1. Rated a "Best Buy" by a national computer magazine.
	2. Given a good review in a national or local publication.
	3. No reviews found.
Worst	4. Given a poor review in a national or local publication.

Figure 10- 2. Constructed measure scales for computer selection decision.

After the decision maker had defined the measures, he could enter the levels on the measures for each alternative. This step was straightforward, since most of the data was available through information in the ads and reviews of the various computers. The decision maker assigned one probabilistic level on the Local Service measure for a company that had just opened a local dealership. He assigned a probability of 20% that the dealership would close and that no local service would be available.

The next step was to assess preferences. Since the measures had few uncertainties, the mid-level splitting technique was used to assess the single measure utility functions. The tradeoffs were mostly assessed using price as a basis. Figure 10- 3 is the bubble diagram for the tradeoffs for the computer selection decision.

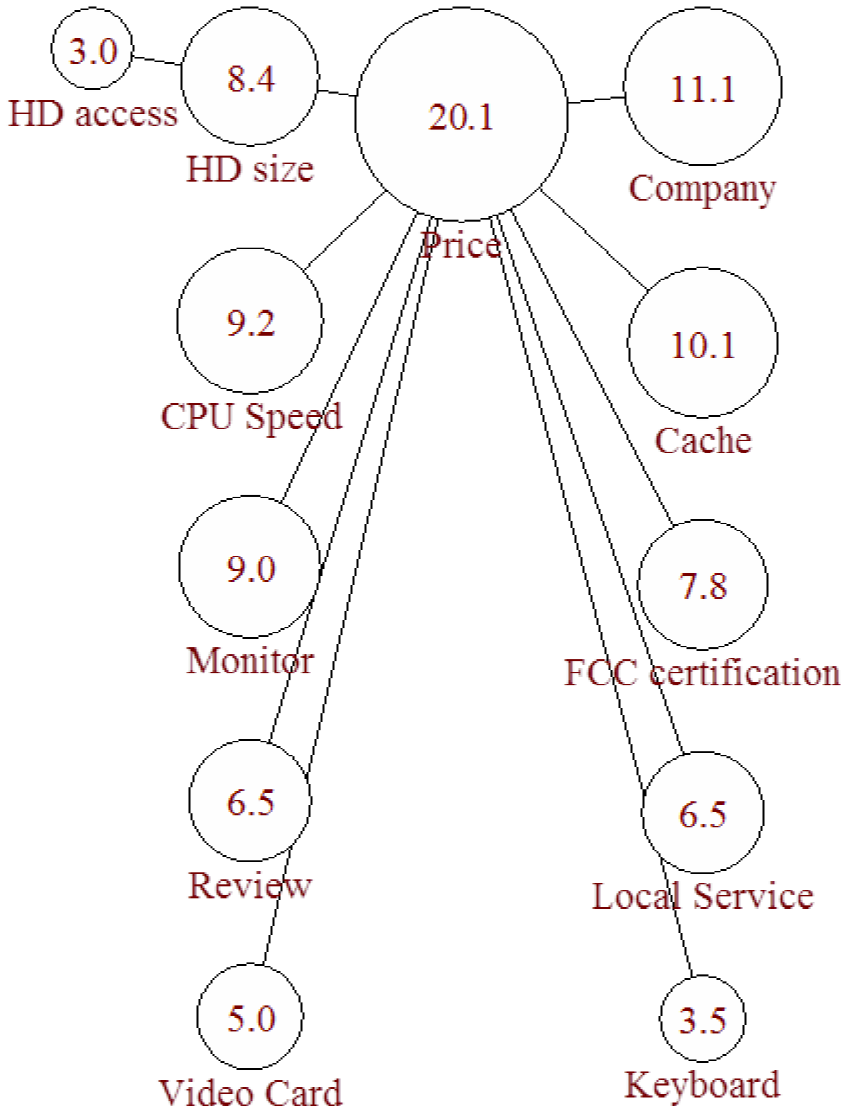


Figure 10- 3. Tradeoff assessment "bubble diagram" for buying a computer example.

After the preference assessment had been completed, the alternatives could be ranked.

The ranking results are shown in **Figure 10-4**. These results show that the computers from local vendor one represented the best price performance combination based on the decision maker's preferences. The decision maker was also willing to pay the price to get the best available performance from that vendor. Insights gained from the analysis included the realization that the availability of local service was very important and overrode any perceived quality advantages from the national mail order vendors. The decision maker agreed with the results of the analysis and bought the highest ranked computer system.

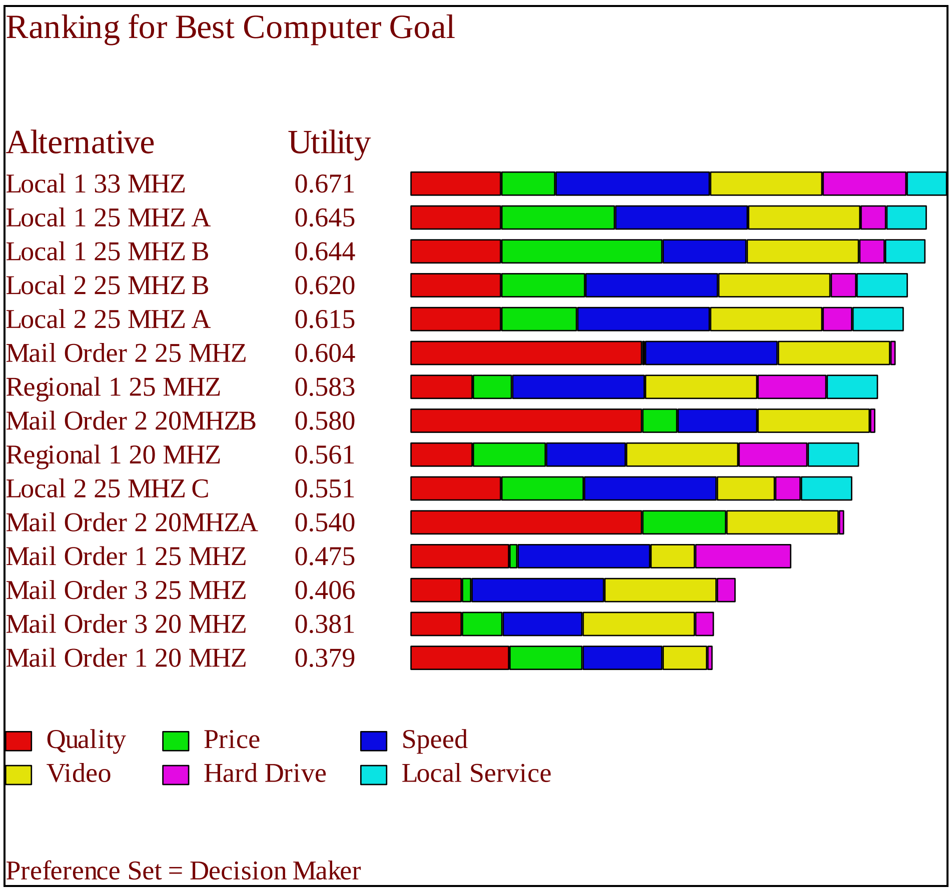


Figure 10- 4. Ranking results for computer selection example

The computer selection example is included in the file **COMPEX.LDW**.

Buying a House

The most important decision made by many families is buying a home. This example shows how you can use LDW to help evaluate the many factors that differentiate one house from another. The example is based on a family selecting a home from those available at a particular time in the Denver, Colorado area. The house selection example is included in the file **HOUSEEX.LDW**.

The first step was to identify a preliminary list of homes to evaluate. The family conducted an informal screening process with a Realtor's help to identify an initial set of homes in their price range.

Next they developed a goals hierarchy to reflect their goals in selecting a home. No two families 'goals will be the same. Considerations that are very important to one family may not be important at all to another. Thus the goals hierarchy for a decision such as this will be a very personal reflection of the needs and desires of the decision makers.

It is unlikely that another family could use this goals hierarchy as is, although some ideas in it could provide a valuable starting point.

In developing the goals hierarchy, the family used their likes and dislikes about the homes they had looked at so far as a starting point for the hierarchy. The goals hierarchy has four first level sub-goals -- Maximize Quality, Minimize Costs, Maximize Size, and Maximize Location Quality. The family subdivided these goals into many measures and sub-goals. There is a lot to think about when buying a house! Many lowest level sub-goals simply show the presence of a particular item, such as a clothes dryer. Others represent very subjective considerations such as privacy and exterior appearance. The complete hierarchy is shown in **Figure 10-5**.

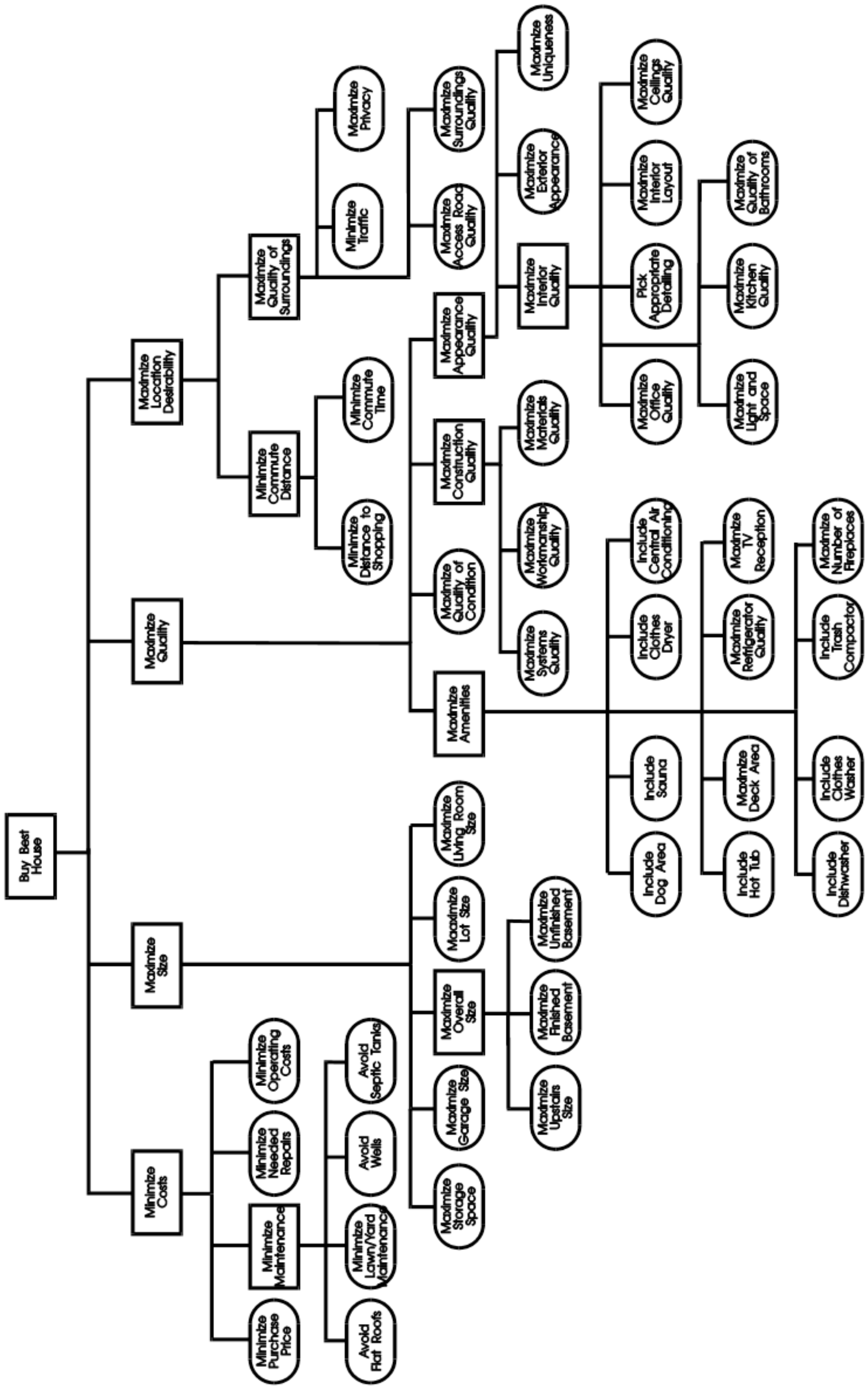


Figure 10- 5. Goals hierarchy for house example

The definition of measures continued as in the computer selection example, with much time spent on properly defining the constructed measures that evaluated the more subjective concerns. To aid in evaluating houses, the family developed a form they could fill out when they visited each house. This form included the definition of each measure, so they could evaluate each house consistently. Figure 10- 6 and Figure 10- 7 present the two pages of this form.

Evaluation form for Best House decision

Prepared By____________________

Date____________________

Alternative____________________

Best House Goal

Costs Goal

Needed Repairs: __________ (thousand dollars)
range: 10 (least preferred) to 0 (most preferred)

Operating Costs: __________ (dollars/month)
range: 1000 (least preferred) to 300 (most preferred)

Purchase Price: __________ (thousand dollars)
range: 220 (least preferred) to 150 (most preferred)

Location Goal

Quality Goal

Condition: __________ (constructed)

1) New
2) Pristine
3) A Few Flaws
4) Run Down
5) Handyman Special

Size Goal

Garage Size: __________ (number of cars)
range: 0 (least preferred) to 3 (most preferred)

Living Room Size: __________ (sq. ft.)
range: 100 (least preferred) to 700 (most preferred)

Lot Size: __________ (acres)
range: 0.15 (least preferred) to 5 (most preferred)

Storage Space: __________ (constructed)

1) Abundant
2) Adequate

Figure 10- 6. First page of house evaluation form

Maintenance Goal

Flat Roof: __________ (yes/no)
1) No
2) Yes

Lawn/Yard: __________ (constructed)
1) None
2) Some
3) Extensive

Septic Tank: __________ (yes/no)
1) No
2) Yes

Well: __________ (yes/no)
1) No
2) Yes

Commute Goal

Commute Distance: __________ (minutes to lot)
range: 45 (least preferred) to -2.67296e-014 (most preferred)

Shopping Distance: __________ (minutes to grocerie)
range: 10 (least preferred) to 2.46601e-015 (most preferred)

Surroundings Goal

Paved Roads: __________ (yes/no)
1) Paved
2) Not Paved

Privacy: __________ (constructed)
1) Isolated
2) Private
3) Well Shielded
4) Some Impingement
5) Crowded

Surroundings Qual.: __________ (constructed)
1) Panorama
2) Creekside
3) Forest
4) Flawed Forest
5) Nice City Street
6) Flawed City Street
7) Funky
8) Tract

Traffic: __________ (constructed)
1) Dead End
2) One Lightly Traveled
3) Two Lightly Traveled

Figure 10- 7. Second page of house evaluation form

The preference assessments were done in the normal fashion using the mid-level splitting technique to assess the single-measure utility functions. All of the tradeoffs were assessed against purchase price.

The family used the Compare Alternatives option extensively in gaining an understanding of the ranking results. For example, one house they looked at was an older custom built home with a Japanese motif and a spectacular view of the city of Denver. However, the house was rather small and needed extensive renovations. When compared to the highest ranking house it was found that the custom features could not make up for the small size and needed work, as shown in Figure 10- 8.

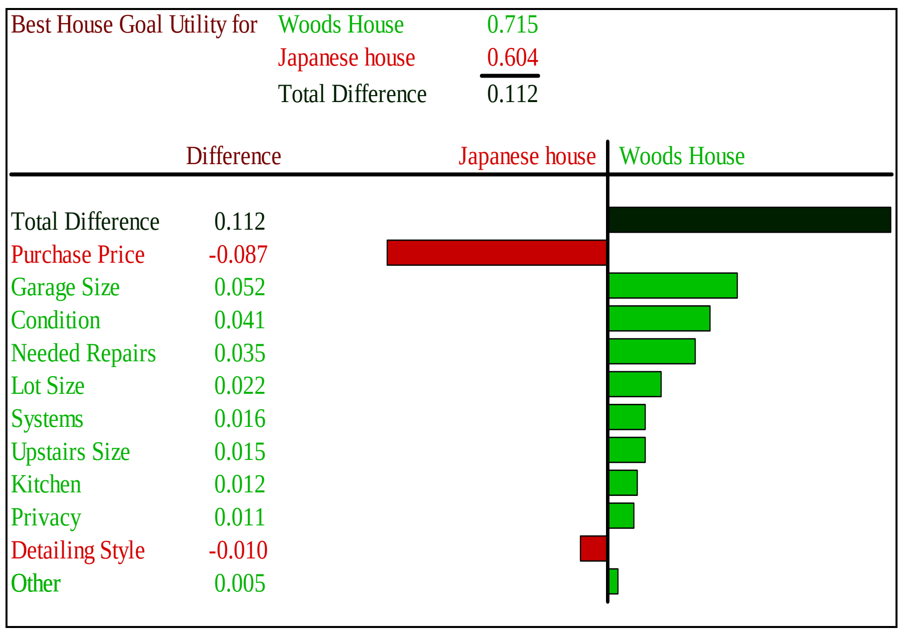


Figure 10- 8. . Alternatives comparison for two homes

Reservoir Location Selection

The final example is a planning decision faced by a large urban water district. They were planning a large new reservoir for backup and emergency water storage. Because of the reservoir's size, it would be costly and would also have significant environmental and social impacts. In addition, the location of the reservoir would affect how well it would fit into the district's existing operational system. A planning team was charged with the task of evaluating potential reservoir locations and making a recommendation to the district's board of directors. The team used an initial screening process to identify a set of potential sites for evaluation. They used Logical Decisions to help develop a quantitative ranking in support of their more qualitative recommendations. The team included the ranking results as part of the alternatives analysis for the project's environmental impact assessment documents. The reservoir selection example is included in the file **RESEX.LDW**.

The reservoir ranking differs from the previous examples in that the ranking represents the consensus of a team of experts, rather than the preferences of an individual. The project team used the Logical Decisions preference assessment process as a structured forum where they could discuss the relative importances of different aspects of the project. These discussions allowed the project team to arrive at a consensus preference set and thus a consensus overall ranking of the alternatives. This ranking also helped the project team formulate and organize their qualitative recommendations. The team used sensitivity analyses extensively to identify the effects of changes in the measures' relative importances.

Six reservoir sites were selected for evaluation. Some alternatives were enlargements to existing reservoirs, while others were entirely new sites. Several sites could fit more than one size of reservoir, but with differing impacts and operational effects. The team developed multiple alternatives with differing reservoir sizes at these sites. The sites were ranked independently of size, with costs being measured on a dollars per acre foot basis. (An acre foot is a measure of water volume and thus reservoir capacity.) A separate analysis used the ranking results to select the recommended reservoir size.

The team developed the goals hierarchy together with the technical experts and consultants working on the project. To identify the measures and lower level sub-goals for each major sub-goal, the team held a meeting with the experts in that area. These meetings helped ensure that the proper data was collected for each site and that the data was collected uniformly. Figure 10-9 shows the goals hierarchy for the reservoir selection process.

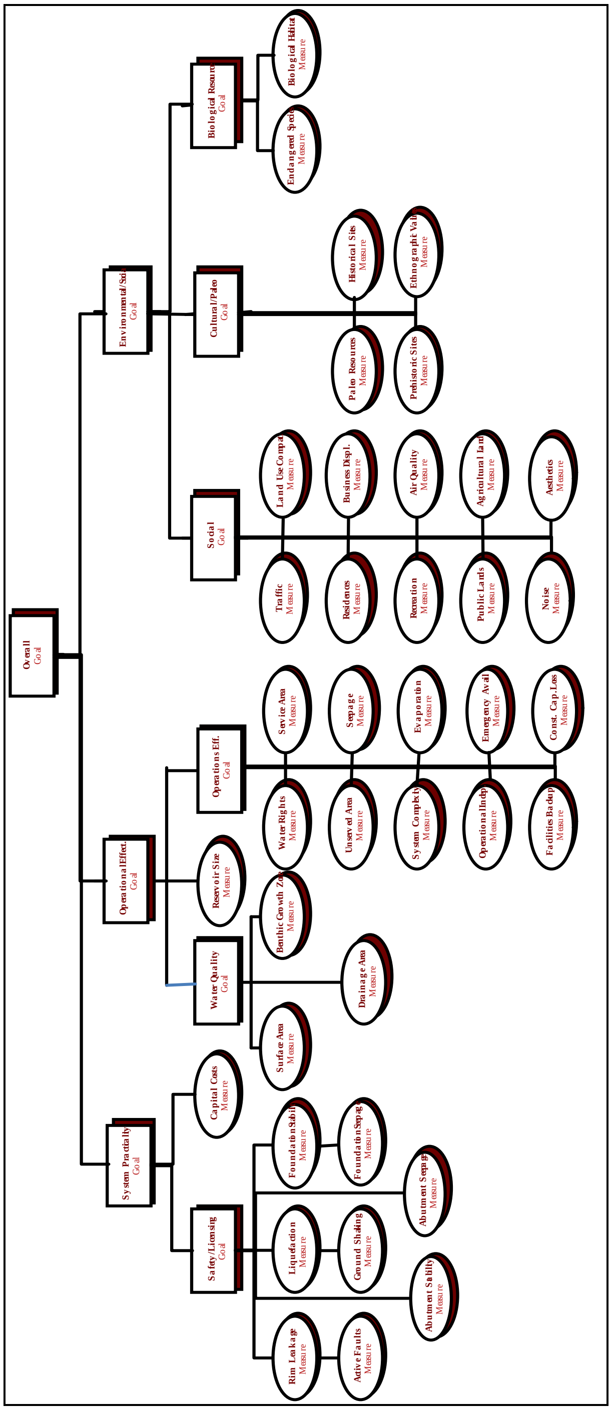


Figure 10- 9. Goals hierarchy for reservoir siting example

Many measures represented counts of the number of impacts in different categories. These category counts were converted to "equivalent" counts of the most significant category. Expert judgments were obtained of the count in each category representing an impact equivalent to one unit in the most significant category. These equivalent counts were then used when developing tradeoffs involving these measures. For example, the Prehistoric Sites measure counted the number of sites of different types that would be affected at each reservoir location. The experts categorized the types of prehistoric sites as shown in Figure 10- 10. The most significant category of prehistoric sites was "residential base sites with interpretive value." The overall level for the prehistoric sites measure was reported in units of "equivalent number of residential base sites with interpretive value affected." Sites in the other categories were converted to those units by multiplying the number of sites by the number in the last column of Figure 10- 10. For example, 20 processing sites would be the equivalent of two residential bases with interpretive value. A site with 1 residential base with interpretive value and 20 processing sites would thus be assigned an overall level of 1 + (20*0.1) = 3 on the prehistoric sites measure.

Category	**Sites to equal one Residential Base With Interpretive Value**	**Fraction of one Residential Base With Interpretive Value**
Residential Base With Interpretive Value	**1.0**	**1.0**
Residential Base	**1.11**	**0.9**
Processing Site	**10**	**0.1**
Isolated Rock Art	**200**	**0.005**
Prehistoric Isolates	**4000**	**0.00025**

Figure 10- 10. Equivalences for Prehistoric Sites measure in reservoir example.

The team used this approach on the following measures:

- Prehistoric Sites,
- Historic Sites,
- Paleontological Impacts,
- Biological Habitat,
- Endangered Species,
- Noise,
- Agricultural Impacts, and
- Business Impacts.

The preference assessments were done in a series of meetings with experts in the various disciplines. Tradeoffs involving the measures evaluated by the discipline were assessed. Then a final overall preference assessment meeting was held with representatives from the disciplines and from the water district. Tradeoffs involving the most important measures from each discipline were assessed. These tradeoffs were combined with the tradeoffs from the earlier meetings to obtain weights for the less important measures. **Figure 10-11** shows the tradeoff "bubble diagram" for the study.

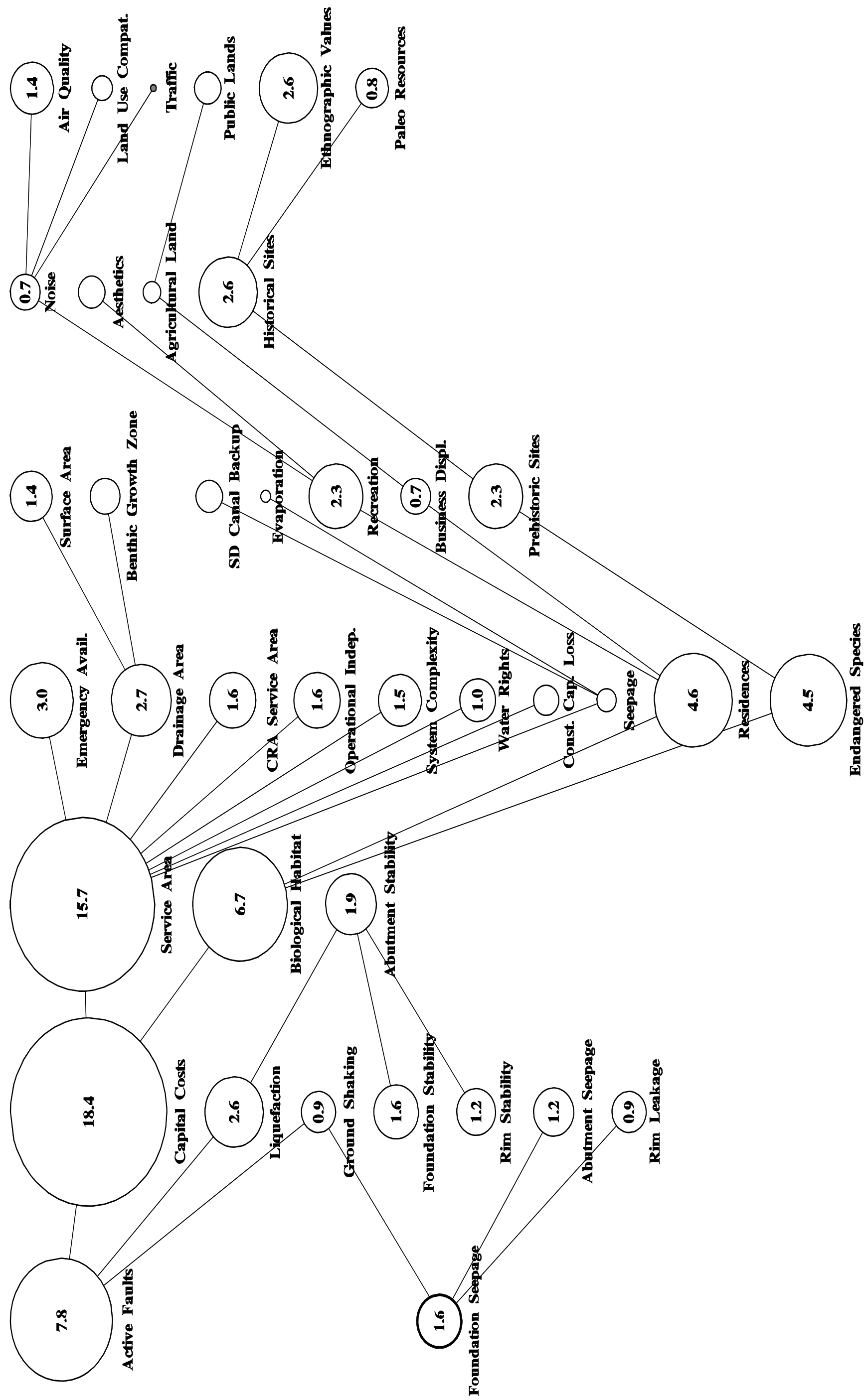


Figure 10- 11. Tradeoff "Bubble Diagram" for reservoir siting example.

SECTION

Commands Summary

11

Commands Summary

This section summarizes the commands available in Logical Decisions for Windows (LDW). The summaries are in alphabetical order by menu.

AHP Menu

The AHP menu appears whenever you are doing an assessment using the Analytic Hierarchy Process.

AHP::Cancel Cancel the AHP assessment. LDW will return you to the dialog box where you started the assessment without saving.

AHP::Done Finish the AHP assessment. LDW will save the results and return you to the dialog box where you started the assessment.

AHP::Estimate Ratios When Checked, LDW will estimate a ratio for each cell in the matrix that has not been explicitly entered, based on the ratios entered so far.

AHP::Identify Outliers Ask LDW to identify those cells whose entered ratios differ most from the ratio computed from the diagonal of the AHP matrix. When you select the option LDW will ask you how many cells to highlight.

AHP::Hide All Statistics When checked, LDW will not display any of the three statistics in the cell at the upper left of the hierarchy -- lambda-max, the consistency ratio and the consistency index.

AHP::Hide Weights When checked, LDW will not display the computed weights along the matrix diagonal.

AHP::Show C.R. Only When checked, LDW will only display the Consistency Ratio statistic in the cell at the upper left of the hierarchy. The lambda max and consistency index will not be displayed.

Assess Menu

The Assess menu has options that let you to assess and review the preference information LDW needs to rank the alternatives. The options are:

Assess::Category Multipliers Lets you enter the category multipliers for a measure.

Assess::Common Units The Assess::Common Units option in the SUF Menu lets you define the conversion to common units for a measure. When you select this option, LDW displays the common units dialog box. See page 7- for how to use this dialog box.

Assess::Consistency Checks Lets you review the tradeoff implied between two measures or goals and to revise the existing tradeoffs if the computed tradeoff does not look reasonable. See page 7- for the options you then have in adjusting the various tradeoffs.

Assess::Evaluation Form Displays an evaluation form that you can print and use to tabulate the measure levels for an alternative.

Assess::Questionnaire Displays a data entry form for the active preference assessment screen. When you select this option, LDW reproduces the assessment screen, but replaces any data entry edit boxes with underlines where respondents can enter their answers.

Questionnaires for AHP assessment screens display all possible pairs in the AHP matrix in a format that lets users graphically indicate relative importances.

Assess::Weights Displays the assess weights dialog box, where you define the weights and interactions for the measures and goals in your analysis.

Edit Menu

The Edit menu provides options to manipulate objects in Logical Decisions windows. Several of these options change depending on the type of object(s) you have selected.

Edit::Add Lets you add a new object to your analysis. You can add a new alternative, goal, measure, measure category, or preference set. You have the option to copy from an existing item.

Edit::Change Measure Units Lets you revise the units for a measure you select. You can change the name of the units and apply a linear transformation to the units scale. A linear transformation is multiplication by a constant and adding another constant.

Edit::Copy Lets you save selected objects for later pasting. These can either be graphics objects (such as lines or text labels) or analysis objects (such as alternatives or goals). Note that Logical Decisions saves the analysis objects you copy internally and not on the clipboard.

Edit::Cut Lets you delete selected objects but save them for later pasting. The objects can either be graphics objects (such as lines or text labels) or analysis objects (such as alternatives or goals).

Edit::Delete Lets you delete an alternative, goal, measure, measure category, or preference set. If you have selected one of these objects in the Goals Hierarchy or Matrix view, LDW will delete the selected object.

Edit::Delete All Alternatives Lets you delete all of the alternatives in the analysis. LDW will add a single alternative called “New Alternative” as a placeholder.

Edit::Graphic Selection::Add Label Lets you add a new text label to the active window.

Edit::Graphic Selection::Change Brush Color Change the fill color of the current graphic selection.

Edit::Graphic Selection::Change Pen Color Change the line color of the current graphic selection

Edit::Graphic Selection::Change Text Font Lets you change the font for text you have selected in the active window.

Edit::Graphic Selection::Edit Text Lets you edit a text label you have selected in a graphics window.

Edit::Insert Lets you add a new alternative, measure, measure category, or goal to your analysis. This option is only available in the Goals Hierarchy, Quick Entry and Matrix views.

Edit::Modify Lets you view the properties dialog box for the object currently selected in the Goals Hierarchy or Matrix view. If one of these windows is not active, LDW will show you a list of the types of objects you can modify.

Edit::Paste Lets you retrieve an object that you have previously saved with the Edit::Cut or Edit::Copy option.

Edit::Undo Undo the last action taken.

File Menu

The File Menu lets you load and save Logical Decisions and other types of files and to print the active window.

File::Exit End your session. If you have not saved your analysis, LDW gives you the option to save it before the session ends.

File::Export Save information in a Logical Decisions analysis to other file formats. The exported data can be the alternatives' measure levels or the utility for each measure and goal. Utilities will be based on the active preference set. You can also export a working utility function to Excel.

File::Import Load data from another file format. You can use the data to create a new Logical Decisions analysis or to update and/or append to the currently loaded data.

File::New Reload the "mini-analysis" shown when you start the program. If you have not saved your current analysis, Logical Decisions gives you a chance to save it before it is overwritten.

File::Open The File::Open option lets you retrieve a previously saved analysis.

File::Print Print the active window.

File::Print Preview Create a view that will show how the active window will look when printed.

File::Printer Setup View the dialog box for the active printer.

File::Save Save your analysis in an LDW File using the most recent file name.

File::Save As Save your analysis using a new name.

File::Save Window::Save as Graphic Save the active window as a picture file. The available formats are Enhanced Metafile, bitmap, JPEG, GIF, and PING. You select the format you want in the select file name dialog box.

File::Save Window::Save as Spreadsheet Save the active window as a Microsoft Excel Worksheet. The window is saved in the Excel 7.0 (.xls) format.

File::Save Window::Save as Text Save the active window as a text file. The available formats are MS Word 2003 and ASCII Text.

Help Menu

The help menu lets you reach the LDW help system. The options are:

Help::About The Help::About option displays the Logical Decisions "about box."

Help::Contents Opens the LDW help system and displays its table of contents.

Help::Enter Key Lets you enter a new software license key.

Help::Index Opens the LDW help system and displays its index screen. You can get help on many different aspects of LDW starting from that screen.

Hierarchy Menu

The hierarchy menu has options related to the Goals Hierarchy view. It only appears when a Goals Hierarchy view is the active window.

Hierarchy::Collapse Hide any objects beneath the active goal or measure in the hierarchy. Changes to “Expand” if the active member is already collapsed.

Hierarchy::Demote to measure Demote the active goal to a measure and demote any measures underneath it to measure categories. Any sub-goals are deleted, but the measures under them are also demoted to measure categories. Any categories under demoted measures are deleted.

Hierarchy::Description::Global Weights Display the weight of each object as a fraction of the total overall weight of 1.0 under its name.

Hierarchy::Description::ID Number Display the ID number of each object under its name.

Hierarchy::Description::Local Weights Display the weight of each object in the utility function (MUF) it belongs to under its name.

Hierarchy::Description::No Description Don’t display anything under each object’s name.

Hierarchy::Description::Type of Object Display the type of each object in the hierarchy under its name.

Hierarchy::Description::Units Display the scale units for each object in the hierarchy under its name.

Hierarchy::Expand Display the objects directly beneath the active goal or measure in the hierarchy. Changes to “Collapse” if the active item is already expanded.

Hierarchy::Horizontal Display Redraw the goals hierarchy with a horizontal orientation, where the Overall goal is centered at the top of the hierarchy and the goals and measures are arranged in layers below it.

Hierarchy::Show Assessment Status Color the hierarchy based on whether preferences have been assessed for each object in the hierarchy. Measures and goals that have not been assessed will be colored red. Measures and goals that have been assessed will be colored blue. Goals that don't have their own MUF will be colored gray.

Hierarchy::Show Shadows Redraw the goals hierarchy with black shadow boxes behind each object in the hierarchy. This is a toggle. Selecting the option again will cause the shadows to disappear. Showing the shadows is the default.

Hierarchy::Vertical Display Redraw the goals hierarchy with a vertical orientation, where the Overall goal is at the upper left of the picture and the goals and measures are arranged in columns to the right of it. Vertical Display is the default.

Main Menu

The Main Menu for Logical Decisions appears when you start the program. It has these options:

- **File** -- load and save LDW and other files, and print the active window.
- **Edit** -- add, delete or modify selected objects.
- **View** -- create windows where you can structure the goals, measures, alternatives, and measure levels in your analysis.
- **AHP** -- options related to the Analytic Hierarchy Process. Only appears when an AHP assessment is in progress.

- **Hierarchy** -- options related to the goals hierarchy view. Only appears when a goals hierarchy view is the active window.

- **Matrix** -- options related to the matrix view. Only appears when a matrix view is the active window.

- **SUF** -- options related to SUF assessment. Only appears when a SUF assessment is in progress.

- **Tradeoff** -- options related to tradeoff assessment. Only appears when a tradeoff assessment is in progress.

- **Assess** -- structure and do the preference assessments needed to rank your alternatives.

- **Review** -- review the results of the preference assessments.

- **Results** -- rank the alternatives, graph alternatives, do sensitivity analysis and generate other results displays.

- **Help** -- options related to the Logical Decisions help system.

- **Preferences** -- change the names and appearance of selected objects.

- **Window** -- select or rearrange the child windows in the LDW main window.

Matrix Menu

The matrix menu appears when a Matrix view is the active window. It has the following options:

Matrix::Define Probability/Comments Define a probabilistic level for the currently selected cell. When you select this option, Logical Deciisons will display a dialog box that will let you define the probability distribution in several different ways or enter comments.

Matrix::Show Data Entry Status Color the matrix cells according to whether the data in them has been updated. Cell text is red for cells where data hasn't been updated and blue for cells where is has. This is a toggle option. Selecting it again will hide the status colors.

Matrix::Show Measure Categories View the matrix columns for the categories associated with the active measure. This option is only available if the active measure has at least one category. This is a toggle option. Selecting it again will hide the category columns.

Preferences Menu

The Preferences menu lets you change the appearance of selected graphics objects and windows and lets you change the names of various objects in an analysis.

Preferences::Color Preferences Change the colors of various objects in the active window type. When you select the option, Logical Decisions displays a dialog box where you can change the colors of various objects in the active window.

Preferences::Load Preferences Load a file with the preferences that you have previously saved with the Preferences::Save Preferences option.

Preferences::Name Preferences Change the names of various objects in an LDW analysis. When you select the option, LDW displays a dialog box with the current names of various LDW objects.

Preferences::Save Preferences Save a file with the current preferences.

Preferences::Simulation Preferences Set the parameters that control the Monte Carlo simulations. These simulations provide estimates of how uncertainties in measure levels affect the utilities for the alternatives. The parameters you can set with this option are the number of simulation trials and the seed that controls the random numbers that will be selected.

Preferences::Sort Tell LDW how to sort the objects in the active window.

Preferences::Utility Preferences Set the parameters that determine the range for the overall scoring units of utility. With this option you can set the least preferred and most preferred levels for utility and also how many decimal places are displayed when utility numbers are shown.

Results Menu

The Results Menu lets you see the analysis results.

Results::Compare Alternatives Display a table or graph showing the reasons for the difference in overall utility for two alternatives.

Results::Cutoff Summary Display a table showing which alternatives failed one or more cutoffs. The table lists only those alternatives that fail at least one cutoff.

Results::Dynamic Sensitivity See the effect of interactive changes in weights on the alternatives ranking. When you select this option, LDW will display a bar graph showing the overall ranking of the alternatives. Below that in a separate window, LDW displays a bar graph of the weights for the measures and goals. You can use your mouse to change one or more weights and can instantly see the effect of this on the alternatives' overall utilities.

Results::Efficient Frontier Display a cumulative graph showing the alternatives in order of benefit cost ratio.

Results::Graph an Alternative Display a bar graph or petal diagram showing the performance of a single alternative by measures or goals. When you select this option, Logical Decisions displays a dialog box giving you options to customize the alternative graph.

Results::Measure Equivalents Ranking Display an overall ranking of the alternatives along with the levels on a particular measure that would result in the same overall utilities *if all other measures had their most preferred levels*.

Results::Preference Set Summary Display a matrix with the ranking of each alternative on a selected goal or measure for each preference set. This option is discussed in more detail on page 8-.

Results::Rank Alternatives Display a ranking of the alternatives on any goal or measure.

Results::Ranking Results Graph Display a graph showing the performance of the alternatives on selected goals and measures.

Results::Ranking Results Matrix Display a matrix with the utility for each alternative on each goal and measure

Results::Scatter Diagrams Display a graph showing the alternative's performance on two measures or goals.

Results::Sensitivity Graph Display a sensitivity graph that shows the effects on the overall ranking of changing a measure or goal's weight.

Results::Sensitivity Table See the effect of changing the weight of a measure or goal.

Results::Uncertainty Summary Display a table summarizing the uncertainty in the alternatives for a measure or goal. The table has a line for each alternative and provides statistics such as the mean and standard deviation for the probability distribution for the alternative's utility or level for the selected measure or goal.

Review Menu

The review menu lets you generate displays that help you review the results of your preference assessments.

Review::Assessment Summary Display a summary of the preference assessments done for the active preference set. The information displayed varies depending on the assessment methods used.

Review::Comments Summary Display a listing of the comments for all the objects in the analysis.

Review::Common Units Display a graph of a measure's single measure utility function (SUF).

Review::Compute Utilities Compute the utility of a particular levels on a measure. You can also use this option to compute the level on a measure that would result in particular utilities.

Review::Graph Pairs of Measures Display a graph showing sets of equally preferred levels on two measures.

Review::Single Tradeoffs Display a graph of a tradeoff between two measures or goals.

Review::Tradeoff Summary Graph Display a "bubble diagram" showing the results of the tradeoffs assessed so far,.

Review::Tradeoffs by One Measure Have LDW compute and display a set of tradeoffs that compare each measure to a single selected measure. See page 8- for more details on this option.

Review::Weights::Graph Weights Display a bar graph of the weights for the measures and goals.

Review::Weights::Percentage Weights Display the measure's weights as percentages. The table shows two different types of weights – 1) the percentage weights for the measures based on their nominal ranges as defined in the measures' properties dialog boxes and 2) adjusted weights that would result if the nominal ranges equaled the actual ranges for the alternatives.

Review::Weights::MUF Formulas Display the MUF formulas for the goals. When you select this option, LDW displays a table for each goal showing the scaling constants for the scaling constants its active members. The table for each goal also shows its big **K** and the methods used for assessing weights and interactions.

Review::Weights::SUF Formulas Display the formulas used to convert the measure levels to common units.

SUF Menu

LDW displays the SUF Assessment Options Menu when you are using the SUF method in the Assess::Common Units option. It provides options that let you shape the SUF curve for the active measure.

SUF::Assess Utility Assess the active point's utility by asking an assessment question based on a lottery (uncertain outcome).

SUF::Assess Value Assess the active point's utility by asking an assessment question based on the mid-level splitting method.

SUF::Cancel Duplicates the "Cancel" button in the SUF assessment window.

SUF::Delete Split Point Delete the active split point. A split point separates two sub-ranges of the active measure's SUF. When you select the option, LDW combines the two sub-ranges. LDW uses the split point as the mid-preference point of the combined sub-range.

SUF::Done Duplicates the "Done" button in the SUF assessment window.

SUF::Reset Range Restore the curve for a sub-range to a straight line.

SUF::Split Range Split the active sub-range for the active measure's SUF into two parts. The mid-preference point for the old sub-range is the point that separates the two new sub-ranges.

Tradeoff Menu

Logical Decisions displays the Tradeoff Menu when you are using the tradeoff method in the Assess::Weights option. It provides options that let you revise the current tradeoff question.

Tradeoff::Allow Free Float Lets you move the two simplified alternatives in a tradeoff assessment graph freely around the edges and interior of the graph.

Tradeoff::Cancel Duplicates the "Cancel" button in the tradeoff assessment window.

Tradeoff::Directly Enter Tradeoff Lets you directly enter the equally preferred levels for the current tradeoff.

Tradeoff::Equal Duplicates the "Equal" button in the tradeoff assessment window.

Tradeoff::Revise Range Lets you enter revised ranges for the two members in the current tradeoff. These ranges will define the axes in the tradeoff question graph.

Tradeoff::Use Alternatives to Set Range Lets you ask LDW to automatically revise the range for the current tradeoff question.

The alternative that has the most preferred level on one of the tradeoff's members may not have the least preferred level on the other member. Thus, you may not have to give up one member's entire range to achieve the other's most preferred level. This option has LDW recompute the ranges for the tradeoff members by setting the least each member's least preferred level to that member's most preferred level for an alternative that achieves the other member's most preferred level.

View Menu

The view menu lets you create windows where you can structure your analysis.

View::Brainstorming Create a new brainstorming window, where you can quickly add, delete and arrange goals, measures, measure categories and alternatives.

View::Goals Hierarchy Create a new goals hierarchy window that shows the relationships between the goals and measures in your analysis.

View::Matrix Create a new matrix view where you can review the alternatives, measures and their associated levels in a spreadsheet. The possibilities available with this option are discussed starting on page 5-.

View::Select/Change Preference Sets View the preference set selection dialog box.

View::Summary View the summary dialog box.

View::Update Active Window Redisplay the dialog box for the active window.

Window Menu

The Window menu is a standard menu that controls the child windows created in the LDW main window.

Window::Close All Closes all of the child windows in the LDW main window.

Window::Zoom Lets you resize the picture in the active child window. When you select this option, LDW asks you to enter a zoom amount as a percentage of the picture's original size.

Window::Zoom In Increase the size the picture in the **active** child window by 20 percent.

SECTION

Glossary

12

Glossary

The references at the end of each term refer to commands defined in the Commands Summary section (<u>underlined</u>) and to other terms in this Glossary (not underlined)

Active Member

A goal's active members are the goals or measures that are included in its MUF. The active members can be the members directly below the goal in the goals hierarchy or members of a lower level goal that does not have its own MUF.
See also: Goal, Goals Hierarchy, Measure, Member, MUF.

Alternative

Alternatives are the choices to be ranked by the analysis. There is no limit on how many alternatives you can define, provided sufficient memory is available. Alternatives consist of a name and a level for each measure. Levels may be point estimates (single numbers), text labels or probabilistic.
See also: Level, Measure, Point Estimate, Probabilistic Level.

Analytic Hierarchy Process

A process for computing the relative importances of a set of alternatives or goal members. The decision maker is asked to provide the ratios of the performances (or importances) of all the possible pairs of objects in the set. A method based on linear algebra is used to compute the relative utilities or weights for the objects in the set.
See also: Alternative, Measure, Utility, Weight.

Big K

One of the scaling constants in a MUF formula. Big **K** defines the degree of interaction between the members of a goal. When big **K** equals 0.0, an additive MUF formula is used and big **K** does not appear in the formula. The small **k**s must sum to 1.0 when big **K** is 0.0. If big **K** is greater than 0.0, the active members of the goal interact destructively, so that a low utility for one member can result in a low utility for the goal. When big **K** is greater than 0.0 the members of the goal interact constructively, so that the sum of the small **k**s is

less than 1.0. If big **K** is less than 0.0 a high utility for one member can result in a high utility for the goal. In this case, the small **k**s sum to more than 1.0.
See also: Constructive Interaction, Destructive Interaction, Goal, Member, MUF, MUF Formula, Small **k**, Utility.

Common Units

See Utility.

Certainty Equivalent

The certainty equivalent of a probabilistic level of a measure for an alternative is the level for that measure that is *equally preferred to* the uncertain outcome defined by the probability distribution.
LDW computes the certainty equivalent by finding the expected utility (defined by summing (integrating) prob(x)U(x) for all levels x whose probability is greater than 0) for the probability distribution. The certainty equivalent is the level y such that U(y) equals the expected utility for the probability distribution.
See also: Alternative, Level, Measure, Probabilistic Level, Utility.

Constructive Interaction

A type of interaction between a goal's active members where a high utility for one member leads to a high overall utility for the goal. Constructive interaction is modeled by a multiplicative MUF formula where the sum of the weights (small **k**s) is more than 1.0, and the interaction scaling constant big **K** is less than 0.0.
See also: Big **K**, Destructive Interaction, Goal, Member, MUF, MUF Formula, Small **k**, utility, Weight.

Default

A default is a value for a variable assigned by LDW in the absence of a specification from the user. Defaults include

- Measure Levels for Alternatives -- set to the most preferred level for the measure.

• SUF curves -- set to straight lines over the measure's entire range.

• Level types -- assumed to be point estimates rather than probabilistic

• MUF scaling constants -- assumed that all active members of a goal have equal weights (equal small **k**s in an additive MUF)

See also: Initialize.

Destructive Interaction

A type of interaction between a goal's active members where a low utility for one member leads to a low overall utility for the goal. Destructive interaction is modeled by a multiplicative MUF formula where the sum of the weights (small **k**s) is less than 1.0 and the interaction scaling constant big **K** is greater than 0.0.
See also: Big **K**, Goal, Member, MUF, MUF Formula, Small **k**, Utility, Weight.

Efficient Frontier

A cumulative graph showing the alternatives ordered by decreasing benefit/cost ratio. In the absence of other constraints, the efficient frontier shows the order in which you would select multiple alternatives if you wanted to maximize their benefits subject to a budget constraint.

Goal

A set of measures (and possibly other goals) treated as a unit for ranking purposes. The goals form a hierarchy ranging from most to least general. Each analysis is required to have at least one goal, called Overall. If no other goals have been defined, all of the measures are members of the Overall goal. A measure or goal can be a member of only one goal.
See also: Measure, Member.

Goals Hierarchy

An representation like an organization chart of a set of goals and measures that organizes them from most to least general. Goals and measures can be members of another higher (or more general goal) and in turn goals can have members which are lower (more specific) goals or ranking measures.
See also: Goal, Measure, Member.

Initialize

When a variable is initialized it is returned to its default value. When SUFs are initialized, they become straight lines. When tradeoffs are initialized, they are simply deleted.
See also: Default.

Label

A label is a type of measure level that is a text string rather than a number. Measures must use either text labels or numbers, and the two types can't be mixed in a single measure. You specify if text labels are to be used in a measure's dialog box. Each alternative is assigned one of a limited number of possible text labels for each measure that uses labels.
See also: Level, Measure.

LDW File

LDW files are used to save the information from a LDW session. LDW files contain the following information:

- Measure definitions,
- Alternative data, including the levels of the measures and probability distributions,
- Goal data, and
- Preference Set data including SUFs, MUF type and tradeoffs for each set.

See also: Alternative, Goal, Level, Measure, MUF, Preference Set, SUF, Tradeoff.

Level

An alternative's level on a measure is the number on the measure's scale (having the proper units) that indicates

how the alternative performs on that measure. Levels can also be probabilistic, so that the level is defined by a probability distribution instead of a single number. Levels can be text labels, where each alternative is assigned one of a limited number of text descriptors. Levels can also be defined as the weighted sum of a group of measure categories. Levels should not have a value or preference content. Levels are just data. The preference information is added when the levels are converted to utility.
See also: Alternative, Label, Measure, Measure Category, Probabilistic Levels, Utility.

Lottery

A lottery is a standardized gamble used when assessing utilities. A lottery generally has two possible outcomes, each with a well defined probability. Lotteries are often compared to a level that occurs with certainty.
See also: Assess Utility option, Certainty Equivalent, Level, Utility.

Measure

Evaluation measures are the variables that are used to rank the alternatives. The decision analysis literature uses many aliases for measures, including "attributes", "criteria", and "scales".

A measure consists of a name, units and most and least preferred levels. LDW puts no restrictions on the most and least preferred levels. The most preferred level can be greater or less than the least preferred level. There is also no requirement that the ranges on different measures be comparable. The ranges are made comparable when levels on the measures are converted to utility using the SUF for each measure.
See also: Alternative, Level, Range, SUF, Utility.

Measure Category

A sub-measure associated with a measure. You can define measures so that their levels are the weighted sum of several measure category levels. Measure category levels are not converted to common units before they are summed, but otherwise they are exactly like measure levels.
See also: Common Units, Level, Measure, Measure Level.

Member

A member of a goal is either a measure or another goal that is included under the first goal in a goals hierarchy. Note: At least one of the goals in an analysis must only have measures as members.
See also: Goal, Goals Hierarchy, Measure, MUF, Preference Set, Utility.

Monte Carlo Simulation

A method for estimating the uncertainty of a number that is a complex function of one or more probability distributions. It can be very difficult to compute analytically a probability distribution that is the result of combining other distributions. This is the case for estimating a probability distribution over utility from the probability distributions over measure levels, particularly when complex SUFs and MUFs are involved. Monte Carlo simulation avoids this problem by using random numbers to provide an estimate of the distribution. Monte Carlo simulation uses a random number generator to produce random samples from the probabilistic levels. each set of samples is used to compute the utility of one possible outcome of the measure level uncertainties. Each computed utility is called a trial. Many trials are done and the results for each trial are saved. The sorted trials can be used as an estimate of the cumulative probability distribution of the desired utility.
See also: Alternative Uncertainty Graph option, Level,

Measure, MUF, Probabilistic Level, Sample, Simulation Options option, SUF, Trial, Uncertainty Summary option, Utility.

MUF

A Multi-measure Utility Function (MUF) is the formula that combines the utilities for the individual measures computed by the SUFs into the utility for a goal.

A MUF consists of two parts: a SUF for each measure and a set of scaling constants (called small **k**s) that determine the relative importance of the measures. (For goals with other goals as members, MUFs for the member goals may replace SUFs. The scaling constants are similar in both cases.)

LDW uses two types of MUF Formulas to combine the measures -- an additive form where the small **k**s can be interpreted as weights and a multiplicative formula that includes an additional scaling constant called big **K**. Big **K** can be interpreted as the degree of interaction between the measures.
See also: Alternative, Big **K**, Define Interactions option, Measure, MUF Formula, Small **k**, SUF, Tradeoff, Utility, Weight.

MUF Formula

LDW uses two formulas for MUFs. The additive formula is:

$U_g(X) = k_1U_1(X) + k_2U_2(X) + ... + k_nU_n(X)$, where

$U_g(X)$= is the utility of alternative X for the goal g,
$U_i(X)$= the utility of alternative X for the ith member of g, and
k_i= the scaling constant small **k** for the ith member of g.

The additive formula requires that the small **k**s sum to

1.0 and that big **K** = 0.0. The additive formula is used as the default formula, when the Additive MUF option is selected and when big **K** is computed to equal 0.0.

The second MUF formula is the multiplicative formula:

$U_g(X) = ((1 + Kk_1U_1(X))(1 + Kk_2U_2(X))...(1 + Kk_nU_n(X)) - 1)/K$, where

$U_g(X)$ = the utility of alternative X for goal g,
K= the scaling constant big **K** for g,
k_i= the scaling constant small **k** for member i of g, and
$U_i(X)$= the utility of alternative X for member i

The multiplicative MUF formula is used when a non-additive option is selected in Define Interactions. The formula has three interesting limits -- If big **K** equals 0.0, the formula reduces to the additive formula. If big **K** equals -1.0, the formula reduces to

$$U_g(X) = (1 - U_1(X))(1 - U_2(X))...(1 - U_n(X)) + 1,$$

which equals 1.0 if $U_i(X) = 1.0$ for any i. As big **K** gets very large, the formula becomes

$$U_g(X) = U_1(X)U_2(X)...U_n(X),$$

which equals 0.0 if $U_i(X)$ equals 0.0 for any i. Intermediate values of big **K** have intermediate degrees of interaction. Big **K**s less than 0.0 mean that a high utility on an individual member can result in a high overall utility (constructive interaction), while big **K** greater than 0.0 indicates that a low utility on an individual member can result in a low overall utility (destructive interaction).
See also: Additive MUF, Alternative, Big **K**, Define

<u>Interactions</u>, Goal, Member, MUF, Small **k**, Utility.

Nominal Utility

A nominal utility is assigned to all members of a goal when the utility is not directly specified. The nominal utility is assigned when the goal is defined and is generally set to 1.0, so that all members of the goal are assumed to have their most preferred levels if their level is not directly specified. This situation occurs while assessing tradeoffs, when a single measure is used to represent a goal in a tradeoff. When the tradeoff questions are displayed, the decision maker is asked to assume that the representative measure has a certain utility and that all other members of the goal have the nominal utility.
See also: Goal, Measure, Member, Tradeoff, Utility.

Point Estimate

A point estimate for a measure level is a single number that will be the measure's level with certainty. This is in contrast to a probabilistic level, where a measure's level is not known with certainty and must be described with a probability distribution.
See also: Level, Measure, Probabilistic Level.

Preference Set

A Preference Set is a set of SUFs and tradeoffs for the measures and goals defined in the current analysis. A preference set includes a name, a set of category multipliers if needed, a SUF for each measure, and a set of weight assessment data that will allow a MUF for each goal to be computed.
See also: Goal, Measure, MUF, SUF.

Probabilistic Level

A probabilistic level is a probability distribution that describes the level on a measure for an alternative when that level is not known with certainty. This is in contrast to a point estimate, where a measure's level is known with certainty and can be described with a single number or text label.

See also: Label, Level, Measure, Point Estimate.

Range

The range of a measure is determined by the most preferred and least preferred levels of the measure as defined in the measure's dialog box.

A measure is said to be *Increasing* if the most preferred level is greater than the least preferred level. Otherwise it is said to be *Decreasing*. The least preferred level always has a utility of 0.0 on the measure's SUF, while the most preferred level has a utility of 1.0.
See also: Level, Measure, SUF, Utility.

Risk Aversion

The **local risk aversion** (r) is defined as the ratio r = -u''(x)/u'(x), where u'(x) is the first derivative and u''(x) is the second derivative of the utility function. In the case of the exponential utility functions used in LDW this complicated function has a simple result. It is equal to the constant c in the exponential formula $u(x) = a + be^{-cx}$. If r is positive you are locally risk-averse (for measures where higher levels are preferred). If r is negative, you are locally risk-seeking. Both of these parameters are displayed when you do an assessment in LDW with the SUF::Assess Utility option.
See also: Assess Utility option, SUF, Utility.

Risk Premium

The **risk premium** indicates how much you would pay to avoid the uncertainty in a lottery. It is the difference in the expected value of the lottery **B** and the certain level L. If the risk premium is positive and higher levels of the measure are preferred, then you would be willing to accept less of the measure (in terms of expected value) in order to avoid uncertainty. This type of preference is called **risk-averse**. The converse is when the risk premium is negative and you would have to have a higher expected value in the certain

alternative before it is equally preferred to the lottery. This type of preference is called **risk-seeking**.
See also: Level, Lottery, Measure.

Sample

A sample is a single number selected from a probability distribution on the basis of a random number. The random number is used as input to an inverse probability distribution that tells the level associated with a given number between 0 and 1.
See also: Level, Monte Carlo Simulation, Trial.

Small k

Small **k** is the name for the weight (or scaling constant) associated with the SUF for a member of a goal in the goal's MUF Formula. When the MUF for the goal has an additive MUF formula, the small **k**s can be interpreted as weights. When a multiplicative MUF formula is used, the small **k**s do not sum to 1.0 and the interpretation as weights becomes less useful.
See also: Goal, Member, MUF, MUF Formula, SUF, Weight.

SUF

A Single-measure Utility Function (SUF) is a mathematical function that converts an alternative's level for a measure into utility. LDW uses two types of SUF Formulas, linear and exponential. Linear SUFs are straight lines and exponential SUFs are smooth curves.

SUFs can consist of up to 10 sub-ranges, each of which can have a linear or exponential SUF formula. Exponential sub-ranges can be either concave or convex. Each sub-range is defined by minimum, maximum and mid-preference pairs of levels and utilities. The mid-preference pair is the level that gets a utility equal to the average of the minimum and maximum utilities for the sub-range.
See also: Level, Measure, SUF Formula, Range, Utility.

SUF Formula

LDW uses two formulas for SUFs -- the linear formula and the exponential formula. Either of these formulas can be used for any sub-range for the measure, and they may be intermixed freely. The program decides which formula to use based on your input in the Assess SUFs option.

The linear SUF formula is just the formula that gives a straight line from the utility of the least preferred level of the sub-range to the utility of the most preferred level of the sub-range. The formula for a linear SUF is:

$$U(X) = a + bX,$$

where a and b are computed scaling constants and X is a level for the measure.

The exponential SUF formula is used to fit a smooth curve to three points -- the least preferred level of the sub-range, the most preferred level of the sub-range and the mid-preference level of the sub range. The formula is

$$U(X) = a + (be^{(-cX)}),$$

where a, b, and c are computed scaling constants and e is the mathematical constant 2.718...

See also: Assess SUFs option, Level, Measure, SUF, Utility.

Tradeoff

A tradeoff is a pair of equally preferred hypothetical alternatives that differ on only two measures. Alternative B has a more preferred level on measure 1 and a less preferred level on measure 2 while

alternative A has a less preferred level on measure 1 and a more preferred level for measure 2. The levels of the measures are set so that a change in measure 1 just compensates for a corresponding change in measure 2. Equally preferred alternatives should have equal overall utilities, and since alternatives A and B differ only in measures 1 and 2, these compensating changes can be used to compute the relative weights for measures 1 and 2.
See also: Alternative, Level, Measure, Utility, Weight.

Trial

A trial is a single iteration in a Monte Carlo simulation. In LDW a trial results in the evaluation of the utility of an alternative based on a possible resolution of its uncertainties. In the trial, each probabilistic level is replaced by a deterministic sample from its probability distribution. The samples are generated using a random number generator and the inverse probability distribution for the probabilistic level. Once all the probabilistic levels have been replaced, LDW computes and saves the requested utility. After many trials have been computed, the cumulative probability distribution on the alternative's utility can be estimated.
See also: Alternative, Monte Carlo Simulation, Probabilistic Level, Sample, Utility.

Utility

Utility is a standardized measure of the relative desirability of a given level or set of levels for an alternative. Utilities are the output of a Multi-measure Utility Function (MUF) or Single-measure Utility Function (SUF). They are used to convert the levels for measures, which are based on scales with potentially very different units, into a comparable scale with a range defined to go from 0.0 to 1.0. Utility functions generally assign a utility of 0.0 to the least preferred

level for a measure, and assign 1.0 to the most preferable level for a measure. Alternatives with utilities closer to 1.0 are preferred.
See also: Alternative, Level, Measure, MUF, SUF.

Weight

Weights are a casual term for the scaling constants (small **k**s) associated with the members of a goal in the MUF for a goal. Weights have no intrinsic importance, but do provide an *indication* of the relative importance of the measures given the ranges found for a set of alternatives.

The weights in a MUF are determined by the tradeoffs that define the MUF. The tradeoffs define a unique set of weights that will allow all of the equally preferred alternatives in the tradeoffs to get the same overall utility.

See also: Alternative, Goal, Measure, MUF, Range, Small **k**, Tradeoff, Utility.

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Bibliography

B

Bibliography

This brief bibliography provides an introduction to the literature of decision analysis. The methods described in these books are the basis of the algorithms used in Logical Decision. The underlying assumptions, mathematics and philosophy of the approach are discussed in much more detail than is possible in this manual. These books also contain detailed bibliographies that can guide you to the other information sources available. A more extensive bibliography is available on the Logical Decisions web site at www.logicaldecisions.com.

Bell, D., Raiffa, H, and Tversky, A. (1988) *Decision Making: Descriptive, normative, and Prescriptive Interactions.* Cambridge University Press.

A collection of papers that discuss the differences between the the use of decision analysis to describe how people make decisions, how people *should* make decisions and how people can be helped in making decisions.

Chelst, Kenneth and Yavuz Burak Canbolat (2011) *Value-Added Decision Making for Managers*. Chapman and Hall/CRC.

A new textbook introducing multi-objective decision analysis and which has exercises that use Logical Decisions.

Clemen, Robert T. (1990) *Making Hard Decisions: An Introduction to Decision Analysis*. PWS-Kent Publishing Company, Boston.

An excellent introductory textbook in decision analysis.

Keeney, R. L. (1996) *Value-Focused Thinking: A Path to Creative Decisionmaking*. Harvard University Press.

A more accessible and personal discussion of the principles of multi-objective decision analysis first written about in Decisions with Multiple Objectives. Introduces the concept of value focused thinking, which emphasizes developing a global set of values and then looking for creative decision opportunities to advance those goals.

Keeney, R. L. and Raiffa, H. (1976) *Decisions with Multiple Objectives: Preferences and Value Tradeoffs.* John Wiley.

The classic reference on multiple measure utility theory. Required reading for those with a strong mathematical background. Others will find it tough going but may still find some interesting information.

Kirkwood, C. (1997) *Strategic Decision Making: Multiobjective Decision Analysis With Spreadsheets.* Duxbury Press

An introduction to multi-measure decision analysis with good sections on problem structuring. The quantitative sections provide examples using spreadsheets.

Raiffa, H. (1968) *Decision Analysis.* Addison Wesley.

One of the first books to define the field of decision analysis as such. Concentrates on single measure problems. This would be useful for an in depth understanding of SUFs and how to assess them.

Saaty, T. (2008) *Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World.* McGraw-Hill.

A description of the Analytic Hierarchy Process by its creator.

Von Neumann, J. and Morgenstern, O. (1947) *Theory of Games and Economic Behavior.* 2nd edition. Princeton University Press.

The first attempt at a formal approach to decision making and to quantifying preferences. Primarily of historical interest now.

Watson, S., and Buede, D. (1987) *Decision Synthesis:The Principles and Practice of Decision Analysis.* Cambridge University Press.

An overview of decision analysis with emphasis on its practical application. Includes the first discussion of the balance beam method.

Appendix

A

Appendix

This appendix describes the mathematics of computing the relative weights of two measures based on a tradeoff between them. The process is illustrated with a simple example.

Computing Weights from a Tradeoff

The overall utility of any alternative X is assumed to be the weighted average of its SUF utilities as follows:

$$U(X) = k_1U_1(X) + k_2U_2(X) + ... + k_nU_n(X),$$

where $U(X)$ = the overall utility for alternative X
k_i = the weight for measure i; also called the scaling constant **small k** for measure i.

$U_i(X)$ = the SUF utility on measure i for alternative X.

Call the two alternatives in the tradeoff A and B and suppose they differ only in measures 1 and 2. Then the overall utility for the alternatives is

$$U(A) = k_1U_1(a_1) + k_2U_2(a_2) + ... + k_nU_n(a_n),$$
$$U(B) = k_1U_1(b_1) + k_2U_2(b_2) + ... + k_nU_n(b_n).$$

Since the alternatives in the tradeoff are equally preferred, they must have equal overall utilities. This means

$$U(A) = U(B)$$

so that

$$k_1U_1(a_1) + k_2U_2(a_2) + ... + k_nU_n(a_n)) =$$
$$k_1U_1(b_1) + k_2U_2(b_2) + ... + k_nU_n(b_n).$$

but, since alternatives A and B only differ on measures 1 and 2, we have

$$U_i(a_i) = U_i(b_i)$$

for all measures i except 1 and 2. Thus all of these terms cancel out of the equation above leaving us with

$$k_1U_1(a_1) + k_2U_2(a_2) = k_1U_1(b_1) + k_2U_2(b_2).$$

since we are looking for the weights k_1 and k_2, we can rearrange this to give k_2 in terms of k_1:

$$k_2(U_2(a_2) - U_2(b_2)) = k_1(U_1(b_1) - U_1(a_1))$$

so that

$$k_2/k_1 = (U_1(b_1) - U_1(a_1))/(U_2(a_2) - U_2(b_2)).$$

If we know the individual SUFs, we can compute all of the terms in the right hand side of the equation and thus we can find the ratio of the weights for measures 1 and 2. If we establish a tradeoff involving each of the measures and add the restriction that the weights must sum to 1 we can solve for the exact values of all the weights and thus completely define an additive MUF.

Example of Weight Computation

Suppose we have two trucks, A and B that are identical except for their price and horsepower. A costs $10,000 and has 120 hp and B costs $12,000 and has 150 hp. Suppose also that we know that A and B are equally preferred and that the SUFs for cost and horsepower are known to give following SUF utilities:

$$U_{cost}(\$10{,}000) = 0.5$$
$$U_{cost}(\$12{,}000) = 0.4$$

$$U_{hp}(120) = 0.2$$
$$U_{hp}(160) = 1.0.$$

This means that a change in the utility of cost of 0.5 - 0.4 = 0.1 is just compensated for by a change in the utility of horsepower of 1.0 - 0.2 = 0.8. Thus the ratio of the weights for cost and horsepower must be

$$\begin{aligned} k_{hp}/k_{cost} &= (U_{cost}(b_{cost}) - U_{cost}(a_{cost}))/(U_{hp}(a_{hp}) - U_{hp}(b_{hp})) \\ &= (0.4 - 0.5)/(0.2 - 1.0) \\ &= (-0.1)/(-0.8) \\ &= .125 \end{aligned}$$

Thus the weight for cost is eight times the weight for horsepower, given the ranges and preferences of the example. If these were the only measures in the example, their weights would have to sum to 1. This would mean that $k_{cost} = 0.8888...$ and $k_{hp} = 0.1111...$ since then we would have both $k_{hp}/k_{cost} = 0.125$ and $k_{cost} + k_{hp} = 1.0$. As a check we can confirm that U(A) = U(B):

$$\begin{aligned} U(A) &= k_{cost}U_{cost}(a_{cost}) + k_{hp}U_{hp}(a_{hp}) \\ &= .8888U_{cost}(\$10{,}000) + .1111U_{hp}(120) \\ &= .8888 \times 0.5 + .1111 \times 0.2 \\ &= .4444 + .0222 \\ &= .4666 \end{aligned}$$

$$\begin{aligned} U(B) &= k_{cost}U_{cost}(b_{cost}) + k_{hp}U_{hp}(b_{hp}) \\ &= .8888U_{cost}(\$12{,}000) + .1111U_{hp}(160) \end{aligned}$$

= .8888x0.4 + .1111x1.0
= .3555 + .1111
= .4666

Thus these weights meet our requirement that equally preferred alternative receive equal overall utilities. Note that since the SUF utilities are used in computing the weights, changes in the range or SUF for either measure are automatically compensated for when the weights are computed.

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