

Super Decisions Software Guide

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The software for the Analytic Network Process for decision making with dependence and feedback was developed by William Adams in 1999-2003.

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1 Introduction

The Super Decisions software implements the Analytic Network Process (ANP) for decision making with dependence and feedback, a mathematical theory for decision making developed by Thomas L. Saaty. It is an extension of his Analytic Hierarchy Process (AHP) for decision making which involves breaking down a problem into its decision elements, arranging them in a hierarchical structure, making judgments on the relative importance of pairs of elements and synthesizing the results. With the AHP the process is top-down. With the ANP it is recognized that there is feedback between the elements in different levels of the hierarchy and also between elements in the same level, so the decision elements are organized into networks of clusters and nodes. The ANP was briefly introduced in Saaty's first book on decision making, *The Analytic Hierarchy Process*. There is now a book on the Analytic Network Process (new edition 2001) by Saaty, *The Analytic Network Process: Decision Making with Dependence and Feedback*. It is available from RWS Publications, 4922 Ellsworth Avenue, Pittsburgh, PA 15213; Telephone: 412-414-5984; Fax: 412-681-4510.

The Super Decisions software is a simple easy-to-use package for constructing decision models with dependence and feedback and computing results using the supermatrices of the Analytic Network Process. This software was designed to run in many different computing environments from Windows 3.1/95/98/NT to Macintosh to Unix systems such as Linux, SGI's, Sun Systems, etc. There is also a Web version.

2 Building Models

Models range in complexity from a single network to two-layer networks to multi-level complex networks. Each network in a model is in a separate window. Model-building always starts with creating a simple network of clusters, elements within clusters and making links between the elements (which in turn causes a link to appear visually connecting the clusters).

2.1 Simple Networks

By a **simple network**, we mean any network composed of clusters containing elements (or nodes), the links between the nodes, the links between the clusters that result from the links between the nodes, and perhaps the assessments/comparisons. A model that is comprised of a simple network has only one window. This chapter gives the steps for creating, editing, making comparisons and calculating results in a simple network. An example of a simple network is the *Hamburger* model in the sample models.

Hint: To load a sample model go the Help command on the main menu and click the Sample Models sub-command to see a list of available sample models. Click on the one you want to load it.

A simple network contains clusters, nodes, and connections or links. When a *parent* node is linked to nodes in another cluster, these are known as its *children* nodes. The children nodes are to be compared with respect to the parent node. When a parent node is linked to children nodes in another cluster, a line or *link* appears between the clusters with an arrow on it from the cluster containing the parent node. When the parent node and children are in the same cluster there will be a self-loop on that cluster.

When the *Super Decisions* program starts a blank window appears. You can create clusters and their nodes directly in this window using the *Design* command. If you select the *File New* command, and then select *Simple Network Template*, the same thing happens with a blank window appearing where you will create a network.

A simple network can be turned into a two-layer model by right-clicking on a node in one of its clusters then selecting the Make/show subnetwork command; or, equivalently, use the Design command on the main menu. A new window will appear and you can then create clusters and nodes in it in the usual way. A three-level model can be created by selecting one of these nodes and following the same process. There is no limit to the number of levels that can be created.

2.1.1 Creating Clusters

The first step in constructing a simple network is to create at least one cluster and then to create nodes within it. Newly created clusters look like Windows. Nodes are then created within the cluster, appearing as small text boxes within the cluster.

Use the Design command on the main menu to add and remove clusters and nodes. To change the size of a cluster window click on the button on the lower right-hand corner and drag. Clusters can also appear as icons. To select the icon you want associated with the cluster, use the Design, Cluster, Edit command and select the change icon button from the cluster editing window. Or, alternately, you may right click on the cluster or left click on

the minus sign at the top left corner of the window and select Edit cluster from the drop down menu that appears to reach the cluster editing window.

To switch from a cluster window to an iconified view, double-click on the cluster window. To switch back double click on the icon.

You must create at least one cluster in each simple network with the name "alternatives" or some variation such as "1alternatives" to contain the nodes representing the alternatives of choice. The final priorities of these nodes are used in the synthesis computations. The order of clusters in the supermatrix is alphabetical. To control the order preface the cluster names with 1,2,3,... as, for example, 1Actors, 2Environmental forces, 3Economic, and so on. It is usually helpful to make the cluster of the alternatives either first or last so it is easy to find in the supermatrix. A **Selected Cluster** had its title bar slightly darker than the main background of the cluster window. To de-select all clusters click on the background of the network window.

Cluster Menus:

Design Cluster commands

New, Edit and Remove commands may be accessed from the main menu.

Other Cluster commands

Right-click on the background of a cluster window or left-click on the top left corner of a cluster window to drop down the cluster menu containing additional commands:

Edit cluster - brings up the cluster properties dialog box.

Remove cluster - deletes the cluster, connections and comparisons related to it.

Iconify/Expand cluster - a toggle that will collapse a cluster into an icon (if no icon has been chosen it will collapse to its name only) or, alternately, expand from an icon or name box into the full cluster view showing the nodes in the cluster.

Cluster comparisons - starts the process of cluster comparisons from the currently selected cluster with it as parent, and clusters it is connected to as children.

Create node in cluster - brings up a new node dialog box for creating a node. Shortcut: Pressing the *n* key with your cursor located over the background of a cluster will also bring up the new node dialog box.

Organize Nodes - allows you to organize the nodes in a cluster vertically, horizontally, or rectangularly. The organization is in alphabetical order. This command is handy for finding nodes that may have scrolled offscreen.

Creating a Cluster

You can edit clusters and nodes using your mouse or equivalent keyboard shortcut keys. Here are the different ways you can create a cluster. All of these commands will bring up the same new cluster dialog box. To change the default fonts and colors for clusters, select the File Configure command from the main menu. Pressing the <Enter> key after typing the name of a node or its description will create another cluster. Select the Cancel button when you want to stop creating clusters. See [ValCluster], page 4.

Keyboard The command is the key *N* (this must be capitalized). Press *Shift* and *n* with your mouse located where you want to create the cluster.

Mouse Press *Shift* and *Left-Mouse-Button* where you want the cluster to be created.

Menu Choose the *Design* menu. From that menu choose the *Cluster* submenu. Finally choose the *New* menu item from the *Cluster* submenu.

Editing a Cluster

There are several ways to start the editing process of a cluster. All of these commands will bring up a dialog to change that cluster's values. See [ValCluster], page 4.

Keyboard Your mouse **must** be over the cluster you are going to edit. With your mouse over that cluster, press the *Shift* key and the *e* key for a capital E to bring up the editing menu for that cluster.

Menu Command

Choose the *Design* menu. From that menu choose the *Cluster* submenu. Finally choose the *Edit* menu item from the *Cluster* submenu. It will bring up a dialog box asking you to select the cluster you want to edit.

Popup Menu Command

With your mouse on the background in the cluster you wish to edit (but not over any node in that cluster), click the right mouse button. This will bring up a popup menu. Choose the *Edit* menu item.

Removing a Cluster

There are several ways to remove a cluster from a network. All of these commands will bring up a dialog box, asking you if you really want to remove that cluster. Here are the methods one can use to remove a cluster.

Keyboard Your mouse **must** be over the cluster you wish to remove (and not over any node in that cluster). With your mouse over the background of the cluster window, press the *Shift* and *R* keys simultaneously.

Menu Command

Choose the *Design* menu. From that menu choose the *Cluster* submenu. Finally choose the *Remove* menu item from the *Cluster* submenu. It will bring up a dialog box asking for the cluster to be removed.

Popup Menu Command

With your mouse over the cluster you wish to edit (but not over any node in that cluster), click the right mouse button. This will bring up a popup menu. Choose the *Remove* menu item.

Selecting Fonts/Colors/Icons for Clusters

Whether creating or editing a cluster, the same dialog box appears for cluster settings such as the fonts, background color of cluster window, the icon to represent the cluster and so on. In this section we describe the settings that control the cluster appearance.

Name of Cluster

Enter the name of the cluster in the first field. You may enter an unlimited number of characters.

Description of Cluster

Enter a description for the cluster in the second field. You may enter an unlimited number of characters.

Selecting font for title

Select the type of font, size of font and style of font(italics, bold, etc.) for the cluster window title using the three buttons here.

Selecting font for icon

Select the type of font, size of font and style of font(italics, bold, etc.) for the cluster icon title using the three buttons here.

Changing Icon

Click the Change Icon button with your mouse and select a new icon by double clicking on the one you want from among those that appear in the Icon Chooser dialog box. You can also browse for and select fonts from a different directory than the default one. The selected new icon will appear in the Editing dialog box. Save to exit the dialog. To switch back and forth from the icon to the window double click on the icon or the background of the cluster window.

Changing Window Color

Click the Change Color button with your mouse and select a new color by double clicking on the one you want from the Color dialog box that appears. Select the OK button to effect the color change.

Saving Changes

Click the Save button to permanently change to the creating/editing selections you have made for this cluster window. If the dialog box disappears before you have had a chance to save the changes, it may have morphed into a minimized icon on the Windows menu bar at the bottom of the screen. Double-click on it to open it again and then click the Save button.

2.2 Creating Nodes within Clusters

After you create the clusters you need to create nodes in them and then connect the nodes between clusters or within a single cluster. This section explains how to add, edit, remove and connect nodes.

Creating Nodes

You can edit clusters and nodes in the Create/Edit Node dialog box using your mouse or equivalent keyboard shortcut keys. The Create Node and Edit Node dialog boxes allow one to set the node's values, such as font size and type, select a new icon, and select a color for the node name text box. Select the "Create another" button at the bottom of the dialog box to continue creating new nodes.

Keyboard Press *Alt* and *n* with your mouse located over the background of the cluster window in which you want to create the node to bring up the New Node Dialog box where node values are set.

Mouse Press *Shift* and *Left-Mouse-Button* in the cluster window where you want the node to be created. The new node will be placed where the mouse pointer was.

Menu Choose the *Design* menu. From that menu choose the *Node* submenu. Finally choose the *New* menu item and when the list of possible clusters appears select the cluster where you want the new node.

Editing Nodes

There are several ways to start the editing process of a node. All of these commands will bring up the Creating/Editing Node dialog box to change that node's values.

Keyboard Your mouse **must** be over the node you are going to edit. With your mouse over that cluster, press the *Alt* key and the *e* key to bring up the editing menu for that node.

Menu Command

Choose the *Design* menu. From that menu choose the *Node* submenu. Finally choose the *Edit* menu item from the *Node* submenu. It will bring up a dialog box asking you to select the cluster and node you want to edit.

Popup Menu Command

With your mouse on the background in the node you wish to edit, click the right mouse button. This will bring up a popup menu. Choose the *Edit node* menu item.

Removing Nodes

There are several ways to remove a node from a network. All of these commands will bring up a dialog box, asking if you really want to remove that node. Here are the methods one can use to remove a node.

Keyboard Your mouse **must** be over the node you wish to remove. With your mouse over the node, press the *Alt* key simultaneously with the *r* key and confirm that you wish to remove the node.

Menu Command

Choose the *Design* menu. From that menu choose the *Node* submenu. Finally choose the *Remove* menu item from the *Node* submenu. It will bring up a dialog box asking you to select the cluster and the node in that cluster to be removed.

Popup Menu Command

With your mouse over the node you wish to edit, click the right mouse button. This will bring up a popup menu. Choose the *Remove node* menu item.

Selecting fonts/colors/icons for Nodes

When you are creating and when you are editing a node, you use the same dialog box for setting values. In this section we describe the various inputs this dialog expects, and what they are used for.

Name of Node

Enter the name of the node in the first field. You may enter an unlimited number of characters.

Description of Node

Enter a description for the node in the second field. You may enter an unlimited number of characters. Carriage returns are not recognized.

Main Font selection

Select the type of font, size of font and style of font(italics, bold, etc.) for the node text box title using the three buttons here.

Icon Font selection

Select the type of font, size of font and style of font(italics, bold, etc.) for the node icon title using the three buttons here.

Changing Icon

Click the Change Icon button with your mouse and select a new icon by double clicking on the one you want from among those that appear in the Icon Chooser dialog box. You can also browse for and select fonts from a different directory than the default one. The selected new icon will appear in the Editing dialog box. Save to exit the dialog. To switch back and forth from the icon to the window double click on the icon or the node text box window.

Changing Node Text Box Color

Click the Change Color button with your mouse and select a new color by double clicking on the one you want from the Color dialog box that appears. Select the OK button to effect the color change.

Saving Changes

Click the Save button to permanently effect the creating/editing selections you have made for this node. If the dialog box disappears before you have a chance to save your changes, it has probably been minimized and is now located on the bottom Window Menu bar. Double-click on it to open it up again and click on the Save button.

2.3 Making Connections between Nodes

After you have created clusters and nodes in your network, they must be connected. Connections in a Super Decisions model are determined by asking, for a particular node, what other nodes need to be compared with respect to it. A comparison group is formed having that node as the parent node and the nodes to which it is linked as children. The children nodes of such a comparison group may all be in the same cluster as the parent (inner dependence) or a different cluster (outer dependence). A node may serve as a parent in more than one comparison group. Connections may only be created between nodes. Clusters become connected as a consequence of node connections.

Cluster Connections

When a parent node has children nodes in another cluster, then those two clusters are automatically connected and a line appears going *from* the parent node's cluster *to* the children nodes' cluster. When the children nodes are in the same cluster as the parent node, then that cluster becomes connected to itself. This is called inner dependence. To get a line going the opposite direction, you must connect a parent node in the second cluster to some children in the first cluster. There must be an *alternatives* cluster in every lowest level, or terminal, sub-network.

Node Connections

To form a comparison group select a node, the node that you wish to become the parent node, right click on it to drop down a menu, select the "Node connexions from" command and follow the instructions to connect to the desired children nodes in another cluster (or in the same cluster). The children nodes must be

together in the same cluster. It is not allowed for some of them to be in one cluster and some in another cluster, and still belong to the same comparison set. You may make two (or more) different comparison sets for the same parent. *Shortcut: Left-click on the parent node and right-click on each of the children nodes in turn. You may make more than one comparison set at once by left-clicking once on the parent node, then right-clicking on nodes in one cluster after another til you finish making all the connections for that parent.*

Cluster Connections

- Clusters are automatically connected when nodes within them are connected. See *Node Connections*. The cluster linking arrow goes from the cluster containing the parent node to the cluster containing the children nodes.
- If you have a cluster link going one direction from cluster A to cluster B and you wish to also have a cluster link going the other direction, select a node to become a parent node in cluster B and connect to some children nodes in cluster A.

Outer Dependence

Outer Dependence is when a cluster is connected to a cluster other than itself. Such a connection means at least one node in the first cluster is the parent for a comparison group of children nodes in the other cluster.

Inner Dependence

Inner Dependence is when a cluster is connected to itself, which occurs when the parent node and the children nodes forming a comparison group are in the same cluster.

Node Connections

Nodes may be connected in several ways:

- Use the Design/Nodes connections from command on the main menu and follow the instructions to select the parent node and its children nodes.
- Place the cursor over the node that is to be the parent node, right-click on it to get a drop-down menu of node commands and select the "Node connexions from" command. Follow the instructions to connect the current node to its children nodes.
- Turn on the "Do connexions" mode by left clicking on the menu icon with the three arrows. When this icon is depressed you can connect nodes by left-mouse click on the node that will become the parent and right-mouse clicking on the children nodes. Similarly, you can disconnect by left-clicking on the parent node and right-clicking on some previously connected children nodes.
- *Tip: Be Careful! You will lose any judgments you have entered for nodes when you disconnect them.*

You may multiple select and connect nodes as follows:

- To quickly connect all nodes in clusters: shift left-click on any node in the "from" cluster; shift right-click on any node in the "to" cluster.
- To quickly select multiple nodes in a cluster, hold down the Ctrl key and left-click on each node to be selected.

- *Tip: Do not make spurious links where you do not plan to make judgments; the implied equal judgments that will be input as a result will affect your answer in unintended ways.*

2.4 Rating networks

The *Design* command on the main menu is used to create or remove a Ratings Window attached to the current network. Networks with Ratings windows attached have the word Ratings on the title bar.

An Example

For example, a network to evaluate employees might have two nodes under which the alternatives (the people) are to be rated. They are leadership and years of experience. These categories are established for Leadership: excellent, above average, average, below average, and poor. These categories are established for Years of Experience: hi, medium, low.

The categories for Leadership are pairwise compared to establish priorities for excellent, above average, etc. Then those for Years of Experience are pairwise compared to establish priorities for hi, medium, and low. Then each person (the people are the alternatives of the decision) is rated by being assigned a category under each node, for example, the first person gets average for Leadership and hi for Years of Experience; and the second person gets excellent for Leadership and low for Years of Experience. This rating process leads to priorities for the alternatives and replaces direct pairwise comparison of the people under Leadership and Years of Experience.

A "multiply and add" process across the rows in the Ratings Window gives the total for each row. That total is the answer. It is the performance number for that alternative.

The Commands to start or open a Ratings Window

The command below will cause a Ratings window to appear that will be associated with the current network. If one has already been created it will open up. You must select the nodes from the network with respect to which the alternatives will be evaluated in the Ratings window. These are called the criteria. Next create rating categories for each of these criteria, prioritize the categories, and finally enter the alternatives. When this is finished the structure is done and you must perform the actual assessments by rating each alternative under each "criterion" node. To see the results of your work select Calculations in the Ratings window. Close the Ratings window to return to the network. To reopen it use the Design Ratings command again. The alternatives will not appear in the network. To see the results within the network for the alternatives use the Synthesize command. These priorities are passed up to the next higher network, if there is one, and processed as usual.

Design, Ratings

or

Design, Remove Ratings

Commands in the Ratings Window

The *Edit* command is used to select criteria from the model that will then appear as column headings in the Ratings window, or to add alternatives.

The *Edit, Criteria Categories* command brings up the category editor.

You may either add the ratings categories for these criteria next or you may add the alternatives. After adding the ratings criteria you must create categories for each one.

Commands to create and prioritize the Categories

Choose the *Edit, Criteria Categories* to bring up the category editor. Select a criterion to get into the Category editor where you will create the categories for that criterion and make comparisons for them. For example, you might enter Hi, Med, Low.

Tip: A shortcut to the category editor is to right-click on any criterion (or column heading) to get into the category editor for that criterion.

Select the *Comparisons* button in the Category editor to bring up the pairwise comparison mode where you will establish priorities for the categories. Go through the pairwise comparison process just as you would for any other nodes. You will be comparing Hi to Medium for preference, and entering a judgment of, for example, 5 or strong, to show that Hi is strongly preferred to Medium. After you have made the judgments you can see the resulting priorities in two ways:

1) Select the *Computations, Show New Priorities* command in the pairwise comparison mode

or

Select the *Computations, Ideal Priorities* command. The first shows the results of the pairwise comparisons normalized to one, that is the priorities add up to one. The second shows the priorities normalized by dividing each by the largest one; the largest priority becomes one. The second numbers are used for the category priorities to perform the "multiply and add" process in the Ratings Window that gives the total for each row.

Using Templates for Categories

You may save a category as a template from the Category editor after you enter the names, and, if you wish, the pairwise comparisons, too. Use the *File, Open Template* or *File, Save Template* commands from within the Category Editor to open pre-existing templates with names and comparisons of categories already in place, or to save as a template the current one. Make sure you have done the comparisons before you create the template if you wish to have them included. There are existing templates in the Samples directory, normally found in c:/Program Files/Super Decisions/samples. Category templates are named with the extension .rcp.

Entering the alternatives in the Ratings Window

Select the *Edit, Alternatives* command from the Ratings window and enter the names of the alternatives to be rated against the criteria. This will create a table with names of alternative as the row headings on the left and the names of criteria names as column headings across the top.

Usually ratings structures are created for bottom level networks. The alternatives are not entered as nodes in a cluster, but are entered into the Ratings window spreadsheet as row headings. If alternatives have been entered in a cluster in the main network, they are disregarded and replaced by the alternatives in the spreadsheet. It is best *not* to put them in the network itself.

Assessing the Alternatives in Ratings

Select the command *Assessments/Ratings* to open the Ratings Window.

Left-click on a cell in Ratings to get a list of the categories for the criterion listed at the top of the column. Left-click on the category that best represents the assessment for the alternative at the left of the row.

The score for an alternative is computed by multiplying the idealized priority of the selected category times the limiting priority for the criterion obtained in the network for each cell and summing across the row.

The Calculations command in Ratings

To show the results in ratings select the *Calculations* command on the Ratings window menu.

Priorities gives the scores normalized by dividing by the total of all the alternatives' scores.

Totals gives the scores without normalizing

Column Priorities shows the priorities of the column headings, the criteria.

Matrix Priorities shows the numbers in each cell and the column priorities. These numbers can be blocked and copied into a spreadsheet. You may first need to expand the window so that the numbers line up right.

2.5 Subnetworks

Nodes in any network may have subnetworks attached to them. Such nodes are called **control nodes** and are identified by having the word Subnet in red at the bottom of the node . A subnetwork is a simple network made up of clusters, elements, connections, and comparisons just as simple networks are. Each subnetwork is in its own separate window with the name of its control node in the network "above" on its title bar.

The window containing the top network in a Super Decisions model is titled the Super Decisions Main Window. Super Decisions models must have a main network and may have subnetworks, sub-subnetworks and sub-sub-sub... networks. There can be any number of levels of subnetworks. However, the usual model is composed of three levels:

1)The top-level or Main network contains the Benefits, Opportunities, Costs and Risks nodes (often called the BOCR nodes).

2)Attached to each of the BOCR nodes is a subnetwork containing control criteria nodes. Not every node in the subnetwork is a control criterion node - often only those that have high priorities are chosen to become control nodes.

3)The bottom level consists of subnetworks attached to these control criteria. Such bottom level networks are often referred to as *decision networks* because they must have a cluster containing nodes that are the alternatives of the decision as well as other clusters.

To Create a Subnetwork: Right-click on the node that will become the control node and select the command *Make/show subnetwork*. This will bring up a new window where you will build the subnetwork.

Hint: You may open an existing network in the new subnet window. Sometimes subnetworks have the same or very similar structures, so it may be useful to save a "template" of such a network and open it in multiple subnetworks, then make any changes that may be needed. Such a template must be a single network. Be sure to save your entire model after "opening" such a template. The original network model that served as a template will still be there unchanged.

To Show an Existing Subnetwork: To get into an existing subnetwork, right-click on its control node to get the drop-down menu and select the *Make/show subnetwork* command, or left double-click on the control node to which the subnetwork is attached (click on the name of the node, not on the word Subnet below the node name), or use the *Networks* command on the menu bar of any network window in the model and go to the subnetwork you want.

Removing Subnetworks: To remove a subnetwork, right-click on its control node to get the drop-down node menu and select the *Remove subnetwork* command. Or, alternately, select the Design menu and the Create or Remove Subnetwork command.

2.6 Basic Control Networks

A control network is any network that contains nodes with subnetworks attached to them. The top level network of a full model contains merit nodes: *Benefits*, *Opportunities*, *Costs* and *Risks*, the BOCR nodes, that have subnetworks attached to them. The networks in this level contain nodes known as controlcriteria that then have subnetworks. The criteria nodes are often general concepts such as Environmental, Social, or Political. The subnets under the control criteria are called the decision networks as they contain a cluster with the alternatives of the decision appearing as nodes in it. The networks with the control criteria in them are often hierarchical in nature with no feedback links.

In most decisions it is possible to identify the factors that offer benefits or opportunities, or have to do with costs or risks. The factors are best evaluated by grouping those that influence benefits together, and similarly grouping the others. This is done through a system of control nodes. The BOCR nodes are control nodes with networks beneath them that contain their control criteria nodes. Each of the control criteria nodes in turn have a decision subnetwork containing the alternatives of the decision.

A complete model consists of the following parts:

1. A Rating model of personal criteria to evaluate the importance of Benefits, Opportunities, Costs and Risks in this decision;
2. A main control network containing the Merit control nodes: Benefits, Opportunities, Costs and Risks, to which the importance weights from the first model are applied;
3. Subnetworks of control criteria for each of the merits;
4. The decision subnetworks that contain other factors of the problem and the alternatives. Each control criterion has a decision subnetwork.

In some complex models it becomes clear that benefits, opportunities and costs, for example, do not have equal weights in the decision. An example of this type of model is the National Missile Defense Model in the sample models. In this case it is possible to put strategic criteria in the main network to weight the BOCR. Personal criteria include things like growth, security, survival, and stability; things that have nothing to do directly with the problem itself, but that are important for determining the importance of the BOCR. To set up the Ratings spreadsheet use the Assess/Compare Ratings command.

When you start a new model with the *File, New* command you will be given a choice of starting templates.

Ratings networks Networks that have Rating modules attached are identified by the word Ratings on their title bars. The Rating module resembles a spreadsheet with alternatives

listed for the rows and selected nodes in the network listed as the columns. The alternatives must be entered in the spreadsheet by typing at this time. The alternatives are evaluated under each column node using the Rating categories for that column, for example, excellent, very good, good, etc. The Ratings module is created using the *Design, Ratings* command and may be removed using the *Design, Remove Ratings* command. It may also be accessed under the *Assess/Compare, Ratings* command.

2.7 Full Models

A full model is composed of a control network and its associated sub-networks. The *aejcar* model is an example. A simple model is a single network without a control network, such as the *Hamburger* model.

See [Section 2.6 \[Basic Control Networks\]](#), page 12. See [Section 2.1 \[Simple Networks\]](#), page 2.

2.8 Templates

Use the File New command and select one of the templates from the screen that appears to start a new model.

Open File Template

Selecting this template will open an existing model in the current window, clearing the previously loaded model if there is one.

Selecting the New Window command will open a new window. If you then use the Open File Template to open a model, you will have the previously loaded model open in one window and the newly opened model in another window.

Simple Network Template

The entire model for a simple network is contained in a single window. Thus this template simply leaves a blank window where you will make the network by using the *Design* command to create clusters and their nodes. All clusters and their nodes are in this window, so you need a cluster with the name *alternatives* for the *Synthesize* command to find results.

A hierarchy is a special kind of network with all the connections leading in one direction away from the goal cluster. For a hierarchy create a cluster for the goal node with a single goal element in it; a cluster for criteria with the criterion nodes in it; and a cluster for alternatives with alternative nodes in it. Then make the proper connections by left-clicking on each parent node and right-clicking on each of its children nodes. Do this for all nodes that have descendants. You must name the alternatives cluster with the word alternatives or some close variation of it.

Clusters are arranged alphabetically in the supermatrix, so if there are five clusters and you want the alternatives to show up at the bottom of the supermatrix, preface their cluster name with a number 5.

Small Network Template

The small template creates a model with a top-level network that has a goal in a goal cluster and the *Merits* of *Benefits*, *Opportunities*, *Costs*, and *Risks* in a cluster titled Model. We

refer to these as the *BOCR*. The second level consists of four subnetworks, one attached to each of the BOCR. These networks are started for you by having an alternative cluster already in place. You then need to complete each of them by adding the appropriate clusters, nodes and connections to create a network.

The template wizard walks you through selecting which of the BOCR you want to include (it is not necessary to include all four), and entering the names of the alternatives. It then creates three levels of networks, beginning with the BOCR control network, next the control criteria networks for each of these, and finally the bottom level “decision networks” containing a cluster with the alternatives in it.

The top-level control model will then appear. This network is actually the same as a hierarchy having a goal and the four BOCR as descendants of the goal. By default the selected merits have equal weights; i.e. if you selected all four BOCR, each has a weight of 0.25. It is possible to change the weights by going into the comparison mode from the goal and entering pairwise judgments, or setting the weights directly using the Miscellaneous, Direct Data entry command in the pairwise comparison mode. Or you may create a structure to rate the BOCR there in the network with a goal, criteria and perhaps subcriteria and create a Ratings module with the *Design Ratings* command, select the criteria as Ratings columns, enter the BOCR as alternatives, and rate them. The BOCR values from the Ratings module will override any values in the network.

The default formula used in all templates is the *additive(negative) formula*. In the Costs and Risks subnets one must ask which alternative is most costly or risky. To change to another formula go to the *Design Standard Formula* command.

Additive(negative)	Formula	$\$NormalNet(Benefits)*\$SmartAlt(Benefits) +$
		$\$NormalNet(Costs)*(-\$SmartAlt(Costs)) + \$NormalNet(Opportunities)*\$SmartAlt(Opportunities)$
		$+ \$NormalNet(Risks)*(-\$SmartAlt(Risks))$

Using a template will assure that the formula is correct for combining the results in the top-level network as they feed up from the subnets. Formulas are applied only in top-level networks. Bottom level subnets simply feed the synthesized values for the alternatives upward, and they are combined by applying a formula in the top-level network. Select the command *Design, Standard formula* to see which formula is selected with a check mark.

Full Template

Select the *File, New* command and *Full Template* to get the template that creates a full model comprised of a top network which may have Benefits, Opportunities, Costs and Risks nodes. The most general model would contain all four, but the template allows you to select which of the BOCR you want.

The selected nodes from the BOCR will have attached **control criteria subnetworks** created for them. The template walks you through entering the names of your control criteria, and produces a simple hierarchy with a goal connected to the control criteria. Control criteria are often in the form of a hierarchy. The template puts the same control criteria in each of the BOCR subnetworks; for example, Economic, Social, Political. You may add nodes (subcriteria for example), in any of the subnetworks, change the names and make judgments to prioritize the control criteria. You may modify these subnetworks at any time.

Each of the original control criteria you entered will have what is called a **decision subnetwork** attached that contains one cluster of alternatives. You are expected to add the other clusters and make the connections.

Tip: Often decision networks are similar in their clusters, connections and even judgments. You may complete the first one, including connections and the judgments where they are the same, then save it to a separate file name. You may then go into another decision network, clear it of the automatically created alternative cluster, and open the saved decision network in it using the File, Open command, then modify as necessary.

2.9 Saving Models

Saving is automatic and you can set the interval at which the automatic save occurs from every 10 seconds to every 30 minutes by selecting the *File, Configure* command and the General tab.

The normal way is to save a complete model in a file which will have a .mod extension. You may also save parts of a model:

- 1) **save the current network only;**
- 2) **save the current network and its subnetworks.**

You may also save models in a **compressed format with the extension .mod.gz**. Models saved in a compressed format take 2 or 3 seconds longer to save and to load, but may be considerably smaller, depending on what attached files are included in it that may not compress so well. Models that have been saved in compressed format are opened in the same way as regularly saved models using the *File Open* command.

Use the *File Save* command to save the currently loaded model as a file with a .mod extension.

Use the *File Save As* command to save the currently loaded model under a new name.

Use the *Advanced Save* to save the currently loaded model in a compressed format, or to save only portions of the currently loaded model. Using the Advanced Save Options you can select how much of the model you wish to save, and whether or not to compress:

Save this much:

- Whole Model
- Only this network and its subnets
- Only this network (no subnetworks of it)

Compression Options:

- No compression
 - Compress this model only
 - Compress models from now on
-

3 Formulas

Formulas are needed in a top-level network of a complex model to control how the results are fed up from the bottom level networks and synthesized. Formulas are not needed in simple models consisting of a single network.

Formulas and Formulaic Networks

A network is formulaic when it is a top-level network with a formula that controls how the synthesized values of the alternatives are being fed up from subnetworks attached to nodes in it and combined with priorities of nodes in the top network. Only networks that have subnetworks are allowed to have formulas. Otherwise it is a simple network that gets its synthesized priorities directly from the Limit supermatrix.

A pre-set formula, the *Additive(negative)*, is automatically associated with a new model when it is started using either the “full” or “small” template. To use templates select the command:

File, New

then select:

Full template - a three level complex model

Small template - a two level complex model

Open file - opens an existing model

Simple Network - starts with blank window for user to build own model.

There are five possible formulas. You may switch from one to the other at any time, or select one in the first place, by using the command:

Design,Standard Formulas

The currently selected formula has a check mark by it.

The default formula for a model started from a template is:

1) *Additive(negative)*

$$\begin{aligned} & \$NormalNet(Benefits)*\$SmartAlt(Benefits) + \$NormalNet(Costs)*(-\$SmartAlt(Costs)) \\ + & \$NormalNet(Opportunities)*\$SmartAlt(Opportunities) + \$NormalNet(Risks)*(- \\ & \$SmartAlt(Risks)) \end{aligned}$$

The other formulas are:

2) *Additive(reciprocal)*

$$\begin{aligned} & \$NormalNet(Benefits)*\$SmartAlt(Benefits) + \$NormalNet(Costs)*\$SmartInvAlt(Costs) \\ + & \$NormalNet(Opportunities)*\$SmartAlt(Opportunities) + \$NormalNet(Risks)*\$SmartInvAlt(Risks) \end{aligned}$$

3) *Additive(probabilistic)*

$$\begin{aligned} & \$NormalNet(Benefits)*\$SmartAlt(Benefits) + \$NormalNet(Costs)*(1- \\ & \$SmartAlt(Costs)) + \$NormalNet(Opportunities)*\$SmartAlt(Opportunities) + \\ & \$NormalNet(Risks)*(1-\$SmartAlt(Risks)) \end{aligned}$$

Note: There is a similarity between priorities of alternatives and probabilities. If x is the probability of something happening, then $1-x$ is the probability of not happening. If x is the priority of an alternative being risky, then $1-x$ is the priority of it not being risky.

4) *Multiplicative*

$\$SmartAlt(Benefits) * [invert \$SmartAlt(Costs)] * \$SmartAlt(Opportunities) * [invert \$SmartAlt(Risks)]$

Note: With this formula there is no use weighting with the priorities of the BOCR as whatever values are used simply cancel out. For the same reason doing sensitivity on the BOCR when this formula has been used is useless.

5) *Multiplicative power weighted*

$[root \$SmartAlt(Benefits) \$IdealNet(Benefits)] * [neg_root \$SmartAlt(Costs) \$IdealNet(Costs)] * [root \$SmartAlt(Opportunities) \$IdealNet(Opportunities)] * [neg_root \$SmartAlt(Risks) \$IdealNet(Risks)]$

Note: This formula is experimental. It raised the priority of the alternative coming up from the subnet to the power of the priority of the merit (Benefits, for example.)

6) *User defined* You may create your own formula if you build the model from scratch not using a template. Select the command *Design, Standard formulas* and type a formula in yourself.

To edit the currently selected formula use the commands:

Design, Add/Edit Formula

This opens the Edit Formula dialog box and you can then modify the formula as you wish. Anytime this dialog box is closed with the Save button rather than the X in the upper right hand corner, it is assumed that this is now a user-defined formula and that will be checked as the selected formula. You can change it back to any of the other formulas by selecting the one you want.

Caution: An additive formula is automatically created for any user-built model that has subnets attached to nodes in its top-level network. It weights the alternative priorities coming up from the subnet under each node by the priority of that node in the top-level network, then sums for all such nodes with subnets. This is almost never what you would want and you are strongly advised to visit that formula, which will be identified as a user defined formula, and fix it.

More About What Formulas Do The formula tells in what form priorities of alternatives are being passed up: Ideals (the largest value in any vector is 1.000), Normals(normalized so that the values in the vector sum to 1.000) or Totals (raw values are passed up with no normalizing of any kind being used) and Smart(which uses the best of the three for the given situation). Formulas also specify how to combine priorities of nodes in the formulaic network with the priorities of the alternatives from the subnets.

Usually, the top-level control network is the only one that has a formula, although intermediate level networks may also have formulas. Any network with a formula is identified by the word *formulaic* on the title bar. Bottom level networks should not be formulaic (for there are no alternatives feeding up from lower level networks that have to be combined). Intermediate levels might be formulaic, but in general are not. The Synthesis results for the alternatives in a bottom level, or simple, network are obtained directly from the values in the limit supermatrix and presented in three ways: ideal, normalized and total(which are the raw values that appear in the limit supermatrix).

It is also possible to use formulas in the intermediate networks between the top-level one and the decision networks at the bottom, but it is not required, nor very usual at the current stage of development of the theory.

Rules for Constructing Formulas

There are two types of terms involving node names that appear in formulas: terms involving the priorities of the named nodes in the current network where the formula is, and terms involving the priorities of alternatives that are being fed up under the named node. The node name is always enclosed in parentheses in the formula.

The meaning of \$ when used in a formula: The \$ in the formula means compute the results using the formula for each alternative.

For priorities of nodes in the current network use these conventions:

- **IdealNet** The term Net means with respect to the current network. IdealNet(Benefits), for example, means idealize the priorities of all the nodes in the network that have subnets by dividing by the priority of the largest, and use the resulting priority of Benefits.
- **NormalNet** NormalNet(Benefits), for example, means use the normalized priority of the Benefits node. The normalization is carried out only among the nodes that have subnets.
- **TotalNet** TotalNet(Benefits), for example, means use the direct priority that Benefits has in the network.
- **Rat** The term Rat means use the value for the named node from the ratings spreadsheet attached to the current network
- **IdealRat** IdealRat(Benefits) means use the idealized value for Benefits as it appears in the ratings spreadsheet.
- **NormalRat** NormalRat(Benefits) means use the value for Benefits obtained by normalizing rating results.
- **TotalRat** TotalRat(Benefits) means use the total value for Benefits as it appears in the ratings spreadsheet.

For terms involving priorities of alternatives being fed up under the named node use these conventions:

- **SmartAlt** Picks the best form of the alternative values to pass up: if the subnet is a bottom level one, pass up the Ideal values from synthesis in the subnet; if it is a bottom level subnet where the alternatives' values come from ratings, or if it is an intermediate level subnet, pass up the Raw values from synthesis in the subnet.
- **IdealAlt** If, for example, the node with the subnet is Benefits, IdealAlt(Benefits) means use the idealized values for the alternatives from its subnet.
- **NormalAlt** NormalAlt(Benefits) means use the normalized values for the alternatives from the subnet under Benefits.
- **TotalAlt** TotalAlt(Benefits) means use the normalized values for the alternatives from the subnet under Benefits.

The synthesis results for the alternatives can be displayed from any network or subnetwork and they are given in three ways for a given network:

Raw If the network is a *bottom level decision network* the values for each alternative are drawn directly from the Limit Matrix for that network. If the network is an *intermediate network containing control criteria*, the nodes that are the control criteria are normalized

and multiplied times the Ideal values of the alternative vectors coming from the networks below each of them. These weighted vectors are then added to yield the Raw vector.

Normals A vector of priorities for the alternatives is normalized by adding the elements in it, and dividing each element by the sum to yield the normalized vector. The elements in the normalized vector sum to 1. The Normals column in the synthesis table is computed this way from the Raw values.

Ideals The Raw priority vectors are converted to Idealized values by dividing each element in the vector by the largest, so that the best alternative gets a priority of 1 and the others get their proper proportion less than 1. These are the values in the Ideals column in the synthesis table.

The default formula at the beginning of this section may be summarized this way: In the each bottom-level decision network compute the Ideal priority vector for the alternatives. Pass that vector up to the next higher level, the control criterion level. Normalize the control criteria in that level and multiply times the vectors being passed up and add. The resulting vector is now in Raw form. There should be four of them, one for each of the BOCR control networks. Pass these vectors up to the top-level main network.

Finally, the priority vectors for the alternatives that are passed up to the top level are weighted by the priority of Benefits, Costs, Opportunities and Risks to yield an overall normalized priority vector for the alternatives. The Costs and Risks vectors have the largest priority associated with the most costly or most risky alternative. So we take 1 minus each element in the formula for these vectors to convert them so the best alternative will have the largest value. This is somewhat analogous to Probability theory. If p is the probability of something occurring, then $1-p$ is the probability of it not occurring.

4 Making Judgments/Assessments

When all of the cluster and node connections have been created, you will want to compare/assess nodes and clusters in each network. Nodes are compared with respect to another node and clusters are compared with respect to another cluster.

Judgments/assessments are done for the nodes in each network. Nodes that form a comparison group must be in the same cluster. These nodes, the **children nodes** are connected from the same **parent node**, and are assessed with respect to how they influence that node, or how that node influences them. The parent node may be in a different cluster from the children, or the same cluster.

Influence must be treated consistently, how the parent influences the children, or vice-versa, but the flow direction should be kept the same throughout the network and throughout the model.

4.0.1 Making Comparisons

To start the comparison process click on the cluster or node that will be the parent of the comparison, then:

1. Select the command *Assess/compare* from the main menu of the network window.
2. Select the sub-menu command *Cluster comparisons* or *Node comparison* to start the comparison process. If a cluster or node has been previously selected, by left-clicking on it, the comparison process will start there. If nothing is selected, the process begins with the first cluster or node (alphabetically organized).
3. Left-click on the Do Comparison button to get into the comparison dialog box. There are five comparison/assessment modes as shown in the table below. The first four are for making paired comparisons, the fifth is for entering direct data.

Troubleshooting Tips

Question: Why am I not able to do cluster comparisons when there are only two clusters? *Answer:* There are no comparisons possible with only two clusters. If one is the parent, the other is the only child and there is nothing to compare it to. *Solution:* Do not try to do cluster comparisons when the network has only two clusters. The cluster weights are automatically set at 1/2 for each.

Shortcuts to the Comparison Window. As the following shortcuts are started from a selected cluster or node, one does not have to specify which cluster or node is to be the parent:

1. Pop-up the cluster menu by right mouse-clicking on the background in a cluster. Select the command *Cluster comparisons* to enter the Comparison Window in the Questionnaire mode; or, alternately;
2. Simultaneously press the shortcut keys *Shift F5* to start the cluster comparison process.

In every comparison mode, a verbal comparison phrase for the selected pair appears at the top of the window. It shows the dominance order with the more dominant of the pair first, and the less dominant second. The node at the beginning is the more dominant: for example, more important, more preferred, more likely, more beautiful. Enter whatever comparison word you wish to have appear in the verbal comparison phrase.

The AHP Fundamental Scale

1 Equal**2 Equally to Moderately more dominant****3 Moderately more dominant****4 Moderately to Strongly more dominant****5 Strongly more dominant****6 Strongly to Very Strongly more dominant****7 Very Strongly more dominant****8 Very Strongly to Extremely more dominant****9 Extremely more dominant**

Reciprocals A reciprocal, such as $1/3$, is used for the *other* judgment in the matrix involving the pair. For example, if the judgment 3 is entered in cell (a,b), the judgment $1/3$ is automatically entered in cell (b,a). A matrix with this special form is called a *reciprocal matrix*.

Decimal Values For elements which are close to each other, you may use the judgments, 1.1, 1.2, 1.3, ...1.9, to make finer distinctions.

- To switch to another pairwise comparison mode, left-mouse-click on the tabs at the top of the dialog box that are labeled Graphic, Verbal, Matrix, Questionnaire.
- To switch to the direct data entry mode, left-mouse click on the menu command *Misc.* and select the sub-command *Direct data entry*.
- To select your own comparison word, left-mouse click on the menu command *Misc.*, select the sub-command *Comparison words* and select from the following four choices: *Importance*, *Preference*, *Likelihood*, *Other*. If you select *Other*, type in the word you want.

In every pairwise comparison mode the current judgment is shown by the depressed square in the tracking boxes at the right-hand side of the screen. If there are n comparison elements, then there are $n(n-1)/2$ judgments. It is not necessary to enter *all* the judgments, though it is better to do so in order to extract the most information from the user about the real dominance relationships.

The first four modes are for making pairwise comparisons. The fifth mode is for entering data directly. The questionnaire mode is the default pairwise comparison mode - that is, the Comparison Window always starts in this mode.

Questionnaire Mode

Select the numerical judgment that best expresses your judgment by right-mouse-clicking on the number closest to the dominant element. If A is preferred "strongly" to B, click on the 5 on the same side of the line as the A, in the row that has A on one side and B on the other. Use the mouse to complete all the judgments.

Graphic Mode

The ratio of the bar lengths is used for the judgment for the current pair of elements. To change the bar lengths, left click with the mouse on a radius line in the pie chart display and drag to change the relative sizes of the areas. The ratio of these areas is the same as the ratio of the bars. Click with the mouse on the judgment tracking boxes at the right of the screen to advance to the next pair. To reset to equal, click the "No Comparison" button. The judgments are

continuous (unlike in the questionnaire mode where they are limited to integers) and thus can assume decimal values as well as the whole numbers of the AHP Fundamental Scale.

Verbal Mode

In the verbal mode words are used on the scale. The lines on the scale represent the judgment numbers of the AHP Fundamental Scale. Left-mouse-click to bring a red bar up to your selected judgment. As in the Graphic Mode, the values are continuous and are not limited to whole numbers from 1 to 9, but can be decimals if the red bar does not rest exactly on one of the lines representing a whole number.

Matrix Mode

Each cell in the matrix mode corresponds to the pair of elements being compared. The judgments are shown as decimal numbers, rounded off to the nearest tenth. When a judgment is displayed in red, and the arrow points up, the element at the top is dominant, in blue, with the arrow pointing left, the element at the side is dominant. **To invert** the dominance order, double-click with your mouse on the arrow in the cell you wish to invert. **Inconsistency improvement** is always done from the matrix mode. Click on the Inconsistency button to have the most inconsistent judgment selected. The most consistent value one could enter for that judgment is displayed on the screen. You may enter that value, or enter another value, or do not change the judgment. Calculations are always based on what is being displayed in the matrix mode. As judgments are changed in the other comparison modes or data is input, the matrix entries are constantly being revised to reflect the last entered values.

Cluster Comparisons/Assessments

Clusters themselves may be compared as well as nodes to determine their weights. The weights of the clusters in a network add up to 1.0. If you choose to treat them as equal and not compare them, each is assigned a weight of $1/n$ where n is the number of clusters. Clusters are compared when there are three or more in the same network. Cluster comparison groups consist of the clusters linked to a particular cluster. If cluster A is linked to B, C, and D, then B, C, and D must be compared for the importance of their influence on A. Or the importance of A's influence on them. It is important to keep the influence questions parallel. Do not ask "influence on" in one comparison and "influenced by" in another one. The cluster comparisons take place in a sub-network and are done with respect to the control criterion the sub-network is attached to.

Example 1 - cluster comparisons when there is outer dependence - A typical pairwise comparison question for the example above is: "With respect to benefits (assuming the control criterion is benefits), which has more influence on A, B or C?" There would also be comparison questions for B versus D and C versus D to complete the comparisons for this group.

If A is also linked to itself (inner dependence), it appears in its own comparison group. If A is linked to itself as well as B, C and D, then one would be comparing A, B, and C with respect to influence on (or by) A.

Example 2 - cluster comparisons when there is inner dependence - An example of cluster comparisons where there is inner dependence. Suppose the clusters are industries: electric, coal, and steel. And suppose the electric industry group is connected to itself as well as to the coal and steel groups. Then the comparison question might be: "Which benefits the electric industry more, electricity, coal or steel?" The electric industry would benefit most from coal, its basic raw material, then steel, to make its machines, but not much from electricity, which it uses only to light the offices.

A single matrix of cluster weights results from comparing all the linked clusters in the network. This matrix is used to weight the cluster blocks of the supermatrix. Each sub-network has a **supermatrix**. The supermatrix consists of blocks of priority vectors for the clusters in the network. The clusters in the sub-network are listed across the top and down the left side of the supermatrix. Beneath each cluster name on the top are several columns labeled with the names of nodes belonging to the cluster, and similarly for the rows. Consider the (A,B) cluster block which is the second block down in the first column of blocks. It is made up of the priority vectors formed by comparing nodes in the B cluster with respect to parent nodes in the A cluster make up the (A,B) cluster block. For it to have non-zero entries, the A cluster must have a link to the B cluster.

The **cluster weight matrix** derived by comparing the clusters is used to weight the cluster blocks in the supermatrix. Before weighting the supermatrix is called the **unweighted supermatrix**. After weighting is called the **weighted supermatrix**. The effect of such weighting is to make the entries in an entire column in the supermatrix add up to 1.0. A matrix is a **stochastic matrix** when all its columns sum to one.

To understand and facilitate the comparisons of clusters, the following should be helpful. If there are some elements in a cluster that influence some elements in another cluster, then that cluster itself must influence the other cluster.

Cluster A influences Cluster C more than Cluster B does if:

1. A has more elements that interact more strongly with C than does B.
2. The elements in A have greater synergy and work together more than those in B.
3. The activities in A are more strongly flowing toward or influencing the activities in C (directly and indirectly) than those in B.
4. The elements in C respond more strongly (with its use of materials, energy, purpose and operation) to the elements in A than to those in B.
5. Elements in A have more of a structural relationship with C than elements in B (that is, A and C is more of a system than A and B; this is kind of like 4).

Node Comparisons/Assessments

Node comparisons are started by selecting the node which is to be the parent node, then selecting the Assess/Compare menu command; or right-click on the node and select Assess/Compare from the drop down menu that appears.

Shortcuts to the Comparison Window. As the following shortcuts are started from a selected node, one does not have to specify which cluster or node is to be the parent:

1. Select a node within a cluster by passing your mouse over it until it is framed with a black outline. Pop-up the node menu by right mouse-clicking on the it. Select the command *Node compare interface* to enter the Comparison Window in the Questionnaire mode; or, alternately;

2. Press the shortcut key *F5*.

See [Chapter 4 \[Making Judgments/Entering Data\]](#), page 20, for detailed information about the comparison modes and commands.

Ratings Assessments

Assessing the Alternatives in Ratings

Select the command *Assessments/Ratings* to open the Ratings Window.

Left-click on a cell in Ratings to get a list of the categories for the criterion listed at the top of the column. Left-click on the category that best represents the assessment for the alternative at the left of the row.

The score for an alternative is computed by multiplying the idealized priority of the selected category times the limiting priority for the criterion obtained in the network for each cell and summing across the row.

The Calculations command in Ratings

To show the results in ratings select the *Calculations* command on the Ratings window menu.

Priorities gives the scores normalized by dividing by the total of all the alternatives' scores.

Totals gives the scores without normalizing

Column Priorities shows the priorities of the column headings, the criteria.

Matrix Priorities shows the numbers in each cell and the column priorities. These numbers can be blocked and copied into a spreadsheet. You may first need to expand the window so that the numbers line up right.

Cycling through Comparisons

Select the **Assess/Compare** command from the menu of a network. You may then select either **cluster comparisons** or **node comparisons**. If there is no currently selected cluster or node, the comparison cycle begins with the first one. A cluster comparison (or node comparison) window will appear. Left-click on the "Do Comparisons" button. This will bring up the comparison window for the cluster or node. Make the comparisons as described under Making Comparisons. When the comparisons are completed, close the window. If you are doing node comparisons, mark the comparison as completed by selecting yes. This will allow the cluster to be shown as having comparisons completed for that node by being outlined in red when "show completed comparisons" is turned on.

5 Supermatrix Computations

Once you have created a network, you will want to make some judgments and do computations (i.e. find out which alternatives are the best).

The *Computations* command is used to obtain results. All of the subcommands under the *Computations* command may be used to display results in a simple network that occupies a single window. The *Synthesize* and *Sensitivity* commands are also used to obtain results for any network that has subnetworks attached to control nodes within it. The subcommands are, briefly described:

- **Unweighted Super Matrix** - made up of the local priority vectors obtained from the comparison groups. The node at the top of a column is the parent of the various comparison groups made up of the nodes at the left. There may be more than one priority vector in a column - there is one for each cluster that contains nodes being compared with respect to that parent node. A super matrix is arranged by components with each cluster and its elements being listed across the top and down the side. The blocks formed by the cluster intersections are the components. To see this best select the Graphical view sub-menu command. The Text view is good for showing more entries on a single screen.
- **Weighted Super Matrix** - the local priority vectors in the unweighted supermatrix have been multiplied times the cluster weights. See the *Cluster Matrix* command below. The process here is to multiply every element in a component of the unweighted super matrix by the corresponding component value in the cluster matrix. The values in the cluster matrix are established by pairwise comparing linked clusters with respect to their influence on the "parent" cluster. If no cluster comparisons are done, default values of equally important are put into the cluster matrix. The result is that the priority vectors in each column are weighted by their cluster importance weight and this makes each column stochastic (i.e., sum to 1) in the weighted supermatrix.
- **Limit Matrix** - in a simple straightforward network the process of obtaining the limit matrix is to raise the weighted super matrix to powers until it stabilizes - that is, all the columns in the matrix have the same values. The entries in a column are the priorities of the nodes at the left (they are "weighted" by cluster weights though, so each cluster's nodes need to be normalized to make their priorities add up to 1.0. There are, however, "difficult" cases to handle. We summarize those as follows:
 - **Sufficiently connected networks** - the calculation of the limit matrix is relatively easy and involves raising the weighted supermatrix to powers (the 2,4,16,32 powers, for example, by successively squaring the supermatrix) until it converges so that each column is the same.
 - **Cycling in the limit** - sometimes successive powers of the supermatrix get into a stable cycle having two or even more limit states. In this case, corresponding columns are averaged from the different states to give the final result.
 - **Multiple unit eigenvalue case** - There is some discussion as to whether this case should be handled in the same way as any other sufficiently connected networks, or whether a more complicated formula devised by Luis Vargas should be used. The complicated formula is included in the software and may be turned on or off using the limit matrix options below.

- **Insufficiently connected network, e.g. a hierarchy** - this is a network with sinks, that is, nodes which are not "with respect to nodes" for any comparison. These nodes can be identified by the columns they head in the supermatrix being completely zero. In this case, taking larger and larger powers of the supermatrix cause it to simply vanish, and we are left with no information. One way to fix this is to replace those zero columns by the same column from the identity matrix (i.e. if column 7 of a 12x12 matrix is zero, replace it by column 7 of a 12x12 identity matrix). We call these columns identity columns. The different ways of remedying this situation are given in the limit matrix options below.
- **Limit Matrix Options** - currently the software contains a number of ways of calculating the limit matrix. This is because there are sometimes unusual network configurations, or pathological cases where different methods of calculating may be appropriate. These will be investigated more thoroughly and those that prove useful retained in later versions of this software. The following is a list of the options, their strengths and weaknesses, and a "suitability" score we have given them (10 would be the best). For more about the actual calculations see the Calculations White Paper by W.J. Adams in the papers database of the Creative Decisions Foundation: www.creativedecisions.net.
 - **Calculus type (9.0)** - Normally this is the type you should select. It is the best available overall. It handles all cases, and gives meaningful answers. **Strengths** - Handles networks with sinks correctly. Also handles networks with sinks in a fairly meaningful way (it never gives bizarre answers, like an alternative getting 100% for no reason). It handles all hierarchies correctly, but it will not give intermediate hierarchy synthesized values. **Weaknesses** - Does not give intermediate hierarchy synthesized values.
 - **Scaling By Scalar (8.5)** This algorithm was designed on the spur of the moment. I had the idea to scale by scalars, instead of but matrix multiplication. That way it would be commutative. It appears to always work the same as the calculus type, and for good reason. With a little work the proof is straight-forward. **Strengths** - Same as *Calculus Type*. In addition it is rescaled always, which makes some folks more comfortable. **Weaknesses** - Same as *Calculus Type*.
 - **New Hierarchy (8.0)** - This algorithm exists to give intermediate results of synthesis in the hierarchy case. **Strengths** - This algorithm gives the intermediate results for hierarchies. It also handles networks without sinks correctly always. Also handles degenerate hierarchy cases better than all other algorithms. **Weaknesses** - Its handling of networks with sinks is not at all canonical. The algorithm does stand on its own merits, but the results don't always work with the logic I would like to see.
 - **Identity at Sinks (7)** - This algorithm works the same as the calculus type in the hierarchy case, and the network without sinks case. However if you have a network with sinks, it puts self-loops on the sinks. **Strengths** - Works well in hierarchies, and networks without sinks cases. **Weaknesses** - Does not give intermediate synthesized values back in the hierarchy case. Also in the network with sinks case, it places undue emphasis on the alternatives. This can result in an alternative getting 100% in cases where it makes no sense (apply it to the national missile defense model in our samples).

- **Sinks formula (6.5)** - This algorithm was the attempt just before the *New Hierarchy* algorithm. It never gives completely bizarre results (as a matter of fact it tends to be very close to the *Calculus Type* algorithm). The reason it gets such a low value is that it fails to handle unbalanced hierarchies, because of weaknesses in the method of putting identity columns at sinks for hierarchies. **Strengths** - Is an easy to understand algorithm. It seems to separate the world into easy parts. It works fine with networks with sinks. **Weaknesses** - It does not handle unbalanced hierarchies correctly because of the logic of adding ones to the diagonal of sinks (For the B^{∞} part, it uses the *Calculus Type* algorithm, which adds ones to diagonals of hierarchies. This causes our problems in unbalanced hierarchy cases. However, if we used the *SM_limitNonHierarchy algorithm* instead, this weakness would leave. Since this is mostly for experimental purposes, this change will not be made anytime soon. Another weakness is in the logic of the algorithm. The *New Hierarchy* algorithm was developed to repair this. However this weakness turns out to be a strength as well (since the simplifying assumption which bothers us, makes the overall calculation easier). Oh yes, it also doesn't give the intermediate synthesis values for a hierarchy.
- **Pre-2001 Version (3)** - This algorithm is a fairly stable algorithm for handling networks. It is not as sophisticated as the earlier mentioned ones. However it does have some extreme shortcomings, which is why it is rated so low. **Strengths** - Handles networks, and pure hierarchies correctly (but not unbalanced hierarchies). **Weaknesses** - If the network has a hard time converging, this will bail before the other algorithms mentioned. It does not handle unbalanced hierarchies correctly. It also doesn't give the intermediate results for a hierarchy of any kind.
- **Pre-2000 Version (2)** - This algorithm is all that is left of the first version of the limit matrix calculation that were included in the code. It is juvenile, but does work for networks without sinks, which was all that were considered at that time. **Strengths** - Not many! It does handle networks without sinks correctly. **Weaknesses** - Every other case it will mess up. Never, ever trust this one!
- **Priorities** - this command gives the priorities of all the nodes in the currently selected (or open) network where the command is invoked.

Tip: For a control model there are usually no alternatives, nor are there supermatrices as there are no connections, so the first 4 commands in this case will yield zeroes.
- **Experimental Priorities** is for research purposes and will soon be removed.
- **Synthesize** - gives the priority vector for the Alternatives in a simple model that has only a single network; it will also synthesize priorities for the alternatives over all the subnetworks beneath the current network in a complex model. For a standard top level control network containing Benefits, Opportunities, Costs and Risks nodes an additive formula is automatically supplied by the software that is used in the Synthesize command. See Formulas in the index for more information.

6 Synthesizing for Results and Sensitivity

RESULTS

The main results of an ANP model are the overall priorities of the alternatives obtained by synthesizing the priorities of the alternatives from all the subnetworks. To get the overall results use the Computations menu in the top-level model. To get intermediate results for a particular subnet you may use the Computations menu in that subnet.

- **Synthesis** Select the *Computations Synthesize* command to synthesize the results for the alternatives. There must be a cluster named *alternatives* in either that cluster, or in attached subnetworks, for there to be synthesis results. If the results are zero, probably you don't have alternatives.

The synthesis command will give the priorities of the alternatives for the network where the command is invoked and all of its subnetworks, sub-subnetworks, etc.

- **Priorities** Select the *Computations Priorities* command to determine the priorities of all the nodes in a network, normalized by cluster (organized by cluster with the sum of the priorities of the nodes in the cluster adding up to 1.0), and limiting with respect to the network (the sum of the priorities of all the nodes in the network adding up to 1.0)

The commands for obtaining final results are:

- **Computations Priorities** This command gives a list of the priorities of all nodes in the current network; both normalized by cluster so that the weights of the nodes in the cluster add up to one, and limiting so that the weights of all the nodes in the network add up to one .

If the network has a hierarchical structure with all influence and links feeding down to nodes in a bottom component, you must use a special command to see the priorities of the nodes that are *not* in the bottom cluster. Select the Computations, Limit Matrix Options command and click on New Hierarchy without limit. This will then show the priorities of the intermediate nodes when the Computations, Priorities command is used. The normal limit matrix option is Calculus type. This is the default option for each network and will automatically be the one used each time you enter that network. You must reset the option each time the network is entered if you want a different one.

or

- **Computations Synthesize** or
- **Computations, Additional Synthesis Command**

If you invoke the Synthesize command from a bottom level subnetwork, it gives the synthesis of priorities for the alternatives in only that network; from an intermediate network it synthesizes for that network and all the subnets of that network. If you invoke the Synthesize command from the top-level network, it gives the synthesis of priorities for the alternatives throughout the entire model. In a sense the priorities of the alternatives are rolled up from the bottom level decision networks to the networks they are attached to, and from there rolled on up to the next network and so on to the top.

Results

Formulas Used in Synthesis

Formulas are needed in a top-level network of a complex model to control how the results are synthesized. In a usual type of network with Benefits, Opportunities, Costs and Risks nodes in the main top level the following formula is used: $\$NormalNet(Benefits)*\$TotalAlt(Benefits) + \$NormalNet(Costs)*(1-\$TotalAlt(Costs)) + \$NormalNet(Opportunities)*\$TotalAlt(Opportunities) + \$NormalNet(Risks)*(1-\$TotalAlt(Risks))$

If you have generated the network using the BOCR template the formula will already be there. If not you must go into *Design, Make Net Formulaic* and enter it yourself.

The \$ in the formula means compute the results using this formula for each alternative. If there are three alternatives, then there will be three numbers produced that are the synthesized overall results for the alternatives. These are the results that are displayed by the *Synthesize* command.

The results for each alternative are always displayed in three ways for a given network:

Totals: If the network is a *bottom level decision network* the values for each alternative are drawn directly from the Limit Matrix for that network. If the network is an *intermediate network containing control criteria*, the nodes that are the control criteria are normalized and multiplied times the Ideal values of the alternative vectors coming from the networks below each of them. These weighted vectors are then added to yield the Total vector.

Normals: a vector of priorities for the alternatives is normalized by adding the elements in it, and dividing each element by the sum to yield the normalized vector. The elements in the normalized vector sum to 1.

Ideals: the Totals priority vectors above are converted to Idealized values by dividing each element in the vector by the largest, so that the best alternative gets a priority of 1 and the others get their proper proportion less than 1.

The above formula may be interpreted this way: In the each bottom-level decision network compute the Ideal priority vector for the alternatives. Pass that vector up to the next higher level, the control criterion level. Normalize the control criteria in that level and multiply times the vectors being passed up and add. The resulting vector is now in Totals form. There should be four of them, one for each of the BOCR control networks. Pass these vectors up to the top-level main network.

The Costs and Risks vectors have the largest priority associated with the most costly or most risky alternative. So we take 1 minus each element in these vectors to convert them so the best alternative will have the largest value. This is analogous to Probability theory. If p is the probability of something occurring, then 1-p is the probability of it not occurring.

Finally, the priority vectors for the alternatives that are passed up to the top level are weighted by the priority of Benefits, Costs, Opportunities and Risks to yield an overall normalized priority vector for the alternatives.

Performing Sensitivity

SENSITIVITY

To display a sensitivity graph select *Computations, Sensitivity* from the menu of the top level model. (You can also perform sensitivity from lower levels.)

This is a **what-if** type of sensitivity that allows you to select any combination of independent variables. The initial sensitivity screen that appears always starts with one node selected, the first alphabetically in the network where the command was issued. More than one dependent variable may be selected. They may be nodes, supermatrix entries, or judgments. For each dependent variable a range of values, and the number of steps, can be selected. So many points are generated for all the possible combinations of dependent variable values. If there is a single dependent variable selected, with a range of priority for that variable from .2 to .4 selected, with 4 steps (5 points of calculation) for sensitivity examination, there would be points for the corresponding alternative values plotted for the dependent variable when its value is .2, .25, .30, .35, and .4. These points would be spread equally across the x-axis. The numbers on the x-axis relate only indirectly: the .30 value of Benefits would be plotted at 0.5. The lines for the alternatives are obtained by joining the points relating to a given alternative. The **Blue Vertical Line** is initially located at 0.5 on the x-axis. This just shows the values of the alternatives at the "experiment" that is halfway through all the experimental points being calculated. Move the blue line back and forth by clicking and dragging and read the value of benefits and the alternative values (under the graph) for the current location of the blue line.

If there are three dependent variables selected, with 4 steps, there would be 53 different combinations of dependent variable values plotted. These are "experiments". The results of the 125 experiments are plotted along the x-axis (and simply joined to make them look like continuous lines). The Dimensions command is especially useful to stretch out the graph along the x-axis so you can examine more closely where the rank switches occur. Try using 800 or 1200 for the x-axis dimension.

Select Dependent Variable from the Edit menu in Sensitivity Analysis to see the Sensitivity input dependent variable list. It always starts with a default initially selected dependent variable that is first in the list of nodes for that network.

To add a new dependent variable select New or to edit one click on it and select Edit to bring up the New parameter dialog box shown below in Figure 45. You can select a mix of dependent variable types, networks, number of steps, etc., but you must set the parameters for each.

1) Type of parameter:

Priorities

Supermatrix

Comparison

2) Network where the sensitivity is being carried out.

The zero network is the top level one, or you could choose:

Benefits subnetwork

Costs subnetwork

Risks subnetwork

3) Enter the starting and ending value of the parameter selected for the range where sensitivity is to be plotted.

4) Enter the number of steps - don't get carried away. The calculations can get huge if you have selected too many dependent variables and have asked for lots of steps.

At any particular experiment, the values for the dependent variables and the alternatives are shown below the graph. You may also elect to have the corresponding values of other parameters shown by selecting the **Extra Params** command on the Sensitivity Analysis Edit menu.

Exporting Sensitivity Data To export the data points of the sensitivity plot to Excel, select File Save from the Sensitivity Analysis menu. Use a name ending in .txt when asked for a file name. Then load Excel, select the File, Open command and open the file. Be sure to change the type of file to *.* to display names of all files so the .txt file will show up. The Excel import wizard will then come up. Step through it selecting OK or Next to Finish at the end. The Excel spreadsheet containing the sensitivity data points will then appear. You can use it then for displaying the data in more ways and for data manipulation - such as arranging one of the alternative columns in decreasing order, so you can see the maximum value obtained.

7 printing

Printing

The *File*, *Print* and *Computations*, *Full Report* commands both do the same thing. They produce a full report on the model and its results.

The report is produced in an HTML format. You can select "Print Preview", then print from the printer icon if you are satisfied with the way it looks.

Or you can save it as an HTML file, and edit it if you like before printing.

8 Other Important Features

Attaching Files

You can attach other files using the paperclip icon on any network window. Note that attached files belong to the network they were attached in. Normally you would probably attach files in the main top-level network. Files you might include:

Word files (with .doc extensions) containing background information and reports

Powerpoint files (with .ppt extensions) containing powerpoint presentations

Excel files (with .txt or .xls extensions) containing other data, exported from the model, for import to the model, or with external calculations *Super Decisions model files* (with .mod extensions) containing other associated Super Decisions models; there might be several models for a complex project

Other Things You Might Never Find Out Otherwise

Linking Nodes Turn on the Make Connections mode by clicking on the Insect-looking icon. Then left click on the parent node and right click on each descendant node to make connections quickly.

Or, even quicker, right-click on the node you want to connect from, and select the *Connect Nodes* command from the node menu that will drop down, then click on the nodes you want to select (or de-select) from the list that appears.

Show Connections Turn on the Show Connections mode by right-clicking on the star-shaped icon. When this mode is on and you move your cursor over a node, the nodes it is connected to are highlighted in red.

Show Completed Comparisons Turn on both the Make Connections mode and the Show Connections mode and left-click on a node to select it. Each cluster that has had the comparisons completed for the nodes in that cluster with respect to the selected node will be outlined in red.

Get to a subnetwork Left double-click on any node with a subnet (such nodes are identified by having a red subnet label attached to their bottom - do NOT click on the label, but on the node background or name). This will bring up that subnet.

Or, use the *Networks* command on the menu of any network to get to the other networks in the model directly. Networks are labeled on the title bar of their window with the name of their controlling node, except for the top or Main network. It is labeled Super Decisions Main Window plus the name of the file containing the model, for example, Super Decisions Main Window Car_BCR.mod.

9 Sample Models

This program comes with several sample models. Super Decisions models fall into two general categories: 1) simple network models in which all the elements of the model appear in a single network of clusters containing nodes (nodes are the most basic elements of any Super Decisions model); and 2) complex models consisting of a control model, containing control criteria nodes to each of which may be attached a simple subnetwork. The sample models fall into these two broad categories and were chosen to illustrate the most important basic concepts of Super Decisions models. The models currently included are located in the *samples* subdirectory.

To quickly load a sample model select the Help command on the menu, then select Sample Models and the model you want.

9.1 Hamburger market share model

The hamburger model was illustrated in the book This hamburger model is the "large" one with 8 clusters that is presented as a sample model in the Super Decisions software user's manual. The goal of this model is to estimate market share among fast food hamburger places for the three competitors, McDonald's, Burger King and Wendy's. It is a simple network model containing feedback and self-loops among the clusters, but with no control model. There is an implicit control criterion with respect to which all judgments are made in this model: Market Share. For example, when comparing the clusters *indirect competitors* to *marketing mix* which is more important for gaining market share. Similarly when the node comparisons are being made.

9.2 US economy model for predicting turnaround time

The US Economy example is a simple network model with no control model. It is a holarchy, meaning it resembles a hierarchy from the top down, but the cluster containing the bottom level of alternatives links back to the cluster containing the main criteria. The purpose of this model was to estimate how long, in months, it would be from the time the model was done until the US Economy turned around. The priorities for 3 months, 6 months, 18 months and 24 months represent likelihoods. For example, a value of .159 for 3 months means that there is a 15.9% likelihood that the economy would turn around in 3 months. To get the exact time in months use the formula: $.159 \times 3 + .129 \times 6 + .237 \times 18 + .475 \times 24$.

There are two US economy projection models. The first, US_EconomyHolarchy.mod was done in December of 1991 and January of 1992. The prediction of the first was that the economy would turn around in October-November 1992, which proved to be correct. The second, US_EconomyResurgence2001.mod.gz, is a prediction of when the economy will turn around in 2001. This model was done in April, 2001, and predicts that the economy will turn around in October-November, 2001.

9.3 National Missile Defense Issue

This is a complex model of three levels to analyze the best strategy for the US in whether or not to develop a missile defense shield. It is a full model with Benefits, Opportunities, Costs and Risks, control criteria subnetworks, and decision subnetworks. Further, the BOCR are

rated with respect to US national interest criteria. A complete paper on the topic is attached within the model.

9.4 Bridge model to choose between two bridges

This model is not yet available.

9.5 Car Choice (Hierarchy)

The car choice model is a hierarchical model that is re-done here as a simple network model. With a model that is a hierarchy, the alternatives at the bottom level are a "sink". That is, all links go into that cluster and none come out. One must link every node in this cluster to itself. This has the effect of introducing an identity matrix for the alternatives cluster into the supermatrix. It appears in the lower right hand corner of the supermatrix. It "catches" the priorities flowing into it. The supermatrix has the wonderful property that the synthesis of the alternatives with respect to the elements of every cluster appear as the bottom level components in the Limiting Supermatrix. This is very apparent in the car model which is also one of the sample models in the Expert Choice hierarchical decision making software. The results here are the same as in the Expert Choice model: the priorities of the cars Volvo, Mercedes, and so on, and they appear at the bottom of the leftmost column in the supermatrix labelled Goal at the top. All components are zero, except those across the bottom level for the alternatives which give all the possible syntheses with respect to what are intermediate levels in the Expert Choice model, but are clusters in the Super Decisions model.

9.6 Carmaker

The model car_BCR.mod is to pick the best among Japanese, European, or Americancar-makers. It is a two level model with Benefits, Costs and Risks subnetworks. This model uses the multiplicative approach to combining the results from the separate BCR networks: $B/(C \cdot R)$. It is intended to illustrate how judgments are made in subnets under control nodes; for example, when making judgments in the benefits subnet, they are made with respect to how they impact benefits.

9.7 Technically hard sample model

Technically hard models are those with "sinks" in them. That is, clusters with links to them, but none out of them. Regular hierarchical models are examples of this, for example, the *car hierarchy.mod* model.

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