MultCSync Manual

Version 1.0

July 2004

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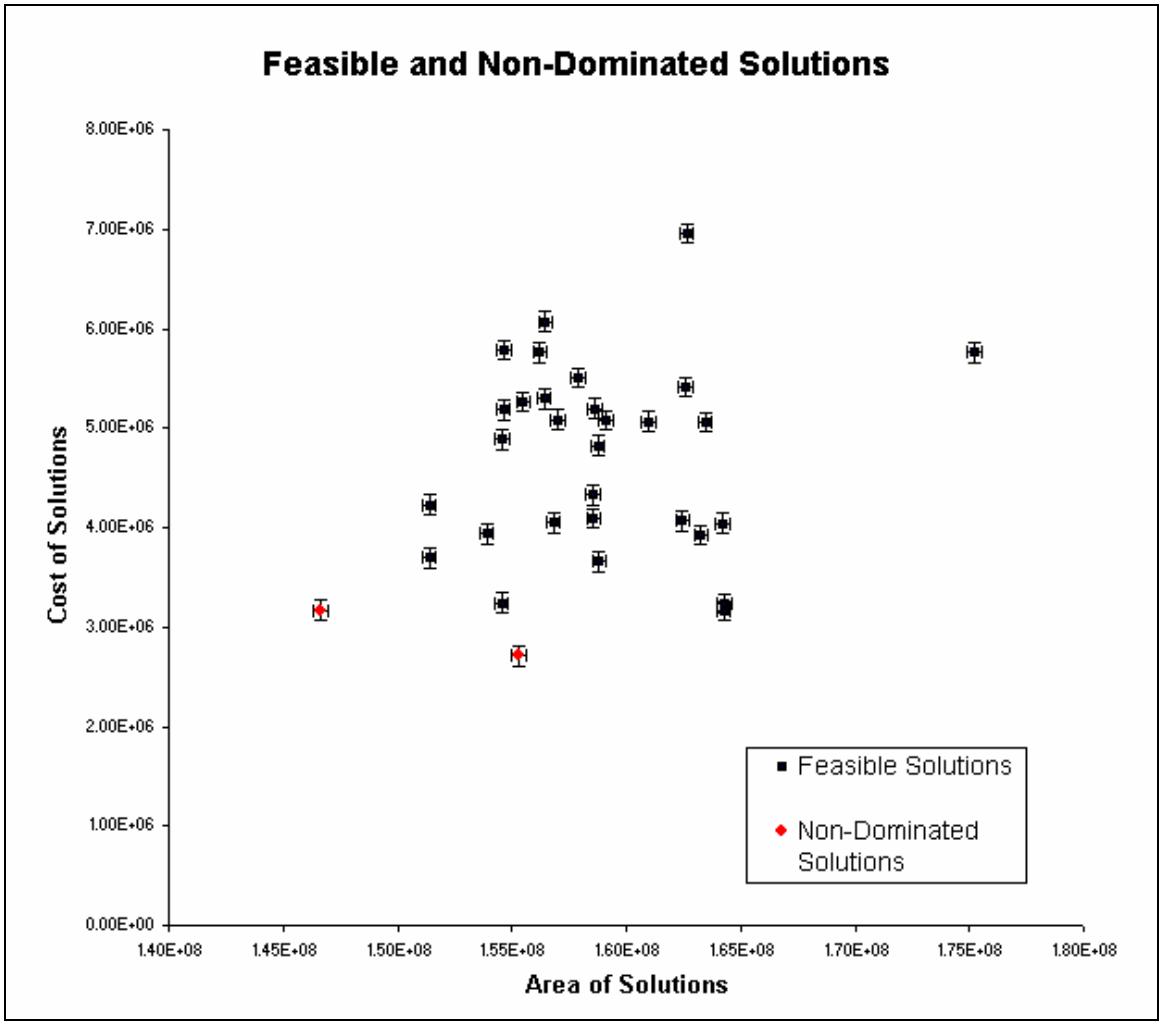

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Disclaimer

Although the MultCSync Version 1.0 software package has been tested and run successfully on computer systems at the University of Texas at Austin, no warranty of MultCSync Version 1.0 is expressed or implied.

The software, data, and related materials contained therein are provided “AS IS,” without warranty of any kind, either expressed or implied, including, but not limited to, the implied warranties of merchantability and fitness for a particular task.

As of July 2004, MultCSync Version 1.0 can be downloaded from:

http://uts.cc.utexas.edu/~consbio/Cons/Labframeset.html

Cover Graphics: Multiple Synchronization Plot which plots each of 36 different conservation area networks according to their respective area and cost (measured in terms of human population density). Out of the original 36 feasible solutions, the plot shows two solutions to be non-dominated.

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Table of Contents

Chapter 1

Introduction

A standard strategy for biodiversity conservation consists of the selection of conservation area networks (CANs): sets of places such as national parks and reserves at which conservation plans are implemented (Margules and Pressey 2000). CANs are selected so that desired features of biodiversity such as species, which are generically called "biodiversity surrogates," are represented in CANs up to specified targets, for instance, 10 per cent of the range of a species (Margules *et al*. 1988). Additionally, well-designed CANs incorporate design criteria such as the size of individual areas, their dispersion over the landscape, and their connectivity. Moreover, CAN selection occurs in the context of many other social claims on land use besides biodiversity conservation. These include use for recreation (including wilderness preservation [Callicott and Nelson 1998; Sarkar 1999]), habitat transformation for agricultural or industrial development, biological and industrial resource extraction, *etc*. CANs are typically initially selected as economically as possible, that is, by representing biodiversity surrogates up to their targets in the smallest possible total area (Sarkar *et al*. 2004). A central task of systematic conservation planning is to find a CAN that not only economically represents surrogates but: (i) incorporates the other design criteria; and (ii) also performs as optimally as possible with respect to the social claims on land use.

In what follows, each CAN that satisfies the biodiversity representation targets will be regarded as a "feasible alternative" or, in short, an "alternative." Given a set of feasible alternatives, besides the design criteria, the various competing social claims on land use can also be modeled as criteria each of which assigns at least an ordinal rank, and preferably a quantitative value, to every such alternative. These criteria are often incompatible in the sense that they cannot all be fully optimized simultaneously. For instance, preserving land for its wilderness value is incompatible with converting it for agricultural use. Selecting the "best available" alternative involves computing "trade-offs" between all the design and social criteria.

A wide variety of techniques exist for such computations ranging from heuristic multi-dimensional optimization algorithms (Dyer *et al*. 1992) to the well-developed multi-attribute value theory (MAVT) and multi-attribute utility theory (MAUT) (Keeney and Raiffa 1993; Dyer 2004). The MultCSync software package implements several of these techniques for use in conjunction with place prioritization software packages that ensure biodiversity surrogate representation. These packages include ResNet (Kelley *et al*. 2002; Sarkar *et al*. 2002), C-Plan (Pressey 1999), and Marxan (Ball and Possingham 2000). Each of these packages implements a different set of algorithms for selecting a CAN that satisfies all biodiversity representation surrogates (and is thus a feasible alternative).

MultCSync begins by computing the subset of “non-dominated” alternatives in the set of feasible alternatives. An alternative, α_j, dominates another alternative, α_i, if α_j is better than α_i by at least one criterion, and no worse than α_i by any of the criteria. An alternative is “non-dominated” if no other alternative dominates it. Non-dominated alternatives are thus straightforwardly preferable to the dominated ones: there is no criterion by which any dominated alternative is better than any non-dominated alternative. If the number of non-dominated alternatives is small, the non-dominated set can be presented to political decision makers who can then select between them on the basis of considerations beyond those that have been modeled. MultCSync implements a computationally efficient (polynomial-time) algorithm (developed in Sarkar and Garson [2004]) for computing the non-dominated set.

However, typically, the cardinality of the non-dominated set increases rapidly with the number of criteria (Sarkar and Garson 2004). In such a circumstance, the non-dominated set may be intractably large for use by decision-makers. It then becomes imperative to refine the non-dominated set, that is, produce a ranking among the non-dominated alternatives, so that some of them can be eliminated. This requires establishing preferences between the criteria and compounding this additional information with the rankings of the alternatives according to the criteria.

MultCSync provides three options for such refinement: (i) it allows the less important criteria to be dropped sequentially, leading to either (a) a new revised non-dominated set or (b) the elimination of some alternatives from the existing non-dominated set; (ii) it allows the use of the Analytic Hierarchy Process (AHP) (Saaty 1980) to produce a ranking of all the non-dominated alternatives; and (iii) it provides a modification of the AHP which brings it in accordance with standard multi-attribute value theory (MAVT) (Kamenetzky 1982; Belton 1986; Dyer 1990; Salo and Hämäläinen 1997). The AHP has routinely been used in the context of CAN design and selection, though without first excluding dominated members of the feasible alternatives set (Anselin *et al*. 1989; Mendoza and Sprouse 1989; Kangas 1993; Peterson *et al.*, 1994; Li *et al.* 1999; Mendoza and Prabhu 2000; Diaz-Balteiro and Romero 2001; Pesonen 2001; Reynolds 2001; Schmoldt and Peterson 2001; Clevenger *et al.* 2002; Villa *et al.* 2002; Ananda and Herath 2003). The two versions of the AHP that are implemented in MultCSync, the “relative” version and the “absolute” version, differ in the way in which the alternatives are ranked.

Under the relative version of the AHP, the priorities assigned to solutions are normalized such that the sum of the priorities for all solutions is equal to one, as specified by Saaty (1980) in his initial version of the AHP. However, this normalization process can have the counterintuitive result that the addition of a non-optimal alternative to a set can engender a rank reversal of the original set of alternatives.

The absolute version of the AHP avoids the possibility of rank reversal by using the maximum and minimum values of solutions relative to each criterion to normalize the priorities assigned to solutions, thus removing from the normalization process a dependency on the number of solutions under evaluation (Dyer 1990). This version of the AHP is consistent with multi-attribute value theory (MAVT). Additionally, regardless of which version of the AHP is used, once the user's preferences with respect to the relative importance of the different criteria are elicited, four different methods are applied to impose a unique ranking on the criteria (Saaty 1980), and the method that maximizes the consistency of the user's preferences (or that minimizes the consistency ratio) will then be used to rank the alternatives.

The initial explicit combination of the non-dominated set and methods (i) and (iii) make MultCSync unique among software packages for multi-criteria decision making. (For a review, see Belton and Stewart [2002].)

Chapter 2

The Main Program

MultCSync Version 1.0 consists of a single executable file (MultCSync.exe) and can be downloaded anywhere onto the user's hard drive. Additionally, the user has the option of using Gnuplot, a free software package for the graphical display of output, in conjunction with MultCSync. The windows version of Gnuplot can be downloaded from: http://www.ncftpd.com/download/.

The MultCSync interface is composed of a main interface (Figure 2.1), as well as a number of auxiliary screens.

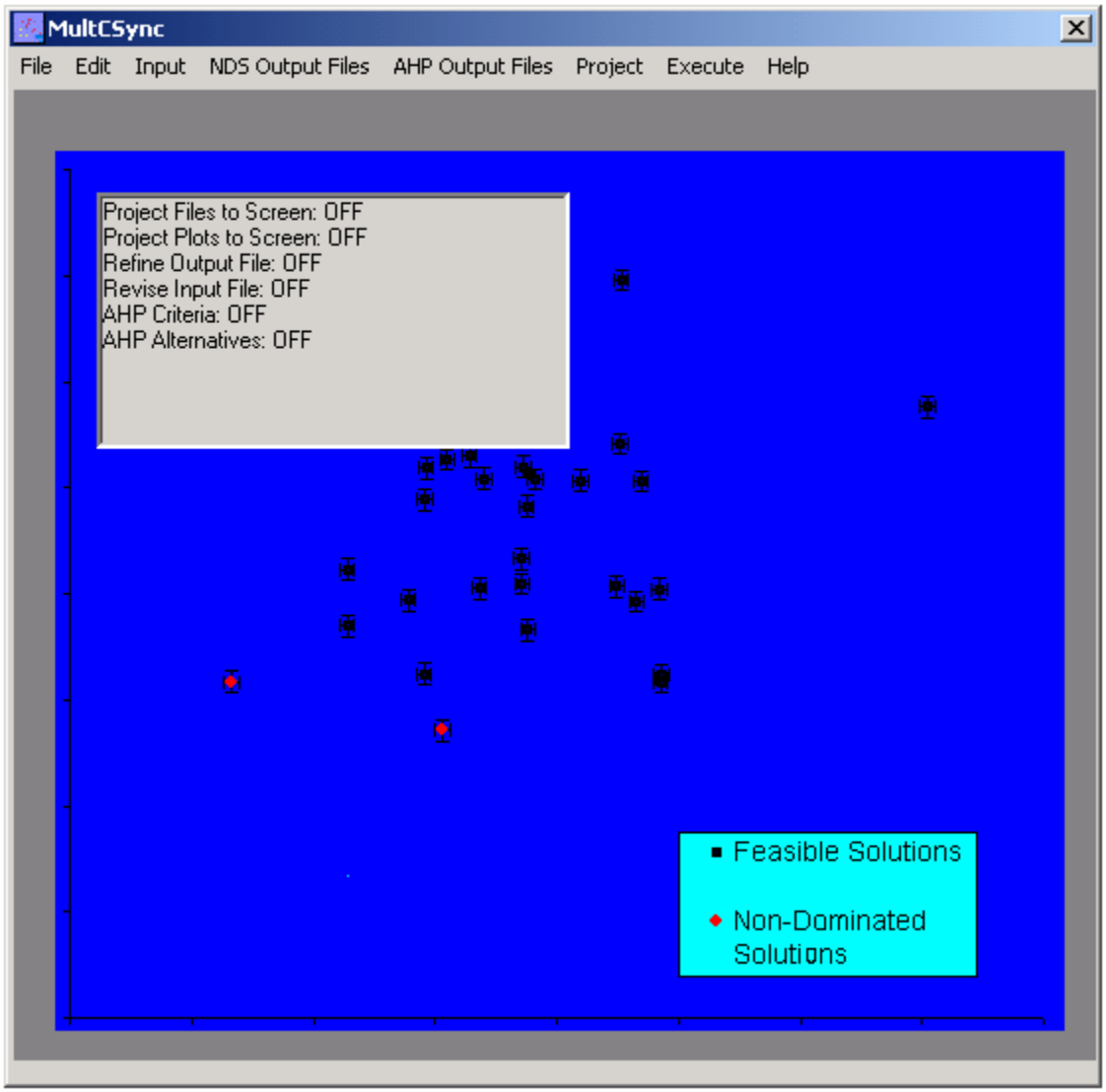

Figure 2.1. The main interface.

There are eight menu options and a progress window in the upper-left hand corner of the interface that informs the user about which options are currently activated (See Figure 2.1). (Upon execution, none of these options are activated; hence they are all labeled “OFF”.) However, instead of explaining the function of each menu item in turn, this manual will describe six different procedures for analyzing and representing a given data set. (See Appendix 1 for a summary of the function associated with each menu item.)

2.1. **Finding the Set of Non-Dominated Solutions**.

Given an **NDS input file** that contains the value for each alternative on each criterion, the following four steps can be performed to produce the **NDS output file**, which contains the non-dominated solutions. (See Chapter 3 for input and output file format.)

1. Under the “Input” menu heading, click “Input to NDS” (see Figure 2.2).

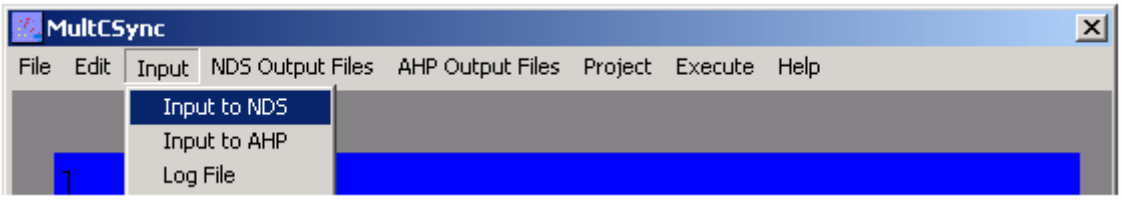

Figure 2.2. The input menu heading.

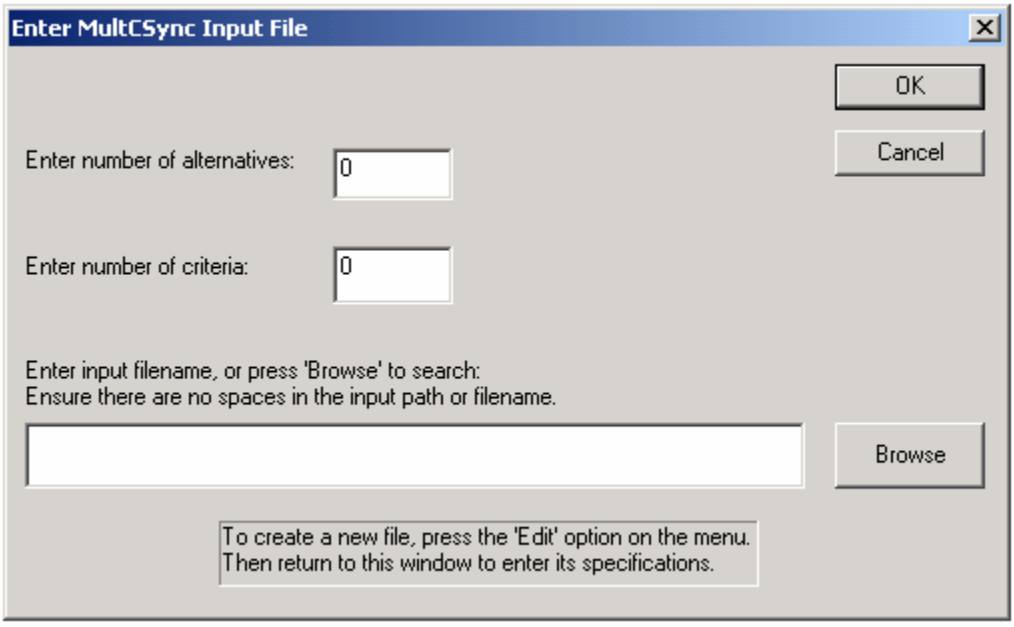

Figure 2.3. The NDS input file dialog box.

This opens the dialog box shown in Figure 2.3. Enter the number of alternatives (number of rows), the number of criteria (number of columns – 1), and the filepath for the **NDS input file** (or click "Browse" to search for the input file). Click "OK" after entering these values.

2. Under the "Input" menu heading, click "Log File" (see Figure 2.2.) This opens the dialog box shown in Figure 2.4. Enter the name of the **log file** into which information about the user settings will be written.

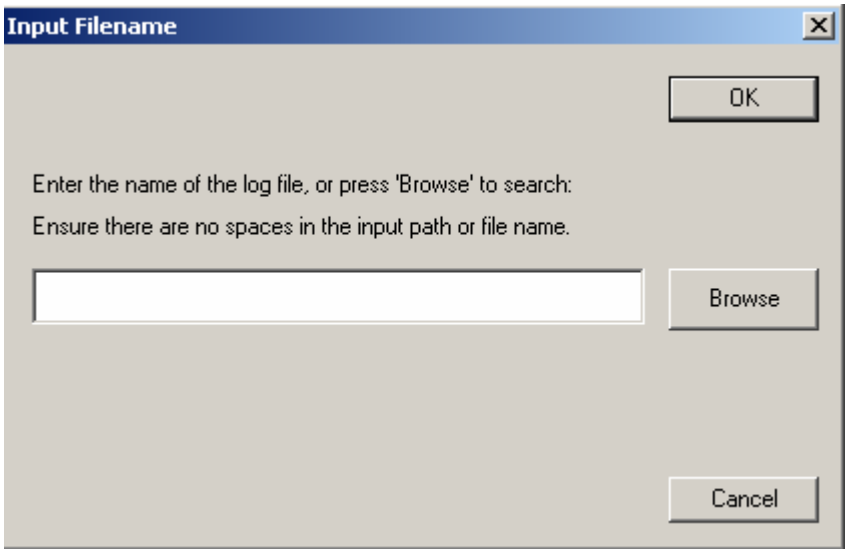

Figure 2.4. The log file dialog box.

3. Under the "NDS Output Files" menu heading, click "Basic Output" (see Figure 2.5). This opens the dialog box shown in Figure 2.6. Enter the filepath for the **NDS output file** (or click "Browse" to search for the output file). Ignore the box labeled "Enter total number of plots that should be produced". Click "OK" after entering the filepath.

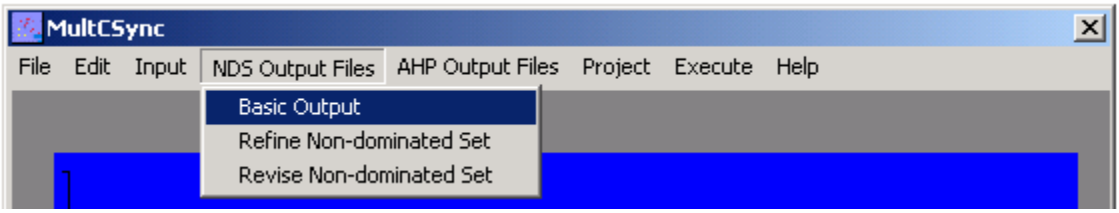

Figure 2.5. The NDS output files menu heading.

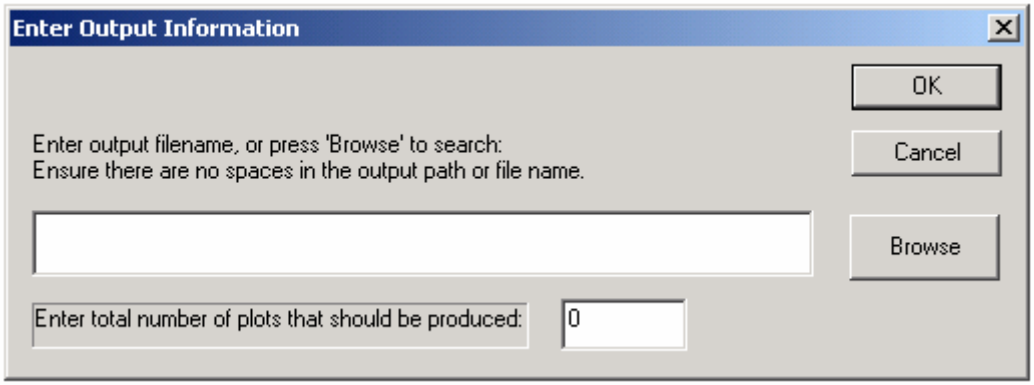

Figure 2.6. The NDS output file dialog box.

4. Under the “Execute” menu item, click “Execute NDS” (See Figure 2.7). After calculating the non-dominated solutions, the program will alert the user to the location of the **NDS output file** into which the solutions have been written.

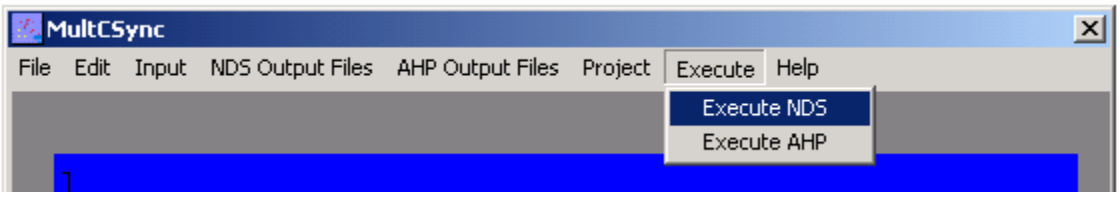

Figure 2.7. The execute menu heading.

2.2. **Refining the Set of Non-Dominated Solutions**.

It may be that the list of non-dominated solutions contained in the **NDS output file** is too large for a given purpose and hence must be refined. By “refining” an output file, what is meant is that a criterion, or set of criteria, is excluded from consideration, and only the set of alternatives that are non-dominated along the remainder of the criteria are retained. Therefore, in order to refine a set of non-dominated solutions, an **NDS output file** must have already been produced by carrying out the procedure described in Section 2.1.

Given an **NDS output file**, the following three steps can be performed to produce a **refined NDS output file**:

1. Carry out the procedure described in Section 2.1.

2. Under the “NDS Output Files” menu heading, click on “Refine Non-dominated Set” (see Figure 2.5). This opens the dialog box shown in Figure 2.8.

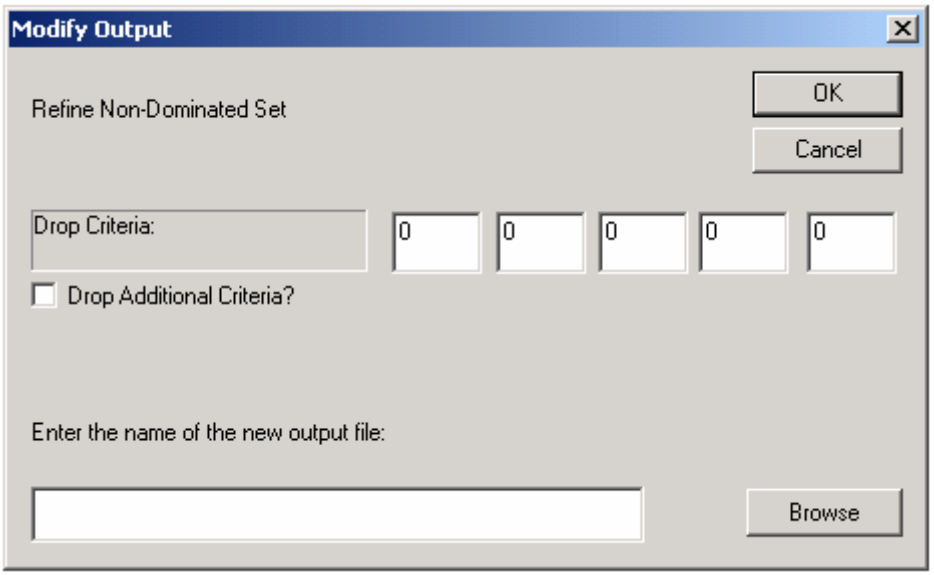

Figure 2.8. The refined NDS output file dialog box.

Beginning with the first of the five boxes next to “Drop Criteria”, enter the number of the criterion to be excluded from consideration. If there are more than five such criteria, then check the box labeled “Drop Additional Criteria?”. Enter the name of the output file for the **refined NDS output file**. Upon clicking “OK”, the progress window in the upper-left hand corner of the interface will reflect the updated settings; Figure 2.9 shows that the “Refine Output File” setting is “ON”.

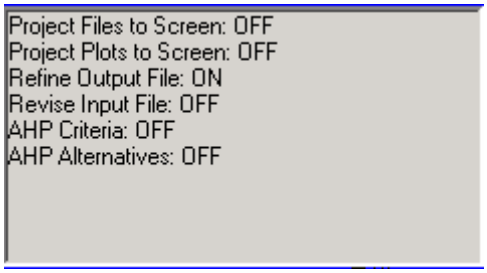

Figure 2.9. The updated progress window.

3. Under the “Execute” menu heading, click “Execute NDS” (see Figure 2.7). After refining the set of non-dominated solutions the program will alert the user to the location of the **refined NDS output file** into which the solutions have been written.

2.3. **Revising the Set of Non-Dominated Solutions**.

Instead of refining the set of non-dominated solutions once they have been created, one can exclude certain criteria from consideration before the non-dominated solutions have been calculated. By “revising” an input file, what is meant is that a criterion from the input file, or set of criteria, is excluded from consideration and the set of alternatives that are non-dominated across the remainder of the criteria are found. Therefore, unlike the procedure for refining the set of non-dominated solutions, the procedure for revising the set does not presuppose that an **NDS output file** has been produced.

Given an **NDS input file**, the following four steps can be performed to produce a **revised NDS output file**:

1. Under the “Input” menu heading, click “Input to NDS” (see Figure 2.2). This opens the dialog box shown in Figure 2.3. Enter the number of alternatives (number of rows), the number of criteria (number of columns – 1), and the filepath for the **NDS input file** (or click “Browse” to search for the input file). Click “OK” after entering these values.

2. Under the “Input” menu heading, click “Log File” (see Figure 2.2.) This opens the dialog box shown in Figure 2.4. Enter the name of the **log file** into which information about the user settings will be written.

3. Under the “NDS Output Files” menu heading, click on “Revise Non-dominated Set” (see Figure 2.5). This opens the dialog box shown in Figure 2.10. Notice that this dialog box is similar to that used to produce a refined output file (as in Figure 2.8); the only difference is the text. Beginning with the first of the five boxes next to “Drop Criteria”, enter the number of the criterion to be excluded from consideration. If there are more than five such criteria, then check the box labeled “Drop Additional Criteria?”. Enter the name of the output file for the **revised NDS output file**.

4. Under the “Execute” menu heading, click “Execute NDS” (see Figure 2.7). After revising the set of non-dominated solutions the program will alert the user to the location of the **revised NDS output file** into which the solutions have been written.

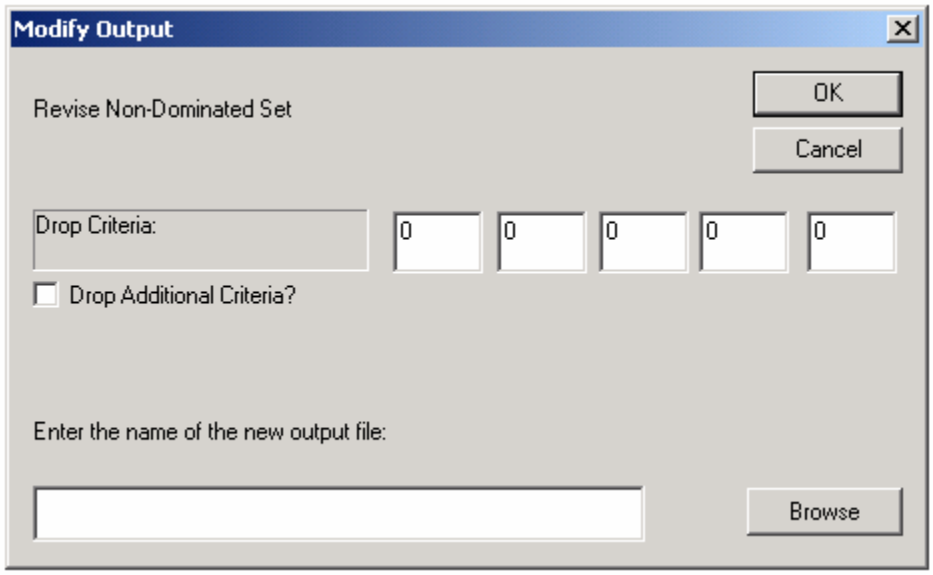

Figure 2.10. The revised NDS output file dialog box.

2.4. **Projecting Output to the Screen**.

There are two ways in which the set of non-dominated solutions can be projected to the screen. The first is that, after the non-dominated solutions are found, the **NDS output file** is automatically opened to the screen. Alternatively, if the user has installed Gnuplot (see page 7 on downloading instructions), the solutions can be automatically projected on a two-dimensional graph.

2.4.1 **Automatically Opening Output Files to the Screen**.

In order to automatically open the **NDS output file**, the **refined NDS output file**, or the **revised NDS output file** to the screen, the following two steps can be performed:

1. Under the “Project” menu heading, click “Project to screen” (see Figure 2.11). This opens a sub-menu. Under the sub-menu, click “Files”.

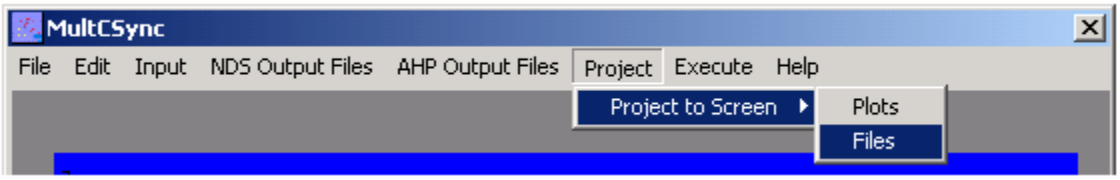

Figure 2.11. The project menu heading.

2. Create an **NDS output file** (Section 2.1), a **refined NDS output file** (Section 2.2), or a **revised NDS output file** (Section 2.3). The file will automatically open to the screen once it is created.

2.4.2 **Projecting the Output File to a Two-Dimensional Graph**.

As the number of criteria in the **NDS output file** may be greater than two, the user must specify which of the two criteria should be projected to Gnuplot, and how many different two-dimensional plots should be created. This can be done by performing the following 5 steps. Gnuplot must be installed on the computer. (See page 7 on downloading instructions.)

1. Under the “File” menu heading, click “Locate Gnuplot” (see Figure 2.12). This opens a dialog box that takes the pathname of Gnuplot. (The name of the Gnuplot executable is typically “wgnuplot.exe”).

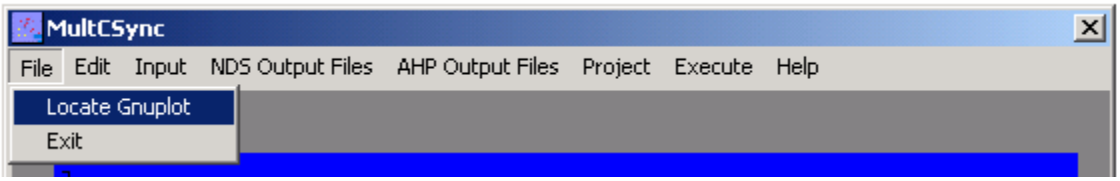

Figure 2.12. The file menu heading.

2. Under the “NDS Output Files” menu heading, click on “Basic Output” (see Figure 2.5). This opens the dialog box shown in Figure 2.6. After entering the name of the **NDS output file**, enter the number of plots that should be produced in the box labeled “Enter total number of plots that should be produced”. This opens the dialog box shown in Figure 2.13.

The program will automatically generate names for each **plot file** that will be produced. For example, if the name of the **NDS output file** is “C:\\MultSync_Output.txt”, and the user wants three different two-dimensional plots to be created, then the dialog box will create names for the three files, e.g., “C:\\MultSync_Output_plot_1.txt”. For each **plot file**, enter the two criteria that should be plotted in that file. An example is given in Figure 2.13.

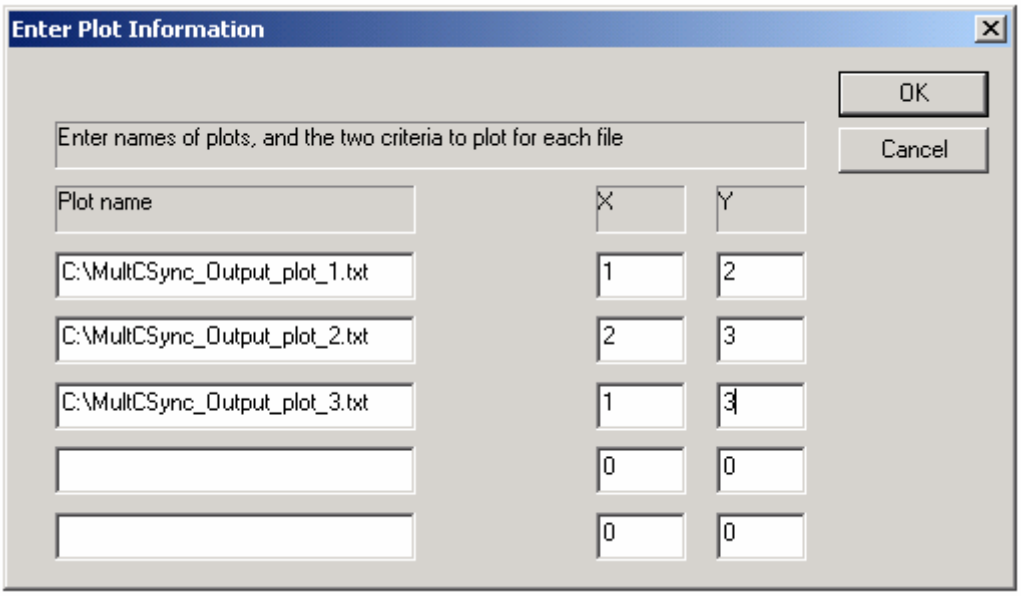

Figure 2.13. Plot information dialog box with example input.

3. Under the “Input” menu heading, click “Log File” (see Figure 2.2.) This opens the dialog box shown in Figure 2.4. Enter the name of the **log file** into which information about the user settings will be written.

4. Under the “Project” menu heading, click “Project to screen” (see Figure 2.11). This opens a sub-menu. Under the sub-menu, click “Plots”.

5. Under the “Execute” menu heading, click “Execute NDS” (see Figure 2.7). Each plot will be associated with two different **plot files**. One of these files will contain *only* the non-dominated solutions. This file will have a “nds.txt” suffix. The second file will contain *all* of the initial alternatives. This file will have a “all.txt” suffix. When each **plot file** has been created, then, assuming that Gnuplot can be opened, a set of Gnuplot windows will appear on the screen. (One window will be opened for each pair of **plot files**.) Figure 2.14 gives an example of a two-dimensional plot created by Gnuplot, in which criterion 1 and criterion 3 are plotted as specified by the example input shown in Figure 2.13. In this example, all of the feasible solutions are depicted as red crosses; the non-dominated solutions as black diamonds.

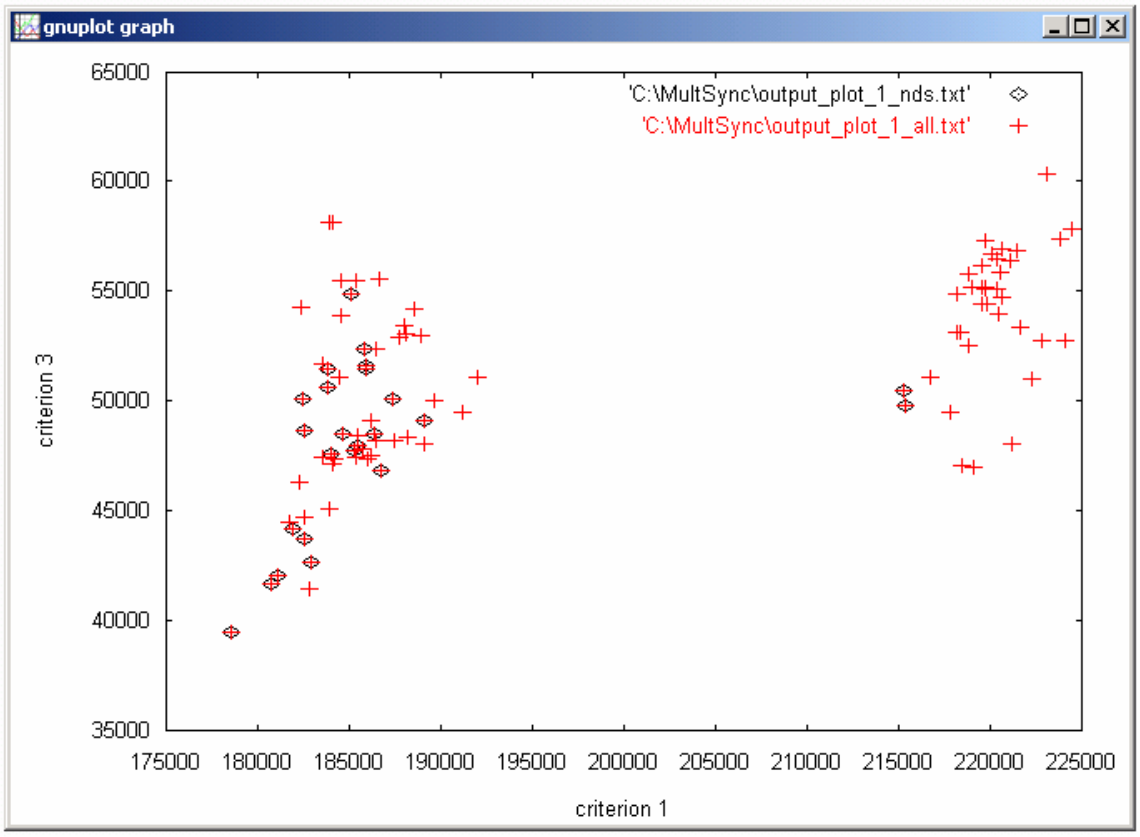

Figure 2.14. Example of two-dimensional plot created by Gnuplot.

2.5. **Ranking the Set of Criteria**.

In order to rank all of the non-dominated alternatives (the ranking of which will be contained in the **alternatives output file**), the user must first rank the criteria themselves in order of importance (the ranking of which will be contained in the **criteria output file**). In order to produce such a ranking, the user must provide MultCSync with information about his or her preferences regarding the criteria. This information will be stored in the **AHP preference file**. This file may be automatically created by MultCSync, or the user may supply it. This section will explain how to use MultCSync to create the **AHP preference file** and how to use that file to create the **criteria output file**. The next section (Section 2.6) will explain how to create the **alternatives output file**. The following 5 steps can be used to produce the **AHP preference file** and the **criteria output file**. (See Chapter 3 for input and output file format.) Note that there must be at least 3 criteria, and no more than 15 criteria.

1. Under the “Input” menu heading, click “Log File” (see Figure 2.2). This opens the dialog box shown in Figure 2.4. Enter the filepath for the **log file** (or click “Browse” to search for the **log file**). Click “OK” after entering the filepath.

2. Under the “Input” menu heading, click “Input to AHP” (see Figure 2.2). This opens the dialog box shown in Figure 2.15.

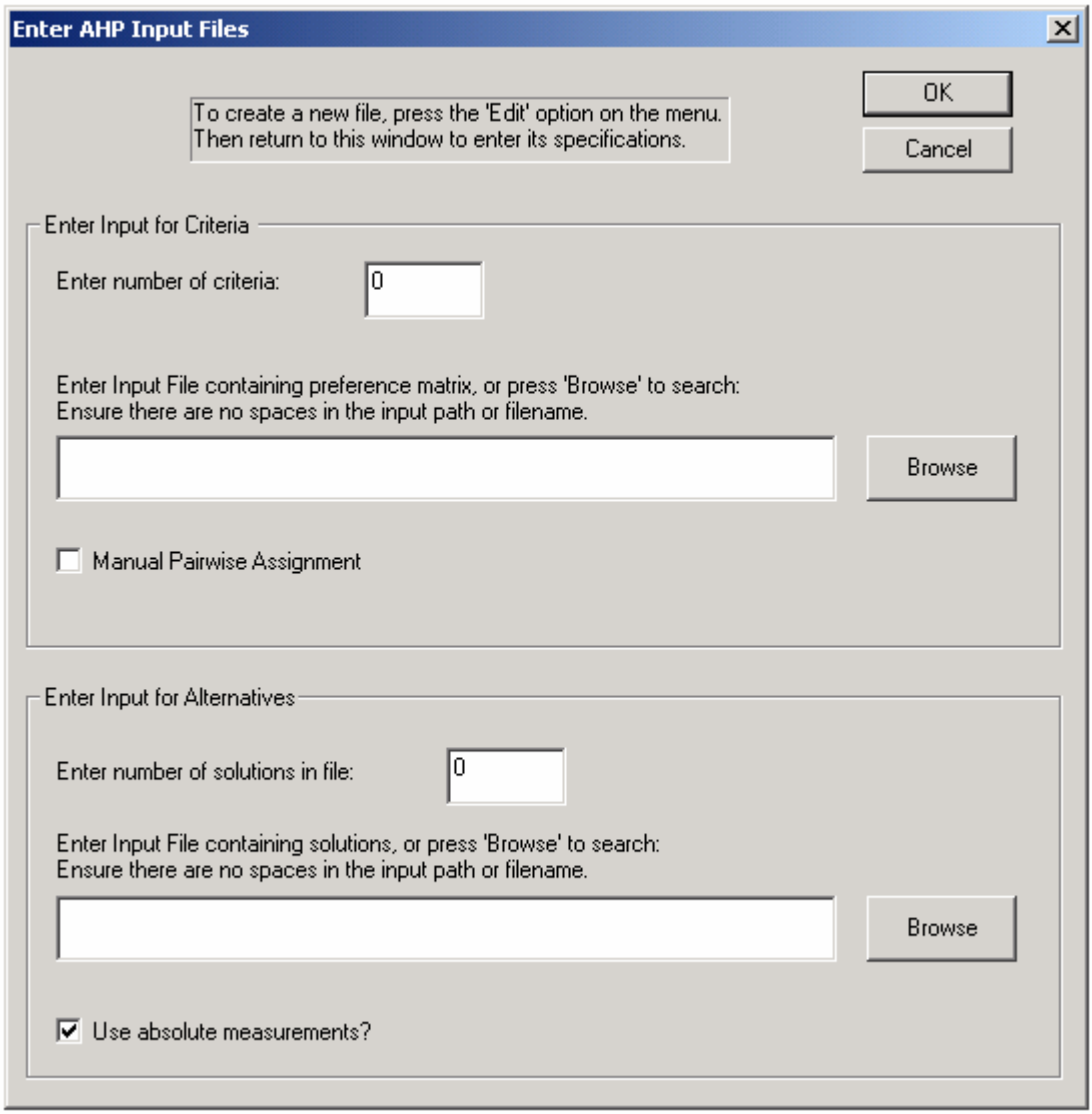

Figure 2.15. The AHP input file dialog box.

Enter the number of criteria to be ranked. If the process for finding non-dominated solutions (NDS) has already been executed, then this number will already be filled in, with the number of criteria set equal to the number of criteria found in the **NDS input file**. Enter the name of the **AHP preference file** to be created (or click “Browse” to search for a pre-existing **AHP preference file**).

There are two different ways to construct the **AHP preference file**. The user can either use MultCSync to construct the **AHP preference file** automatically, or the file can be constructed manually using a text editor. To use MultCSync to

construct the **AHP preference file** automatically, check the “Manual Pairwise Assignment” box. If this box has been checked, the program will aid the user in the construction of the matrix of pairwise comparisons used to determine the relative priorities of the criteria, and this matrix will be stored in the **AHP preference file**. (See step 3a below.) If this box has not been checked, the **AHP preference file** must be supplied by the user. (See step 3b below.) (It is recommended that beginning users of MultCSync check the “Manual Pairwise Assignment” box at this stage in the procedure, in that this option greatly simplifies the process by which the **AHP preference file** is constructed.) Ignore the section of the AHP input dialog box that is entitled “Enter Input for Alternatives” (a description of this section of the dialog box is presented below in Section 2.6). Click “OK” after entering these values.

3a. If the “Manual Pairwise Assignment” box has been checked, then after clicking “OK” in step 2, the Manual Pairwise Comparison dialog box will be opened. An example involving ten criteria is shown in Figure 2.16.

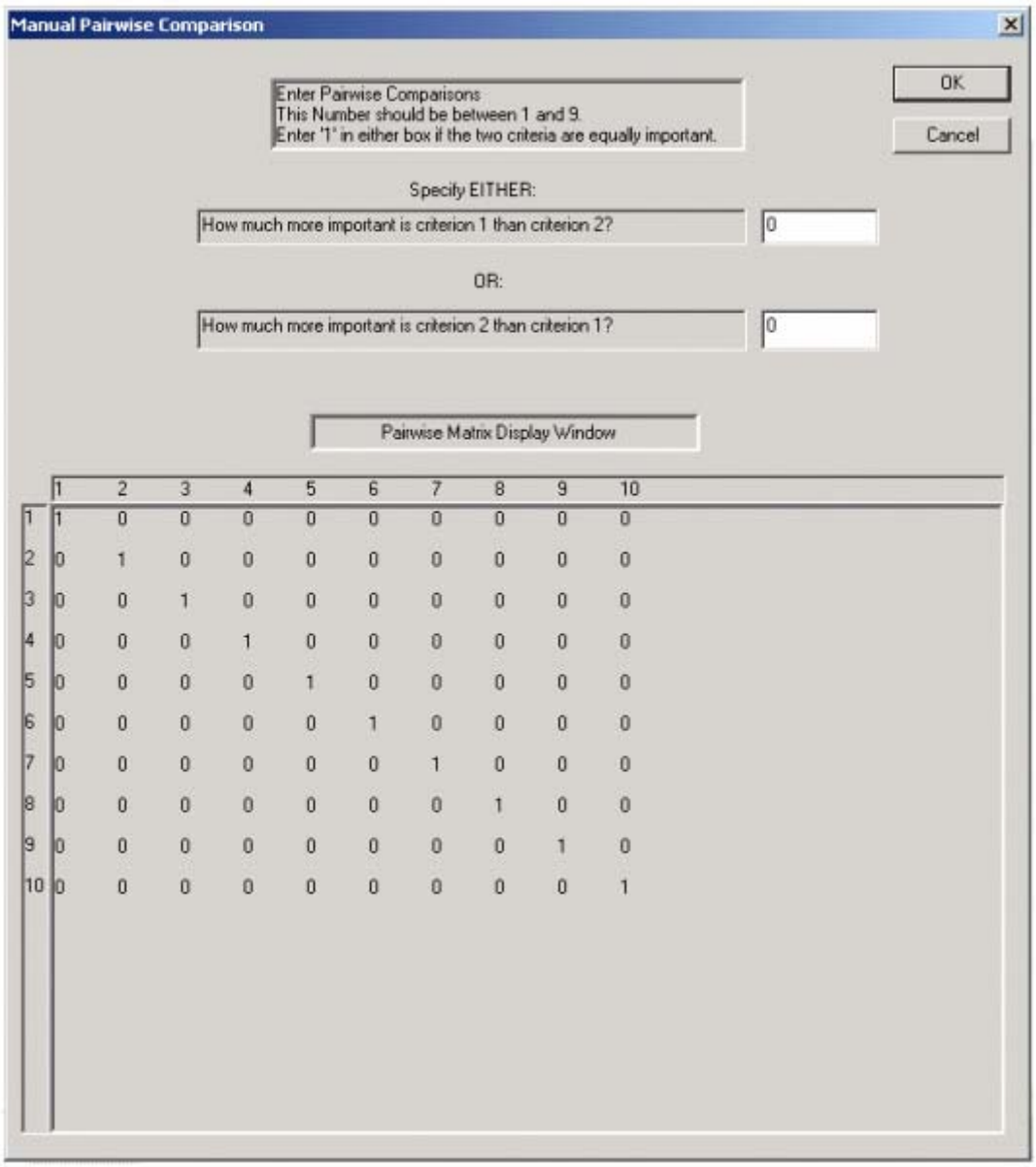

Figure 2.16. Example of manual pairwise comparison dialog box involving ten criteria.

In the “Manual Pairwise Comparison” dialog box, this comparison information is input as follows. In the top section of the dialog box, the user is questioned regarding the importance of two criteria (see Figure 2.17 for an example).

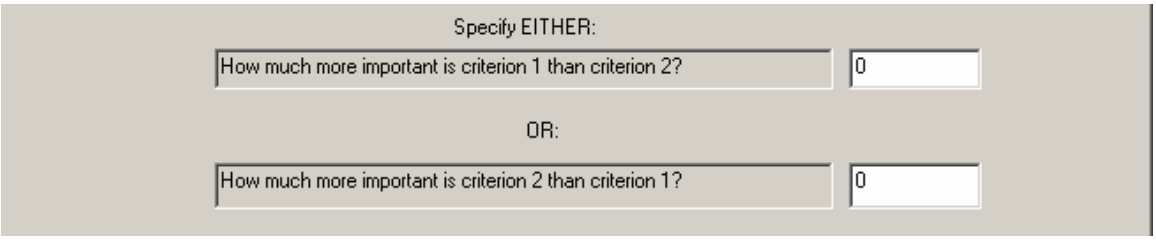

Figure 2.17. Example of criteria comparison boxes found in the manual pairwise comparison dialog box.

If criterion *i* is more important than criterion *j*, then the degree of importance should be entered into the box adjacent to the label, "How much more important is criterion *i* than criterion *j*?" If criterion *j* is more important than criterion *i*, then the degree of importance should be entered into the box adjacent to the label, "How much more important is criterion *j* than criterion *i*?" If the two criteria are of equal importance, then enter a '1' in either the top or bottom box, and click "OK".

(Typically, the scale of comparison is from 1 through 9. If the criterion *i* is as important as criterion *j*, then this relationship is represented by a 1; if criterion *i* is weakly more important than criterion *j*, then this relationship is represented by a 3; if criterion *i* is strongly more important than criterion *j*, then this relationship is represented by a 5; if criterion *i* is very strongly more important than criterion *j*, then this relationship is represented by a 7; and if criterion *i* is absolutely more important than criterion *j*, then this relationship is represented by a 9. The even numbers 2, 4, 6, and 8 are used to represent compromises between the above values.)

If there are *n* criteria to be weighted, then this procedure will be repeated $n(n-1)/2$ times. At each iteration, the pairwise matrix display window (shown in Figure 2.18) will be updated to reflect the user's previous comparisons. If, for example, a 2 had been entered into the top box, then the matrix would updated to the following state, shown by Figure 2.18. When the last comparison has been made, the pairwise matrix will be constructed and saved in the **AHP preference file**.

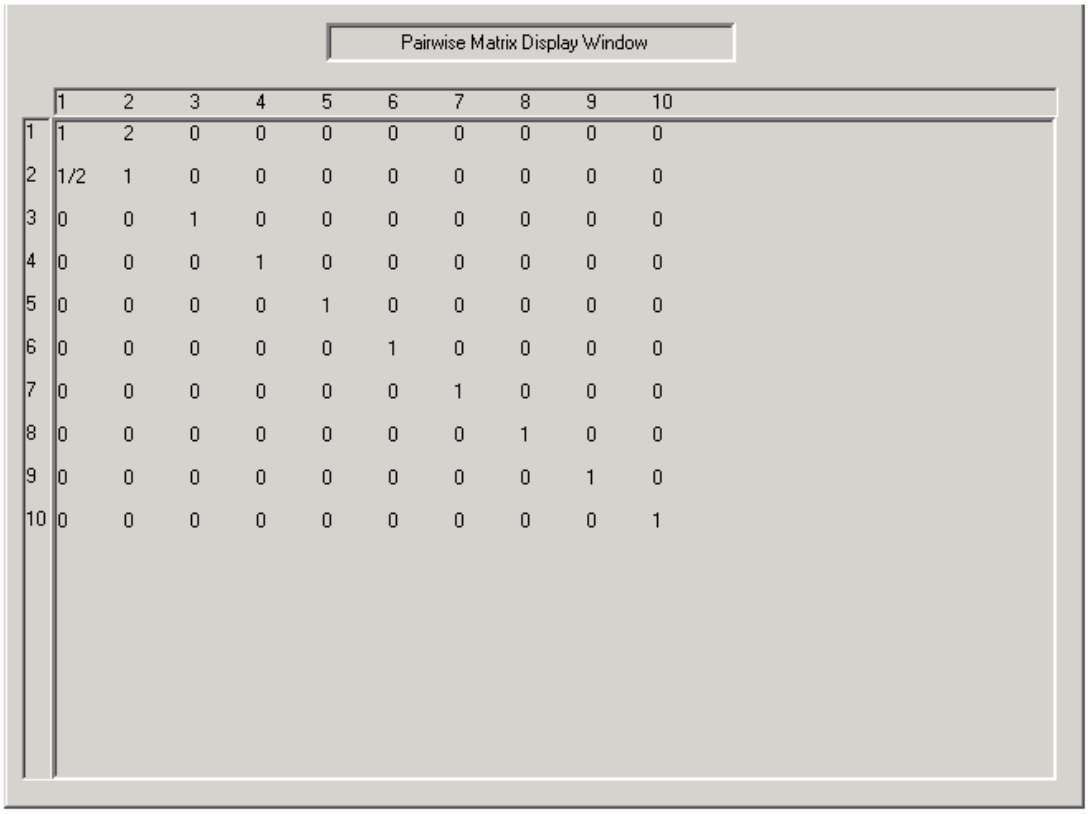

Figure 2.18. Example of updated pairwise matrix display window.

3b. Alternatively, if the "Manual Pairwise Assignment" box is not checked, then the filepath entered for the **AHP preference file** will need to correspond to an existing file. (At any point, the user may open a text editor to create such a file by going under the "Edit" menu of the main interface and clicking "Open File".)

4. Under the "AHP Output Files" menu heading, click "Criteria Output File" (see Figure 2.19). This opens the dialog box shown in Figure 2.20. Enter the filepath for the **criteria output file** (or click "Browse" to search for the output file). (See Chapter 3 for the output file format.) Click "OK" after entering the filepath.

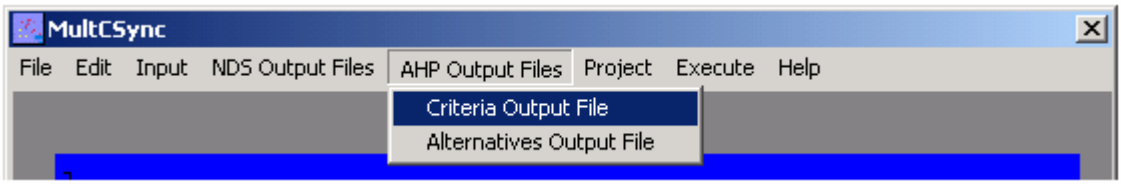

Figure 2.19. The AHP output files menu heading.

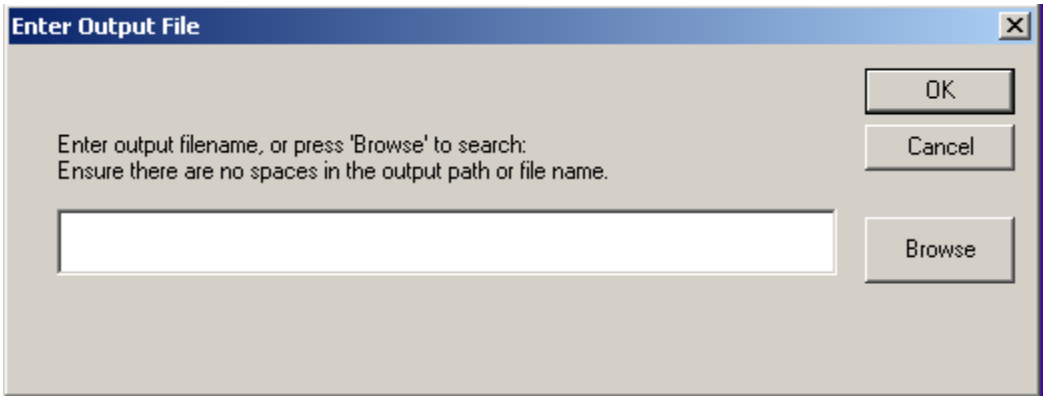

Figure 2.20. The output file dialog box.

5. Under the “Execute” menu heading, click “Execute AHP” (See Figure 2.7). After calculating the relative priorities, the program will alert the user as to the filepath of the **criteria output file**, where the priority information is stored.

The priority information will also be printed directed to the screen, as shown in Figure 2.21.

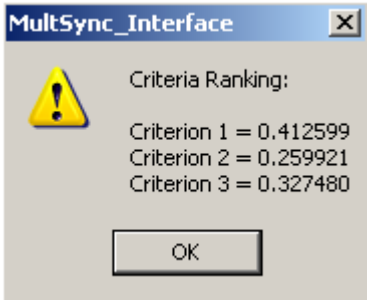

Figure 2.21. Example criteria ranking.

2.6. **Ranking the Set of Alternatives**.

Once the relative priorities of a set of criteria have been determined, this information can be used to rank the set of alternatives that have been evaluated on the basis of these criteria. Given an **NDS input file** and a **criteria output file**, the following 4 steps can be used to produce an **alternatives output file**. (See Chapter 3 for input and output file format.)

1. Under the “Input” menu heading, click “Log File” (see Figure 2.2). This opens the dialog box shown in Figure 2.4. Enter the filepath for the **log file** (or click “Browse” to search for the **log file**). Click “OK” after entering the filepath.

2. Under the “Input” menu heading, click “Input to AHP” (see Figure 2.2). This opens the AHP Input File dialog box shown in Figure 2.15. In the top portion of

the dialog box, enter the number of criteria in the **AHP preference file**, and enter the filepath of the **AHP preference file**. In the bottom portion of the box, enter the number of alternatives in the **NDS input file**, and enter the filepath of the **NDS input file**. Note that the number of criteria in the **AHP preference file** must be equal to the number of criteria in the **NDS input file**. Additionally, since the **NDS input file** and the **NDS output file** have the same format, the **NDS output file** produced by an earlier run (see Section 2.1) can be used as input to this procedure.

The box labeled "Use absolute measurements?", as shown in Figure 2.22, records whether or not the final ranking of the alternatives will be determined using the relative or absolute version of the AHP (see Introduction). The default setting is the absolute version, which avoids the problem of rank reversal. To change from the absolute to the relative version, click the box to remove the checkmark. Click "OK" when all of this information has been recorded.

Figure 2.22. Absolute measurement box.

3. Under the "AHP Output Files" menu heading, click "Alternatives Output File" (see Figure 2.19). This opens the dialog box shown in Figure 2.20. Enter the filepath for the **alternatives output file** (or click "Browse" to search for the output file). Click "OK".

4. Under the "Execute" menu item, click "Execute AHP" (See Figure 2.7). After calculating the relative priorities of the solutions, the program will alert the user to the location of the **alternatives output file** into which the priorities of the solutions have been written.

Chapter 3

Input and Output File Formats

There are two types of input files that are used by MultCSync: the **NDS input file,** and the **AHP preference file**. The **AHP preference file** can be automatically produced (see Section 2.5). However, if the user manually creates the **AHP preference file**, then it must be created using the format specified below.

3.1 Input file formats.

The **NDS input file** must have the following format:

(i) the number of rows must be equal to the number of alternatives that are being analyzed; and

(ii) the number of columns must be equal to n + 1, where n is the total number of criteria. Each column must consist of the following data:

Column 1: this is the identification number for the alternative. This must be an integer;

Column i +1: the value of each alternative for criterion i.

The **AHP preference file** must have the following format:

(i) the number of rows must be equal to n, and the number of columns must be equal to n, where n is the total number of criteria. Hence the **AHP preference file** represents an n x n matrix; and

(ii) for any cell, x_{ij}, of the matrix, where i is the row number and j is the column number, x_{ij} must contain a number representing the strength of the user's preference for i over j. If j is preferred to i, then x_{ij} must contain the inverse of the strength of the user's preference for j over i.

3.2 Output file formats.

There are 7 types of output file that the program can produce. They are the **log file**, the **NDS output file**, the **refined NDS output file**, the **revised NDS output file**, the **criteria output file**, the **alternatives output file**, and the **plot file**.

The **NDS output file**, **refined NDS output file**, and **revised NDS output file** all have the same format:

(i) the number of rows is equal to the number of non-dominated solutions; and

(ii) the number of columns is equal to *n* + 1, where *n* is the total number of criteria. Each column consists of the following data:

Column 1: this is the identification number for the alternative;

Column *i* +1: the value of each alternative for criterion *i*.

Since all of these output files have the same format as the **NDS input file**, the output for a given run can be used as the input file for a new run.

The **criteria output file** has the following format:

(i) the first item specifies the method (Method 1, 2, 3, or 4), that produced the most consistent ranking of criteria (see Introduction on the four methods);

(ii) the second item is a list of each criterion and its associated priority. Thus if there are *n* criteria, this item will consist of *n* rows, each of the following form:

For criterion *n*: *r*

where *r* is the priority of criterion *n*;

(iii) the third item specifies the consistency ratio of the most consistent method; and

(iv) the fourth item specifies that, “a consistency ratio of 0.10 or less is acceptable”.

The **alternatives output file** has the following format: the number of rows is equal to the number of alternatives that are prioritized. Each row has the following form:

Alternative *n* = *r*

where *r* is the ranking of the *n*th best alternative. (Note that the alternative with the lowest *r* is the “optimal” alternative given the criteria ranking.)

There are two different **plot files**. One contains all of the non-dominated solutions, and the other contains all alternatives. The first has a “_nds.txt” suffix, and the second has a “_all.txt” suffix. Each **plot file** has the following format:

(i) a header that provides instructions for manually opening the output file in Gnuplot (each line of this header is prefixed with "#");

(ii) beneath the header, there are *n* rows. For the **plot file** with only non-dominated solutions, *n* is the number of non-dominated solutions. For the **plot file** with all alternatives, *n* is the number of alternatives;

(iii) there are 2 columns. The first column represents the value of each alternative for the criterion to be plotted along the x-axis, and the second column represents the value of each alternative for the criterion to be plotted along the y-axis.

The **log file** contains a record of all the most relevant information during a run of the program. A **log file** is generated each time either "Execute NDS" or "Execute AHP" is chosen from the "Execute" menu item. All log files contain the following information about the input to the program for each run:

NDS input file	Filename/NA
Number of alternatives	Number of alternatives
Number of criteria	Number of criteria
NDS output file	Filename/NA
Refined NDS output file	Filename/NA
Number of criteria excluded	Number of criteria excluded
Revised NDS output file	Filename/NA
Number of criteria excluded	Number of criteria excluded
AHP preference file	Filename/NA
Number of criteria	Number of criteria
AHP solutions file	Filename/NA
Number of alternatives	Number of alternatives
Absolute measurement	Yes/No
Criteria output file	Filename/NA
Alternatives output file	Filename/NA
Project files to screen	Yes/No

Project plots to screen	Yes/No
Number of plots to be produced	Number of plots to be produced
Location of gnuplot	Filename/NA

In addition, if criteria are excluded using either the refine or revise NDS output options, those criteria that have been excluded will be listed in the log file. If projects or files are plotted to the screen, a list of the locations of these plots, along with the criteria plotted in them, will likewise be listed.

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Appendix 1

Index of Functions of Menu Items

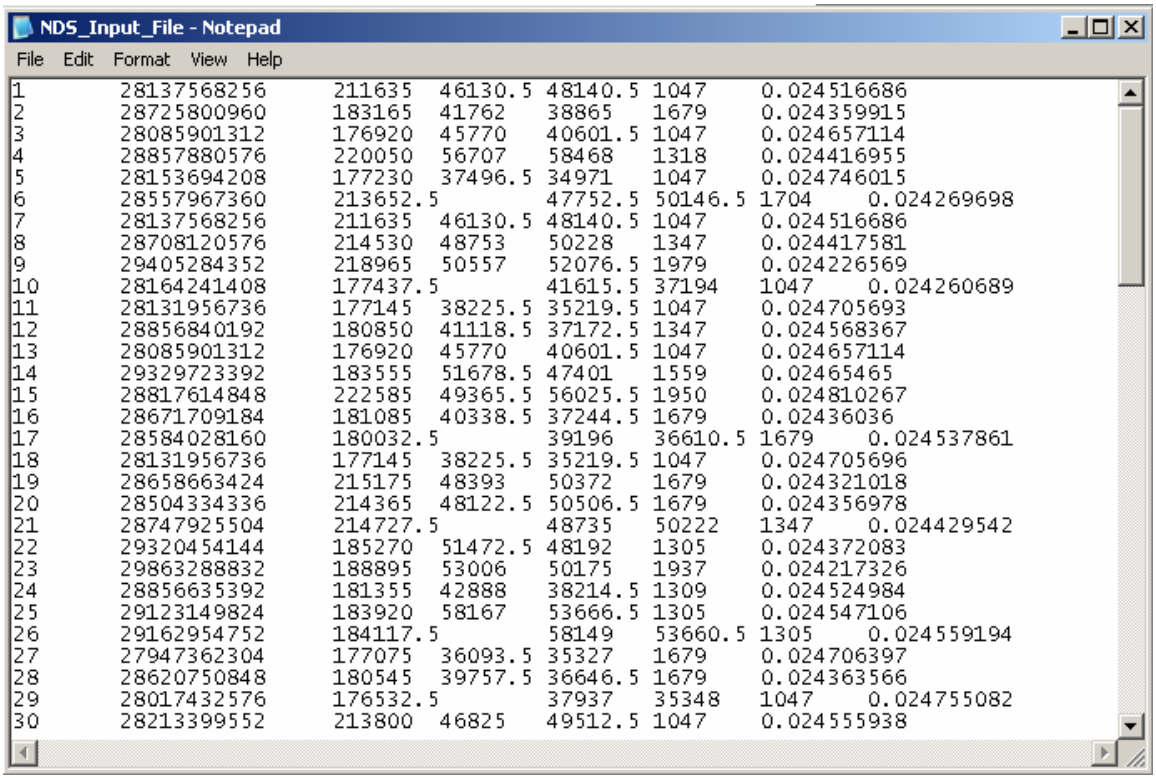
This appendix provides a brief description of the function of each menu item. The first column lists each menu heading; the second, items that fall under that heading; the third, a description of that item's function; and the fourth, the page number in which a procedure involving that function, is described.

Menu Heading	Menu Items	Function	Page
File	Locate Gnuplot	Specify location of Gnuplot plotting software	14
	Exit	Exit program	-
Edit	Open File	Create a new input file or open an existing file	21
Input	Input to NDS	Specify location and structure of NDS input file	8
	Input to AHP	Specify location and structure of AHP preference file and location of NDS file to be ranked	17
	Log File	Specify name and location of log file to be created	9
NDS Output Files	Basic Output	Specify name and location of NDS output file to be created	9
	Refine Non-dominated Set	Specify name and location of refined NDS output file to be created	10
	Revise Non-dominated Set	Specify name and location of revised NDS output file to be created	12
AHP Output Files	Criteria Output File	Specify name and location of criteria output file to be created	21
	Alternatives Output File	Specify name and location of alternatives output file to be created	23
Project	Plots	Plot two-dimensional graphs to screen upon execution	15
	Files	Open NDS output file to screen upon execution	13
Execute	Execute NDS	Find non-dominated solutions from NDS input file	4
	Execute AHP	Rank alternatives from NDS file and AHP preference file	22

Appendix 2

Sample MultCSync Run

This appendix provides a sample run of MultCSync, using data procured for a conservation project in north-central Namibia. The **NDS input file** (Figure A2.1) is the only input file that is necessary for running MultCSync. The input file that will be used in this appendix contains information on 100 alternative conservation plans, or "alternatives", each of which is ranked according to six criteria. Thus the input file shown below contains 100 rows and seven columns. (The first column contains the numeric ID for each alternative.) Note that if a criterion should be maximized instead of minimized, then the values associated with that criterion should be the inverse of the actual value, as in the seventh column shown below.




```
1       28137568256     211635  46130.5 48140.5 1047    0.024516686
2       28725800960     183165  41762   38865   1679    0.024359915
3       28085901312     176920  45770   40601.5 1047    0.024657114
4       28857880576     220050  56707   58468   1318    0.024416955
5       28153694208     177230  37496.5 34971   1047    0.024746015
6       28557967360     213652.5        47752.5 50146.5 1704    0.024269698
7       28137568256     211635  46130.5 48140.5 1047    0.024516686
8       28708120576     214530  48753   50228   1347    0.024417581
9       29405284352     218965  50557   52076.5 1979    0.024226569
10      28164241408     177437.5        41615.5 37194   1047    0.024260689
11      28131956736     177145  38225.5 35219.5 1047    0.024705693
12      28856840192     180850  41118.5 37172.5 1347    0.024568367
13      28085901312     176920  45770   40601.5 1047    0.024657114
14      29329723392     183555  51678.5 47401   1559    0.02465465
15      28817614848     222585  49365.5 56025.5 1950    0.024810267
16      28671709184     181085  40338.5 37244.5 1679    0.02436036
17      28584028160     180032.5        39196   36610.5 1679    0.024537861
18      28131956736     177145  38225.5 35219.5 1047    0.024705696
19      28658663424     215175  48393   50372   1679    0.024321018
20      28504334336     214365  48122.5 50506.5 1679    0.024356978
21      28747925504     214727.5        48735   50222   1347    0.024429542
22      29320454144     185270  51472.5 48192   1305    0.024372083
23      29863288832     188895  53006   50175   1937    0.024217326
24      28856635392     181355  42888   38214.5 1309    0.024524984
25      29123149824     183920  58167   53666.5 1305    0.024547106
26      29162954752     184117.5        58149   53660.5 1305    0.024559194
27      27947362304     177075  36093.5 35327   1679    0.024706397
28      28620750848     180545  39757.5 36646.5 1679    0.024363566
29      28017432576     176532.5        37937   35348   1047    0.024755082
30      28213399552     213800  46825   49512.5 1047    0.024555938
```

Figure A2.1. Example NDS input file. Each row represents an alternative. (Not all rows are shown.) The first column contains the numeric ID for each alternative; the remaining six columns contain the score for that alternative on each of the six criteria, respectively. The first five criteria are to be minimized, and so each of the values that appear in these columns are positive. The sixth criterion is to be maximized, and so the values that appear in this column are the inverse of the actual value.

Upon executing MultCSync, the main interface opens (Figure A2.2). Under the "Input" menu heading, "Input to NDS" is selected in order to enter the information about the **NDS input file**.

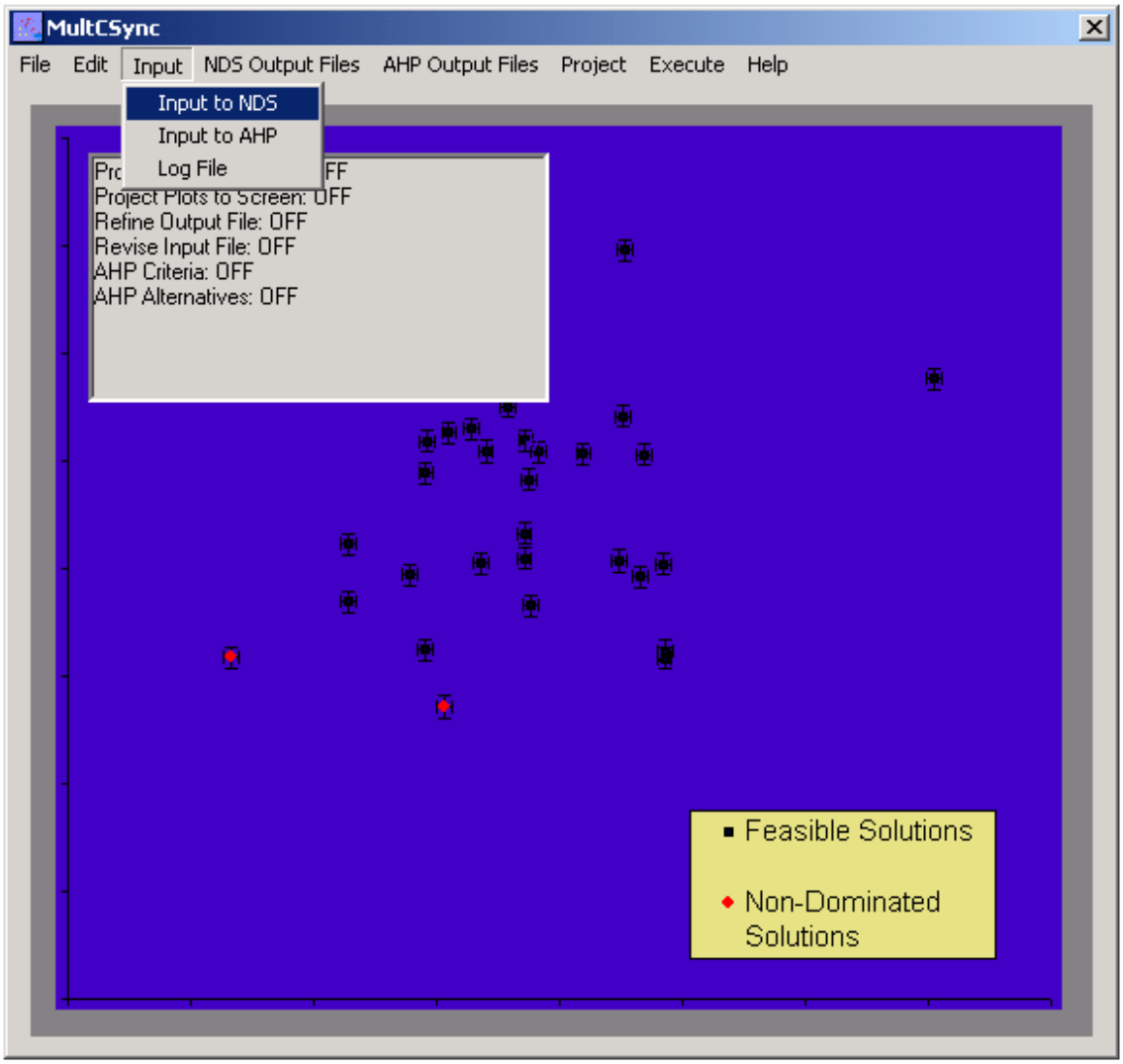


Figure A2.2. The main interface.

This elicits the dialog box shown in Figure A2.3, into which user enters the number of alternatives (100), the number of criteria (6), and the filename and path for the **NDS input file** ("C:\\NDS_Input_File.txt").

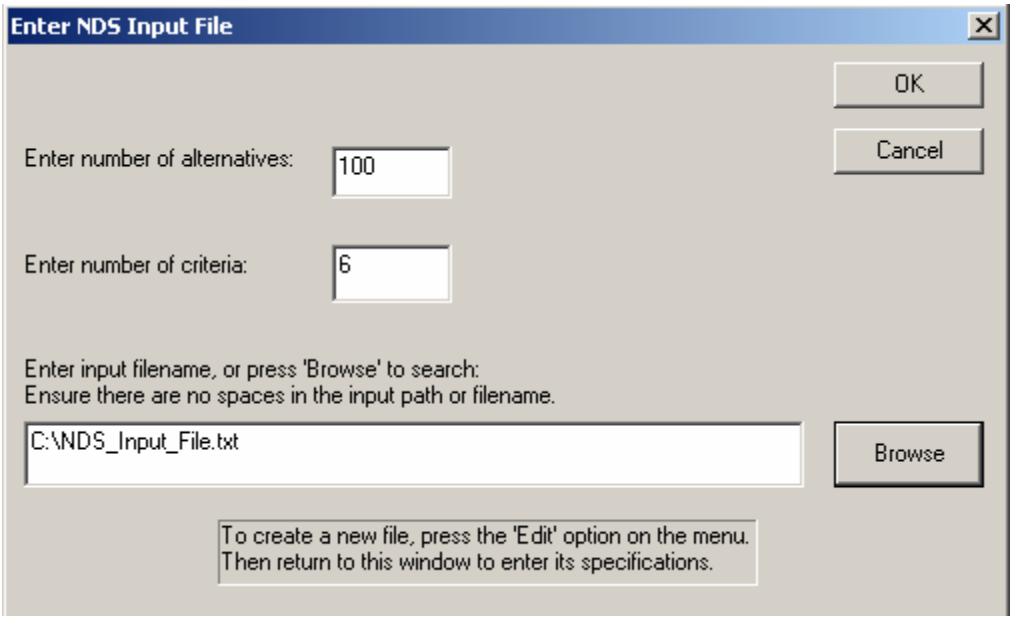


Figure A2.3. Example NDS input dialog box. In this example, the number of alternatives is set at 100, the number of criteria is set at 6, and the filename and pathway for the **NDS input file** is set as "C:\NDS_Input_File.txt."

After clicking "OK," and returning to the main interface, "Basic Output" is selected from the "NDS Output Files" menu heading (see Figure A2.2). This elicits a dialog box that prompts the user for the filename and pathway of the **NDS output file**, into which information about the non-dominated alternatives is written (Figure A2.4).

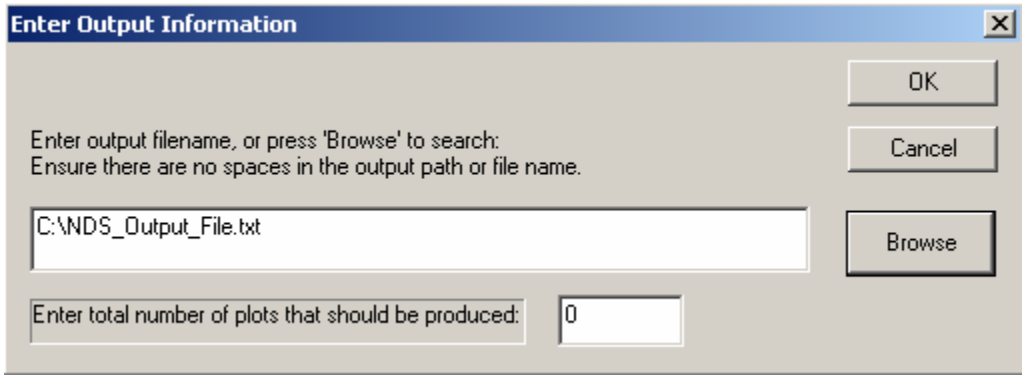


Figure A2.4. Example NDS output file dialog box. In this case, the **NDS output file** is called "C:\NDS_Output_File.txt."

After clicking "OK," and exiting the NDS output file dialog box, "Log File" is selected from the "Input" menu heading of the main interface. This elicits the log file dialog box (see Figure A2.5), into which the user enters the filename and pathway of the **log file**.

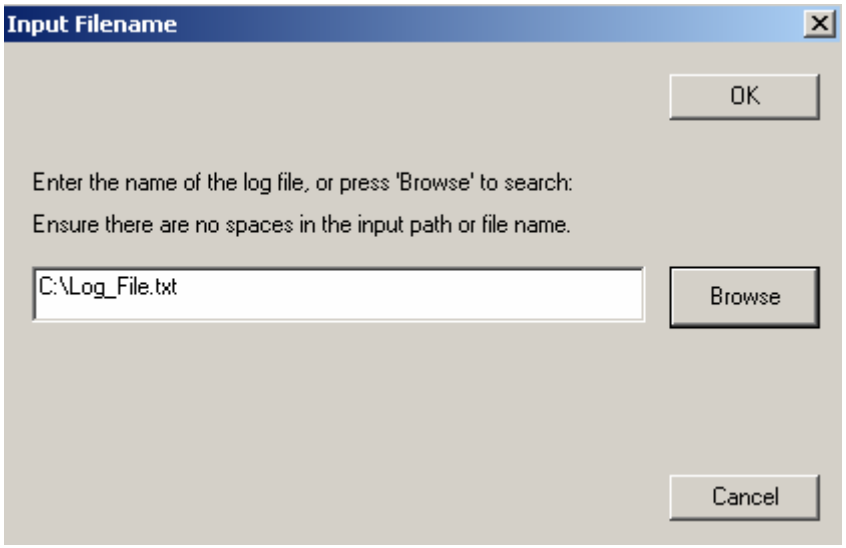


Figure A2.5. Example log file dialog box. In this example the **log file** is called "C:\Log_File.txt."

After clicking "OK," and returning to the main interface, "Execute NDS" is selected from the "Execute" menu heading. This executes the algorithm that computes the non-dominated solutions. The user is alerted once the computation is finished and the non-dominated alternatives have been written into the **NDS output file** (see Figure A2.6). In this example, there are 33 non-dominated alternatives out of the initial 100 alternatives. These are indexed by the numeric ID of the alternative (which appears in the first column), and the information is in the same format as in the **NDS input file**. Consequently, the output file from one run of MultCSync can be used as the input file to a new one.

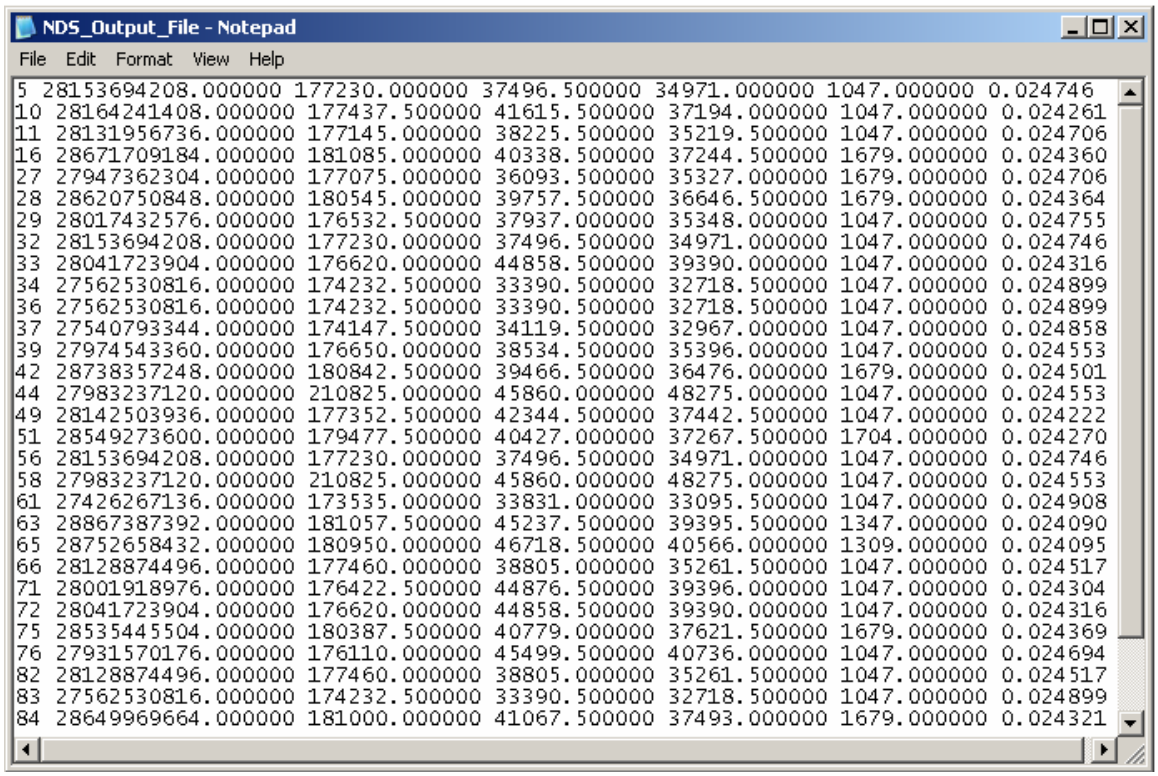


Figure A2.6. Example NDS output file. Each row represents a non-dominated solution. (Not all rows are shown.)

It may be that 33 non-dominated alternatives is too large a set to present to decision makers, and therefore the set should be refined. One way of doing this is by excluding one or more of the criteria from consideration and determining that subset of initial non-dominated alternatives that remains non-dominated after the exclusion. In the following example, the first criterion will be excluded.

Under the “NDS Output Files” menu heading, the user selects “Refine Non-dominated Set”. This elicits the dialog box shown in Figure A2.7. As can be seen, the user can simultaneously exclude several criteria from consideration. Here, as only criterion 1 is being excluded, the user inserts a ‘1’ into the box to the left of “Drop Criteria:”. The filename and path of the **refined NDS output file** (in this example, “C:\NDS_Output_file_refined.txt”) is entered into the box below that.

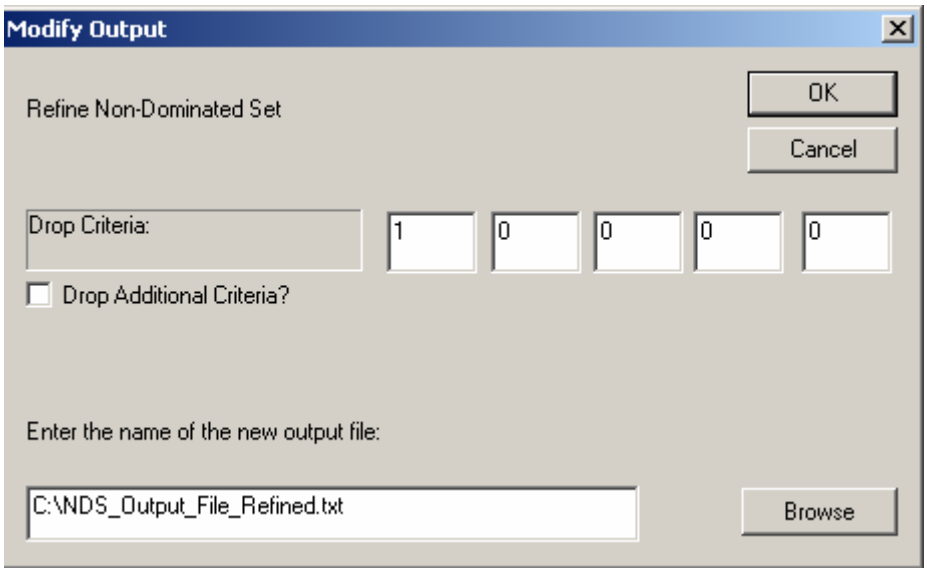


Figure A2.7. The refined NDS output file dialog box.

After entering this information, the user checks “OK” and returns to the main interface. “Execute NDS” is selected from under the “Execute” menu heading of the main interface. MultCSync then calculates the number of non-dominated solutions resulting from the elimination of criterion 1, and after the calculation has been completed, the user is alerted to the number of non-dominated solutions in the **refined NDS output file**, and the location of that file. (See Figure A2.8.) As can be seen, the exclusion of the first criterion only reduced the number of non-dominated alternatives by three; there are now 30 such alternatives. Because the removal of criterion 1 did not substantively affect the set of non-dominated solutions, the user may decide to readmit this criterion into consideration. For the remainder of this example, then, all 33 of the initially identified non-dominated solutions will be taken into consideration, and the AHP process employed to rank this set of alternatives.

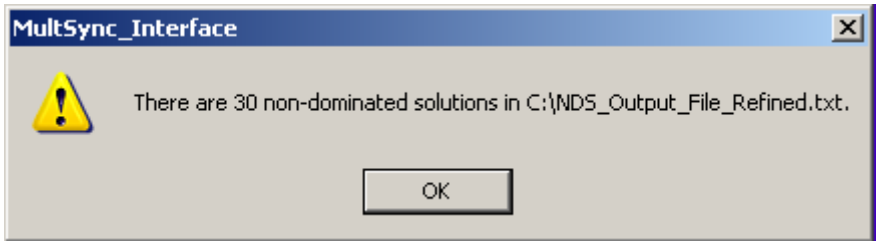


Figure A2.8. Example message after the refining process has executed.

To apply the AHP so as to rank the 33 non-dominated alternatives, the relative priorities of the six criteria must first be determined. “Input to AHP” is selected from the “Input” menu heading of the main interface, eliciting the AHP input file dialog box (see Figure A2.9). Some of the relevant information is automatically filled in: the number of criteria (6) is automatically set equal to the number of

criteria in the **NDS input file**, and the input file containing the 33 non-dominated alternatives is automatically set to the filename and pathway of the **NDS output file**. The user enters the number of non-dominated solutions (33).

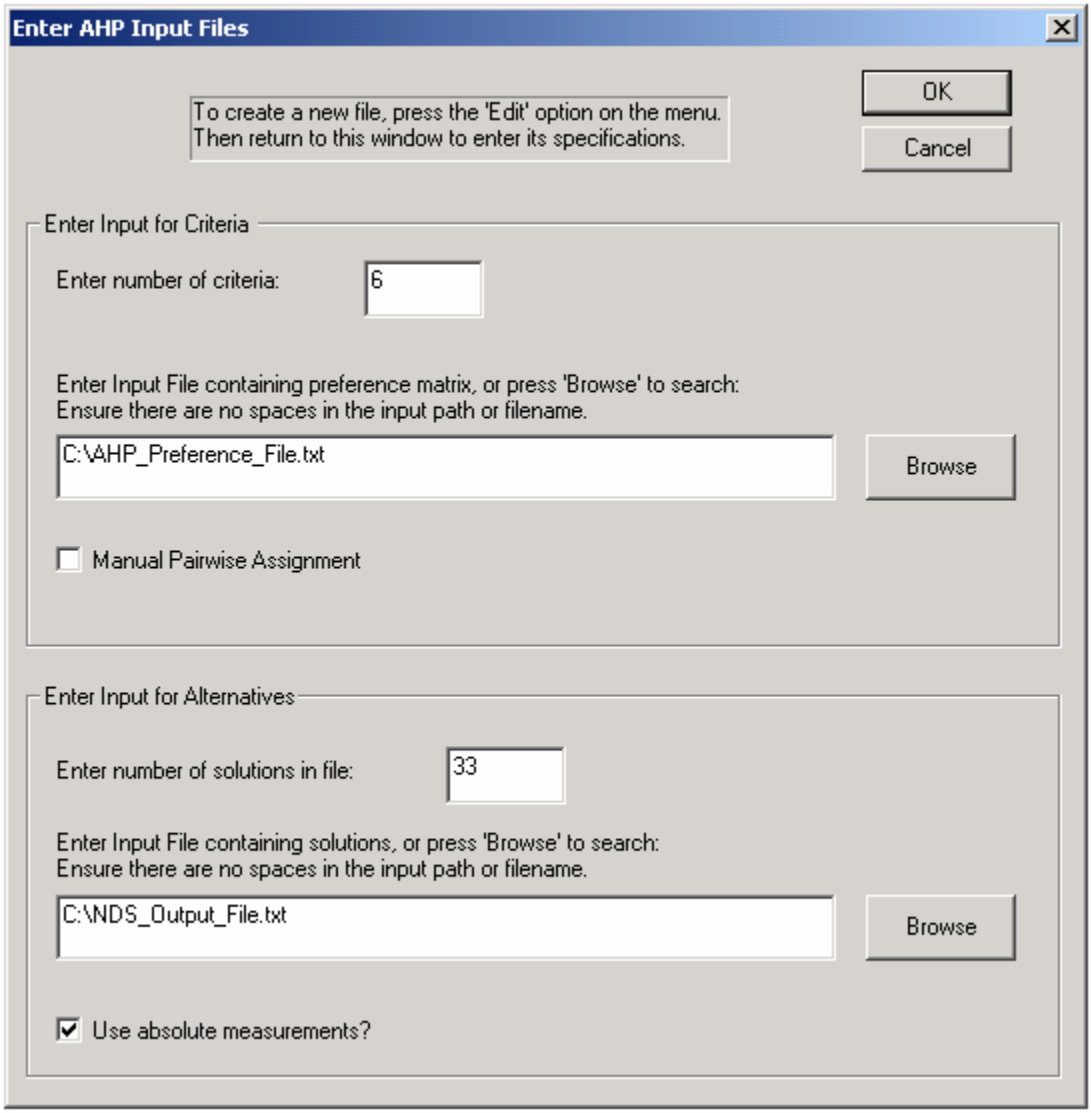


Figure A2.9. Example AHP input file dialog box. The number of criteria is set at 6, the filepath for the AHP preference file is set as "C:\AHP_Preference_File.txt," the "Manual Pairwise Assignment" box is checked, the number of solutions is set at 33, the filepath of the **NDS output file** is set as "C:\NDS_Output_File.txt," and both the "Use Absolute Measurements?" and "Quantitative" boxes are checked.

In order to prioritize the six criteria, the filename and pathway of the **AHP preference file**, which contains the preference matrix, must be filled in. In this example, however, the **AHP preference file** has not yet been created.

Consequently, after filling in the name of the **AHP preference file** (in this example, "C:\AHP_Preference_File.txt"), the user checks the box marked "Manual Preference Assignment" (See Figure A2.9).

The absolute version of the AHP will be used, and so the "Use Absolute Measurements?" box is left checked. Figure A2.9 provides an example of the AHP input file dialog box after the above data have been entered. After clicking "OK" and exiting the AHP input file dialog box, the manual pairwise comparison dialog box opens (Figure A2.10), which will prompt the user to enter the relative ranking of each of the six criteria with respect to all of the others.

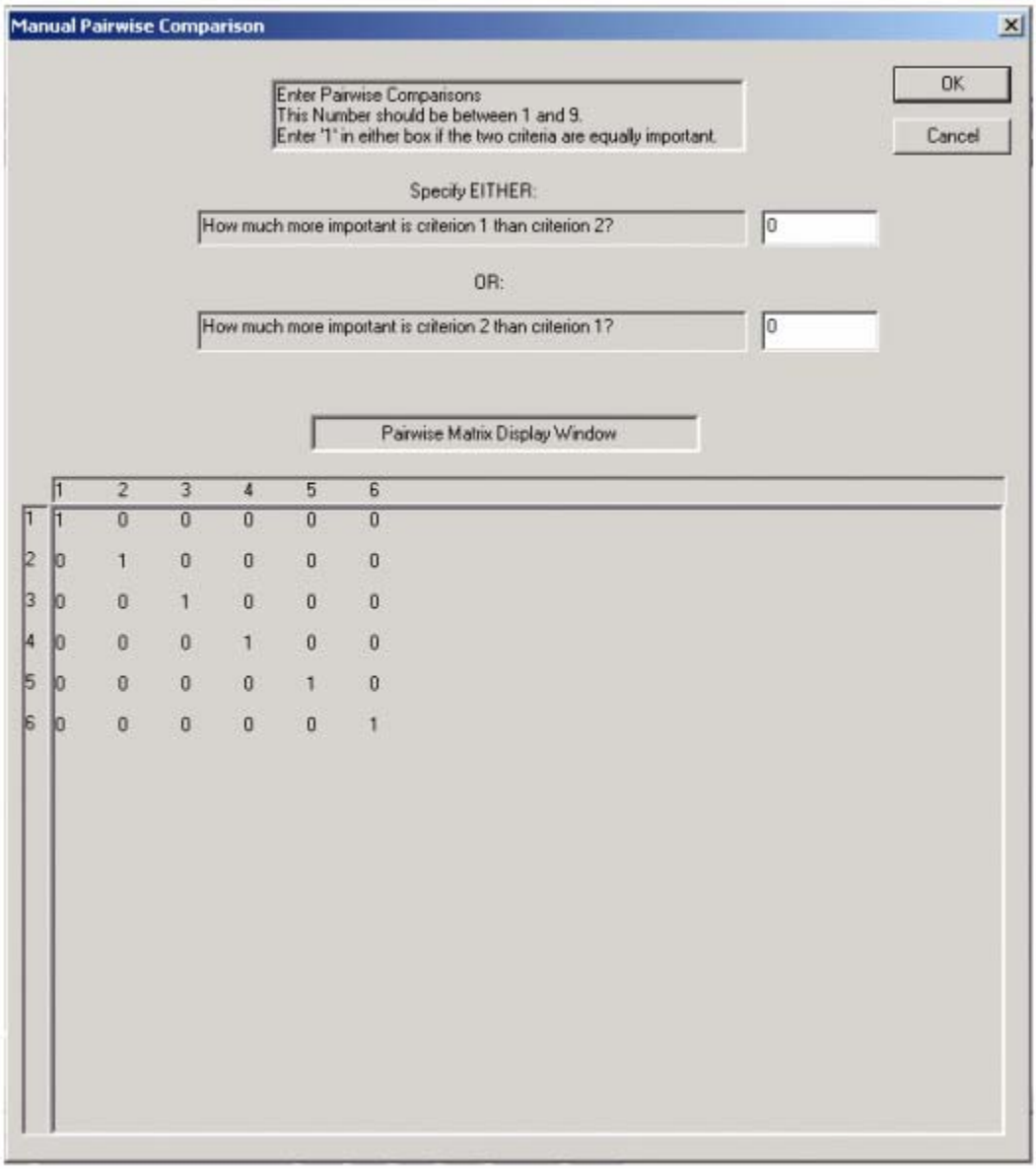


Figure A2.10. The manual pairwise comparison dialog box.

As can be seen, the user is first prompted to compare the first and the second criterion. As criterion 2 is more important than criterion 1 (‘5’ on a scale of one to nine), the user enters ‘5’ next to the box marked: ”How much more important is criterion 2 than criterion 1?” (see Figure A2.11).

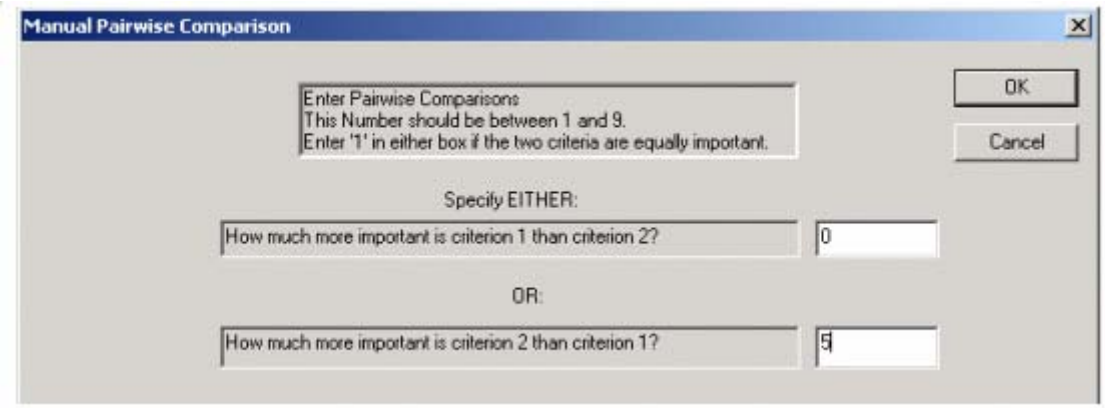


Figure A2.11. Example of a comparison between criterion 1 and 2.

In this example, 15 such comparisons will be made (as shown below in Table A2.1). Upon each comparison, the pairwise matrix display window will be updated. After the last comparison has been made, the **AHP preference file** will be automatically created and filled in (See Figure A2.12).

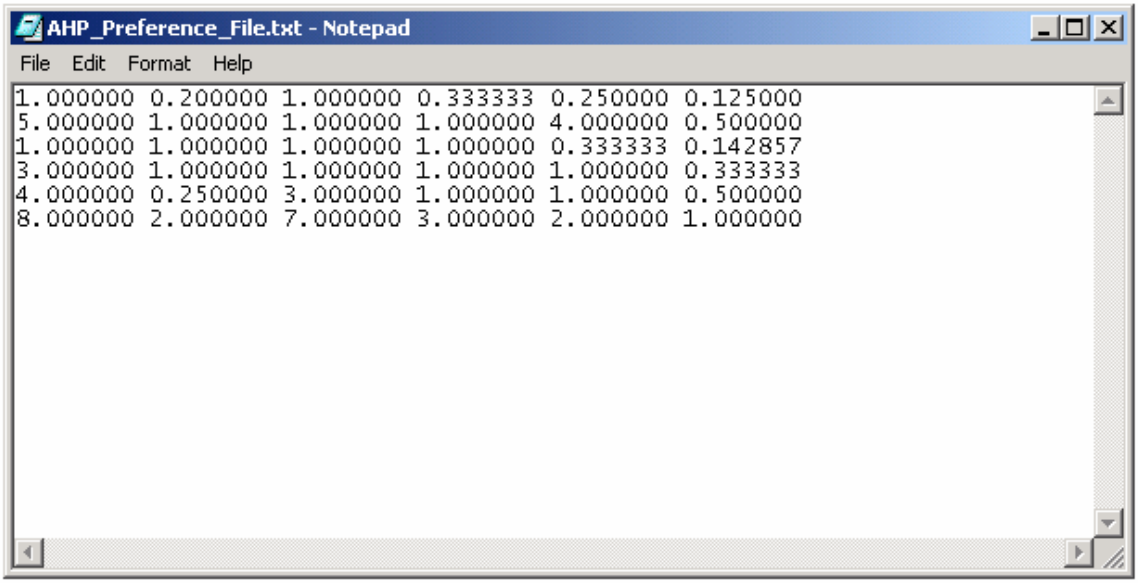


Figure A2.12. The automatically generated **AHP preference file**.

Criteria Compared	Comparison
1, 2	Criterion 2 receives a “5” relative to criterion 1
1, 3	The criteria are of equal importance
1, 4	Criterion 4 receives a “3” relative to criterion 1
1, 5	Criterion 5 receives a “4” relative to criterion 1
1, 6	Criterion 6 receives an “8” relative to criterion 1
2, 3	The criteria are of equal importance
2, 4	The criteria are of equal importance
2, 5	Criterion 2 receives a “4” relative to criterion 5
2, 6	Criterion 6 receives a “2” relative to criterion 2
3, 4	The criteria are of equal importance
3, 5	Criterion 5 receives a “3” relative to criterion 3
3, 6	Criterion 6 receives a “7” relative to criterion 3
4, 5	The criteria are of equal importance
4, 6	Criterion 6 receives an “3” relative to criterion 4
5, 6	Criterion 6 receives a “2” relative to criterion 5

Table A2.1. Evaluation of 15 pairwise comparisons. Column (i) identifies the two criteria involved in each comparison, while column (ii) identifies the results of each comparison. “Criterion X receives a ‘Y’ relative to criterion Z” means that criterion X is Y times more important than criterion Z.

After returning to the main interface, “Alternatives Output File” is selected from the “AHP Output Files” menu. This elicits the dialog box shown in Figure A2.13, into which the user enters the name of the **alternatives output file**, which will contain the prioritization of the six criteria. Upon returning to the main interface, “Criteria Output File” is selected from the “AHP Output Files” menu. This elicits the dialog box similar to that shown in Figure A2.13, and into which the user enters the name of the **criteria output file**, which will contain the ranking of the 33 alternatives.

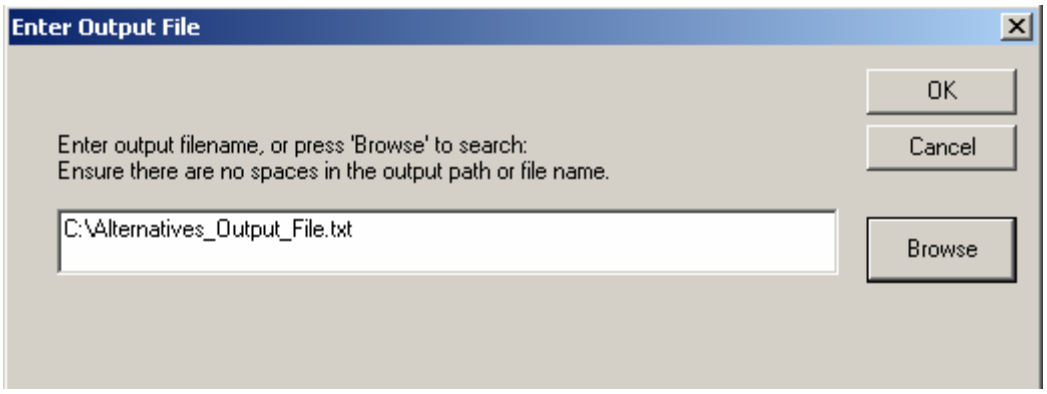


Figure A2.13. Example output file dialog box.

Upon returning to the main interface, “Execute AHP” is selected from the “Execute” menu heading of the main interface. This executes the AHP computation, which produces both a ranking of the criteria and a ranking of the alternatives. The ranking of the criteria will be printed to the screen upon completion of the computation (as in Figure A2.14). The criterion associated with the highest value is the most important relative to the user’s preferences; thus, in this example, criterion 6 is by far the most important of the criteria.

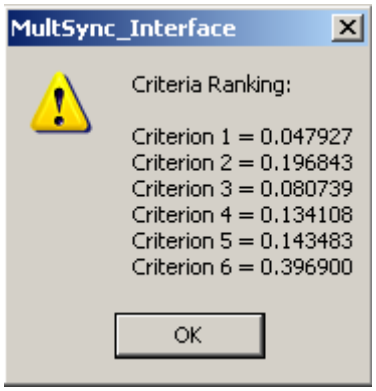


Figure A2.14. Example criteria ranking, which is printed to the screen upon completion of the AHP computation.

The final ranking of the alternatives produced can be found in the **alternatives output file** (see Figure A2.15).

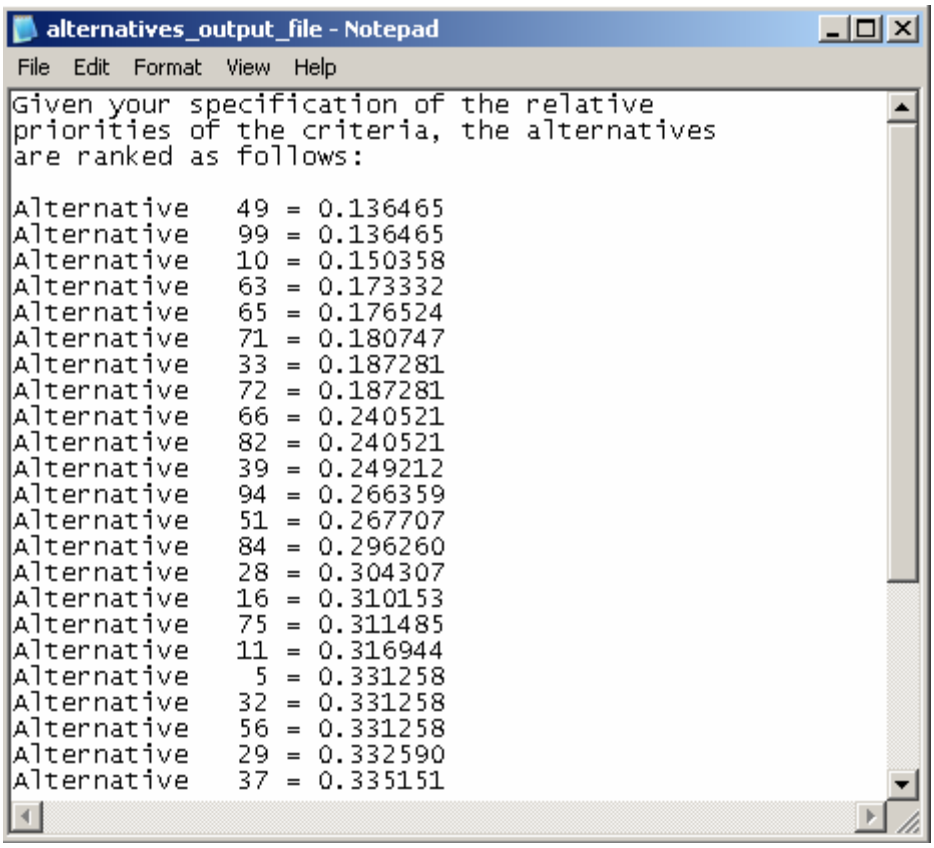


Figure A2.15. Example alternatives output file. Not all of the file is shown. Priorities are identified for each alternative, and the alternatives are ranked on the basis of their assigned priorities, in order of decreasing importance.