U.S. Army Corps of Engineers
Institute for Water Resources

IWR Planning Suite MCDA Module
User's Guide

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IWR Planning Suite MCDA User's Guide

by

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Executive Summary

As the US Army Corps of Engineers (Corps) moves forward in its environmental mission, its decision-making processes need to adapt to incorporate items not easily quantified in dollars. Multi-Criteria Decision Analysis (MCDA) techniques are excellent ways to help Corps' planners and project managers balance their decisions based on Social Equality, Environmental Soundness, and Economic Viability.

MCDA techniques are tools the Corps of Engineers can use to improve the transparency of the decision making process. MCDA provides a proven mathematical means for comparing criteria with differing units such as habitat units, cultural resources, public sentiment and total cost. The stakeholders, both those who support and do not support a project, can provide input into the criteria used to evaluate plans. The plans and their affects are plainly described in the decision matrix allowing the stakeholders and vertical team a greater understanding of the problems associated with a particular plan.

The Corps currently uses a decision model, IWR-Plan, a tool developed by the US Army Institute for Water Resources, to compare and evaluate a number of different plans; however, IWR-Plan is limited in its capacity to compare plans effectively because it can only evaluate one type of benefit to produce the incremental cost analysis. An additional module to the IWR-Plan suite that includes MCDA helps the planner or project manager present a more informed and transparent decision.

The IWR Planning Suite Multi Criteria Decision Analysis (MCDA) Module was developed to provide Corps planners with a toolbox for conducting multi criteria decision analysis and exploring multiple dimensions of a planning decision. This manual provides background on multi criteria decision analysis, an explanation of incorporated methods and algorithms and a tutorial guide for using the IWR Planning Suite MCDA software.

Section 1
Introduction and History

> *…seek balance and synergy among human development activities and natural systems by designing economic and environmental solutions that support and reinforce one another."* (USACE Environmental Operating Principles)

The Corps is often criticized for its environmental decision making because it focuses on economic models rather than ecosystems as a whole when evaluating different plans. The Corps is especially vulnerable to criticism because many of the ecosystems they work with are large and complicated with many, often conflicting parties, as stakeholders. The Corps is aware of their reputation and is taking steps to improve the transparency of its decision-making through the use of Multi- Criteria Decision Analysis (MCDA).

According to the Corps Planning Principles and Guidance, four accounts are established to help the decision maker recommend a plan at the end of the feasibility phase.

a) The National Economic Development (NED) account displays changes in the economic value of the national output of goods and services.

b) The Environmental Quality (EQ) account displays non-monetary effects on significant natural and cultural resources.

c) The Regional Economic Development (RED) account registers changes in the distribution of regional economic activity that result from each alternative plan. Evaluations of regional effects are to be carried out using nationally consistent projections of income, employment, output and population.

d) The Other Social Effects (OSE) account registers plan effects from perspectives that are relevant to the planning process, but are not reflected in the other three accounts. (ER 1105-2-100, 1-3)

All of the criteria used to evaluate the projects will fall under one or two of these accounts. In each of the plans chosen for evaluation, national economic development, environmental quality, regional economic development and social well being should be addressed. It is easy to quantify the NED account because it is based on dollars, but the other accounts are more difficult to quantify. In 1999, the National Research Council (NRC) recommended "that further decision analysis tools be implemented to aid in the comparison and quantification of environmental benefits from restoration, flood damage reduction and navigation projects." (Linkov et al., 11)

A new module for IWR-Plan containing MCDA has been developed as a tool for aiding in the decision making process. It helps the decision maker balance a set of criteria

(acres of wetland restored, habitat units created and number of jobs created) against a given set of solutions. It gives the decision maker a way to quantify how each alternative considered meets a set of existing criteria. The MCDA process can even be used to measure qualitative units such as socioeconomic factors or cultural resources using a user defined scale or a commonly accepted scale such as Saaty AHP scale.

Using MCDA the user can weigh the importance of different criteria by assigning numerical weights to each criterion. By maximizing or minimizing criteria, the study manager can reduce harmful effects and increase benefits of a given criteria in a particular alternative.

MCDA provides a framework for stakeholders to voice their opinions and, in the best-case scenario, come up with a consensus of the objectives for the project. Even if a consensus cannot be achieved; the stakeholders at least know what the other stakeholders want from a given circumstance. In a worst-case scenario, the stakeholders walk away from the process with a better understanding of one another, a benefit derived from allowing the process to act as a type of mediation.

History of MCDA

MCDA arose as an area of specialization within the arena of Operations Research (OR). Operations Research is dedicated to advancing the science of decision making.

Initial applications of OR were in support of military activities. Around 1937, Operational Research analysis was initiated by the British Royal Air Force in a seminal study of the network of radar operators and how the decisions they made affected the results gained from their radar operations.

The Naval Ordinance Laboratory brought the science, renamed operations research, in as a formal program into the United States in 1942. Eventually this resulted in the inclusion of OR groups in all Air Force command units.

Research has moved forward rapidly over the past sixty years. Significant advances continue to be made in OR in general and in multi-criteria decision analysis (MCDA) specifically. Advances are to some degree correlated to increases in computing power and availability, as the greater majority of OR analyses are computationally intensive in nature.

MCDA is applied decision making problems in a variety of areas, such as economics, production and project planning, the statistics and management sciences, engineering design, and of course in several areas of the field of environmental analysis. MCDA methodologies have been developed around a variety of theoretical frameworks like outranking, optimization, goal aspiration, and the combining of different methods.

In the 1960's, the first methods of evaluation that used matrices for selection of plan alternatives were developed. These methods, collectively referred to as weighted

summation analyses, were constrained solely to the evaluation of quantitative numeric criteria where all criteria were expressed in the same units of measure (for example, all criteria values expressed in dollars). These constraints severely limited the potential complexity of the analysis often necessitated by the vagaries of real-world problems.

As such, subsequent research focused on the expansion of MCDA to include criteria measured with different units. Seminal work by French researcher Bernard Roy resulted in the ELECTRE methods. Research during this period culminated in the development of Morris Hill's Weighted Ranking method by means of the Goals Achievement Matrix in 1968, wherein normalized scores provided the key to the resolution of different criteria measurement units, and its widespread dissemination and use in the 1970's.

Research and new developments in MCDA have continued at a prodigious rate through to the present day, spawning new methods that further expand the applicability of the discipline to decision making. Compromise Programming, Outranking methods such as PROMETHEE, the ELECTRE MCDA methods, Concordance/Discordance analysis, Analytic Hierarchy Process, and non-dominant, or Efficient Frontier analysis are all outgrowths of MCDA research that continue to be used, developed, and refined to this day.

Information on specific Corps projects where MCDA has been used is difficult to find. Most literature linking MCDA and the Corps examine environmental cleanup of contaminants and consider MCDA in a more abstract way, suggesting that it was a good thing for the Corps to use.

Things to remember when using MCDA

It is important to remember that MCDA is a decision making tool and not an instrument to actually make the decision for the planning professional. As with all models and computer programs, the answers returned need to be reviewed.

Great care shall be taken when deciding which criteria should be used to evaluate a project. Weighting heavily or choosing many criteria out of particular business line will focus the analysis toward that business line. It is important for the study team to remember the project purposes, and the criteria chosen needs to accurately reflect them.

The Corps has built into the planning process a way for the data used for MCDA analysis to be internally and sometimes externally peer reviewed. The study managers, in cooperation with the project team, currently determine project effects, both positive and negative, in the formal study and NEPA processes. Vertical team integration throughout the study process (including the Feasibility Scoping meeting, Alternative Formulation Briefings and other review meetings) adds a level of assurance the study team is following guidance.

Using MCDA, the project team can clearly demonstrate how they weighted each of the criteria leading to them choosing the plan they did. The use of the MCDA tool will

clarify the vertical team's decision making process to the public. The use of weights will help the stakeholders realize where the emphasis for the project really lies. The use of MCDA will be a benefit to the stakeholders because those items not quantifiable, such as recreation and cultural resources will openly be reflected in the decision making process.

Section 2
MCDA Basic Constructs & Definitions

This guide assumes that you have completed the IWR Planning Suite tutorial. We will be using the IWR Planning Suite database that was created in that tutorial. Therefore if you have not completed that tutorial, please do so now. If you are very familiar with IWR Planning Suite or you have already finished the IWR Planning Suite tutorial, but have misplaced the database you created, you can download a copy of the database by clicking on the following link: http://www.pmcl.com/iwrplan.

What is a Criterion?

A criterion represents a measured quantity in an MCDA decision matrix. In the IWR Planning Suite MCDA module, criteria are synonymous with variables in a MCDA planning set. They may alternatively also be the Cost Effective attribute of a particular planning set. Criteria can either be maximized or minimized. For example, one would want to minimize cost while maximizing habitat units achieved by a particular plan.

The data to be ranked may be quantitative (cardinal) or qualitative (ordinal). Quantitative data is data that can be described in physical units with a real number. Cost is a quantitative criterion. Habitat Units, Acres, Water Depth, and Pump discharge capacity are all quantitative values. Qualitative data is data that cannot be described in physical units, but must be described by a set of discrete, ordered identifiers. This can happen in cases where robust, quantitative data is not available for a particular criterion. If such is the case, then more general identifiers that represent qualitatively the criteria in question may be used.

Qualitative data can be assigned a quantitative number in a ranking system. Some example identifiers representing potential qualitative data sets are:

Type of Criterion	*Qualitative Value*	*Potential Quantitative Value*
Habitat Units	***Ordinal Values (Low to High)***	***3=low*** ***5=middle*** ***7 = high***
Improve Substrate	***True or False***	***1=True*** ***0=False***
Public Agreement	***(None, Few, Average, Many)***	***0=none*** ***2=few*** ***4 = average*** ***6 = many***
Distance	***(Near, Middle, Far)***	***3 = Near***

		4 = Middle ***5 = far***
Risk	***(Low, Medium, High, Critical)***	***9=low*** ***7=medium*** ***5 = high*** ***2 = critical***

Table 1
Quantitative to Qualitative Criteria

Assigning quantitative numbers systems is up to the discretion of the stakeholders. **It is important to remember to look at the scaling of your criteria.** In the example for habitat units, that the medium ranking gets almost twice as much weight as the low ranking. Improper scaling will skew your final answer.

What is a Decision Matrix?

A decision matrix is the foundational structure from which all IWR Planning Suite MCDA work is performed. Simply, it is a matrix of alternative and criteria combinations. Specifically, it corresponds to an IWR Planning Suite MCDA Planning Set, where each Plan Alternative is a row in the decision matrix, and each criterion is a column in the decision matrix.

What are Criterion Weights?

Criterion weights are the mechanism for determining relative importance of each criterion. When analyzing alternatives, we may wish to consider one criterion as relatively more important than another criterion. For example, if a scale from 1 to 20 is used to indicate importance and habitat units are given a 20 and cost is assigned a 1 then habitat units is 20 times more important than total cost.

Analytic Hierarchy Process (AHP) is a method for simplifying the determination of the relative importance of criteria using plain English terms that is described in further detail in section 3. AHP is included within the IWR Planning Suite MCDA tool as an optional weighting scheme.

What is Criteria Optimization?

The attempt to evaluate rows of the decision matrix based on criteria values is an optimization problem. In saying that we are attempting to find optimal solutions, we mean the best solutions based on criteria that involve some values being as low or high as possible (minimized or maximized).

Criteria Minimization

When smaller values of criteria are more desirable, the criteria are minimized. Cost is a criteria for which minimization is often selected, as the lowest possible cost is usually considered part of an optimal solution. Other criteria that may be minimized included habitat disturbed, endangered species taken, cultural resources affected and houses destroyed. The minimization of criteria within the context of a MCDA analysis is the attempt to identify those rows with the smallest criteria values for the criteria being evaluated.

Criteria Maximization

Criteria should be maximized when the larger values are more desirable. For example, Habitat Units are maximized on an ecosystem restoration project. The maximization of criteria is the attempt to identify decision matrix rows with the largest criteria values for the criteria under consideration.

What is Ranking?

Decision matrix ranking is the evaluation of rows in a decision matrix (a planning set). the ranking methodology attempts to find the relative minimum and maximum criteria for all of the rows in order to rank the rows of the decision matrix from the optimal solution row (the least desirable plan alternative) to the least optimal solution row (the least desirable plan alternative). The weights play a factor in ranking by assigning more importance to particular criteria.

Software Terminology

MCDA Plan Alternative

A Plan Alternative in MCDA is equivalent to a decision matrix alternative.

MCDA Planning Set

A MCDA Planning Set stores an MCDA decision matrix. It may also contain the results of an MCDA performed on the decision matrix.

MCDA Plan Study

A MCDA Plan Study is a group of Planning Sets which contain the decision matrix on which the analyses are performed, and the results of all of the different types of analyses performed upon the decision matrix.

MCDA Plan Study Variables

An IWR Planning Suite Variable is equivalent to a MCDA criteria.

MCDA Plan Alternative Attributes

Attributes are associated with a plan alternative in a particular planning set. They contain the results of a particular analysis. Specifically, the Score and Rank of each Plan Alternative is maintained in Score and Rank attributes associated with the plan alternative. The distinction between attributes and variables is that while variables are consistent within a plan alternative, attributes may vary. For example, the cost of Plan A will always be the same but the MCDA score or rank can be different depending upon the type of analysis using a different method, different weights, or different analysis parameters.

MCDA Module

The MCDA Module is a plug-and-play module of the IWR Planning Suite that provides the ability to perform Multi Criteria Decision Analysis using a variety of methods and techniques.

Section 3
MCDA - Weighting, Scoring and Ranking

Reducing the Decision Matrix

MCDA Decision Matrix rows may be reduced by applying filtering techniques to them. In some cases it is appropriate to the needs of the analysis being conducted to reduce the size of the MCDA planning set, or to eliminate those plan alternatives that do not meet the minimum requirements set for an analysis or exceed an established threshold, such as a cost limitation.

Decision Matrix reduction is performed by applying maximum and minimum criteria alue tests to each decision matrix row (plan alternative). These criteria value tests act as constraining limits which remove rows from the decision matrix which fail to pass the constraint test. A new planning set is created at this time to contain the constrained decision matrix so that the original set of alternatives is accessible simply be changing the working planning set. For example, if a maximum value for cost is set to $1,000,000 then any plan alternatives that have a total cost which exceeds this maximum value are removed from the decision matrix and a new planning set is created which contains all alternatives which passed the constraint tests. This reduction in the decision matrix is a function of the IWR-Planning Suite and is not exclusive to the MCDA module.

Weighting Criteria

MCDA allows the user to assign weights to each criterion by assigning user defined values or by using the Analytic Hierarchy Process (AHP).

When the user is defining weights, it is important to remember how the weights will scale the criteria. If the user defined weights are 1, 2, 3, and 4, the criteria weighted with a 4 is four times more important than the criteria weighted with a 1.

AHP Weighting

Additionally, MCDA provides an alternative to the user defined weights called Saaty's Analytic Hierarchy Process (AHP). AHP is a methodology for decision-making that utilizes relative importance descriptions in a pair-wise comparison analysis to set criteria weights. This technique requires the decision maker to consider each single criterion against every other criterion in pairs. In AHP weighting the user selects the phrase describing the relative importance of each criterion combination. There are nine different levels of importance to choose from:

- Equally Important (1)

- Slightly More Important (3)
- Strongly More Important (5)
- Demonstrably More Important (7)
- Absolutely More Important (9)
- Slightly Less Important (-3)
- Strongly Less Important (-5)
- Demonstrably Less Important (-7)
- Absolutely Less Important (-9)

Selecting from these plain English phrases allows the planner to set the weights for each criterion using an easily understandable comparison method. All that is needed is to set how important each criterion is compared to the other criteria, and the weighting will then be automatically calculated based on your selections.

Relative importance will vary with the specifics of each MCDA study and the manner of framing the planning study. For example, a project planner may assume that total cost is more important than the effect on the deer population in a project area, because there is a specific limitation to the total investment that can be made. Conversely, if the project had no cost limitations, the planner might consider the effect on the deer population equally or even more important than total project cost.

As you can see from this example, comparisons of criteria are by their nature very dependent on the individual decision makers' view of their relative importance. One person may feel that a criteria is Strongly More Important than another, whereas someone else may feel that the relationship is one of only slightly more importance.

In a group setting, individuals can come to a mutually agreed upon consensus on the importance through a method such as facilitated conflict resolution. The MCDA tool supports these types of activities by allowing participants to rapidly change inputs to reflect preferences and produce alternative ranking scenarios for discussion.

The AHP Inconsistency Ratio

It is important to pay careful attention to the Inconsistency Ratio calculated as part of the AHP weighting methodology. It serves to indicate the degree of inconsistency in the relative importance chosen for criteria. The AHP Inconsistency Ratio is a number between zero and one indicating how inconsistent the relative criteria importance selections are. Zero indicates there is no inconsistency, and one indicates complete inconsistency. The Inconsistency Ratio should be kept as close to zero as possible, the higher the value the more inconsistent the selection.

Once the Inconsistency Ratio reaches 0.1 or above, the dialog box will become red. Once this value becomes greater than 0.1 you should examine your rankings for any

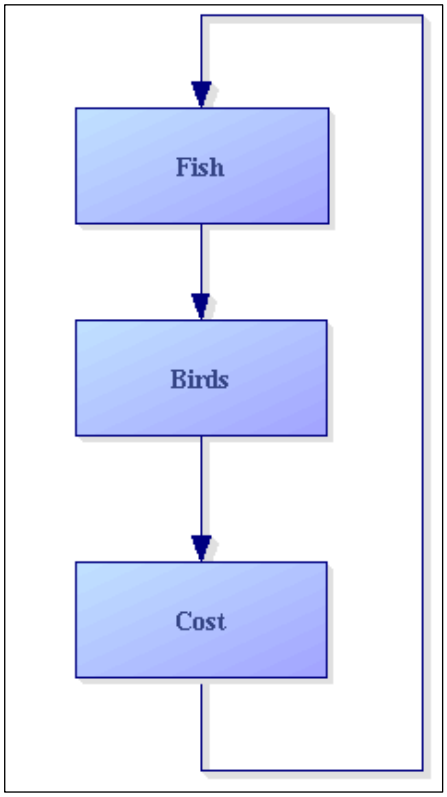


Figure 1
Circular reasoning

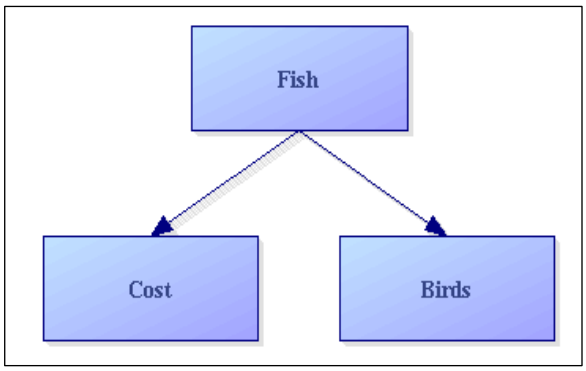


Figure 2
Consistent preferences

inconsistencies and attempt to eliminate them.

Consider the following example of inconsistent choices: Suppose we have three criteria: Fish, Birds, and Cost. Then, further suppose these criteria were described in the following manner:

- *Fish are Strongly More Important than Birds*
- *Birds are Strongly More Important than Cost*
- *Cost is Strongly More Important Then Fish*

There is a subtle but important problem with the description of the relative importance of Fish, Birds, and Cost in this example – it is not logically consistent. We have stated that Fish are more important than Birds, which are more important than Cost, which is more important than Fish, an example of false circular reasoning. These cases need to be considered carefully and examined on an individual basis to avoid creating problems in the analysis.

A diagram representing this can be seen in Figure 1. Note the arrows indicating the circular reasoning; such inconsistencies need to be avoided in order to determine meaningful criteria weights. Using the same three criteria, a consistent set of preferences is also shown in Figure 2.

Available Ranking Methods

The IWR Planning Suite MCDA Module provides several ranking methods, with important variations that need to be understood for each. The ranking methodologies include:

1. Weighted Scoring,
2. Compromise Programming,
3. Outranking (Promethee II)

Efficient Frontier method is also included in the methodologies, but it does not give a ranking. Efficient Frontier helps you determine if your solution is dominated or non-dominated. More about dominated and non-dominated appears in the explanation below about Efficient Frontier.

The result is a robust toolset of ranking algorithms which may be used by the planner to evaluate planning sets using multiple criteria.

Weighted Scoring

The weighted scoring technique is the most common technique used in MCDA. It is the simplest algorithm to understand, but it is also the least robust. The algorithm compares plans to one another and assumes higher end values result in more desirable plan. Because of that assumption, the values are normalized to not artificially weight the plans.

Weighted Scoring is a methodology for evaluating plan alternatives within a decision matrix. Weighted scoring of a planning set is performed as follows:

1) criteria values are normalized by one of three methods: by range, by percent of the maximum, or by percent of the total.

2) criteria values for maximized criteria are multipled by their associated weights to obtain raw weighted scores for each maximized criteria

3) weights of the minimized criteria are converted to negative and multiplied by the criteria values to obtain raw weighted scores for each minimized criteria

4) raw weighted values for alternatives are produced by summing the raw weighted criteria score values for a particular row

5) raw weighted scores are again normalized to produce scores that fall between 0 and 1

Normalization allows criteria comprised of different units, such as dollars and habitat units to be compared with meaningful results. Weighted Scores may be evaluated by a variety of means, including normalization by percentage of maximum criteria value, by range, or by mean values.

Weighted scoring uses a matrix multiplication to arrive at a single score for each alternative. Weighted scoring has three different possible normalization methods that can be applied:

- *Normalization to maximum:*

$$v = \frac{a}{\max a}$$

- *Normalization to range:*

$$v = \frac{a - \min a}{\max a - \min a}$$

- *Normalization to percent of total:v*

$$v = \frac{a}{a + a_1 + a_2 + \cdots a_n}$$

Where

- *a = "raw" value of criterion for alternative*
- *v = normalized value of criterion i for alternative*
- *n = number of alternatives*

Normalization by Range guarantees that each normalized criterion value, whether maximized or minimized, will be in the range of zero to one. The other methods of normalization do not provide this assurance.

Normalization by range also introduces a complexity where criteria minimization cannot be handled by simply negating the normalized criterion. So in this method, minimized criteria are no longer converted through multiplying by -1, but the weights of these criteria are taken as negative, thus reducing the score contribution for minimized criteria.

At the end of this process, "Raw" scores exist, which are then normalized to fall between zero and one.

Compromise Programming

In this method, an ideal point is defined as the "best" that any criterion in the decision matrix can achieve. Then a "distance metric" is developed for each of the actual plans relative to the ideal point. The closer a plan is to the ideal point, and the higher its rank. The algorithm is called compromise programming because it offers a compromise between multiple solutions. The solutions are not necessarily optimal or non-dominated solutions; rather, they are solutions that fit the preferences of the stakeholders. Compromise programming is a goal aspiration technique.

In its simplest form, the distance metric is taken as the weighted sum of the individual distance metrics for each criterion. However, the literature on compromise programming provides for alternative distance metrics using to express absolute deviation or distance from the ideal point.

For compromise programming a scaling factor can be used to normalize the values. The scaling factor is usually 1, 2, or infinity. The three scaling factors offer different ways to measure the distance from the ideal point or aspiration criteria to the point being measured. In this program the scaling factors used are 1 and 2. The users can choose the scaling factors by checking the appropriate bubble in the "Deviation from Ideal" portion on the ranking screen. In the program, a scaling factor of 1 is referred to as being "weighted equally." A scaling factor of 2 is referred to as "weighted proportional to magnitude." A graphical representation of how the scaling factors measure distance appears in Figure 7. <u>The scaling factors cannot be compared to one another because they measure distance in a different way.</u>

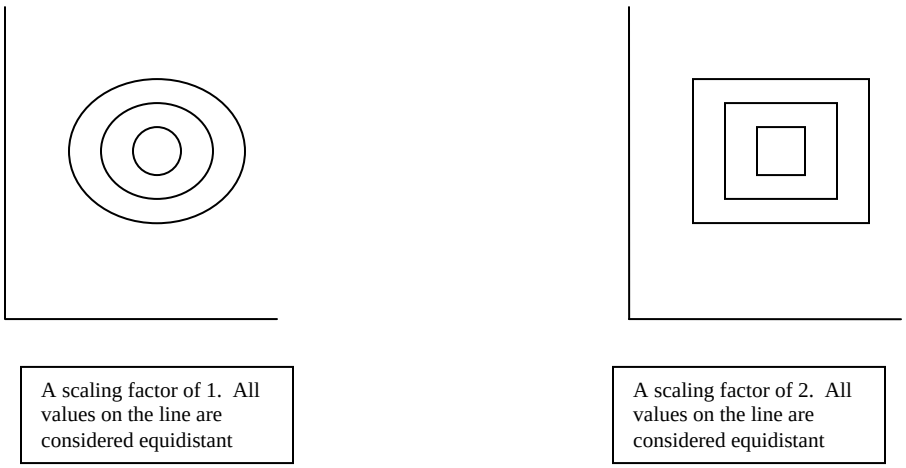


Figure 3 – Compromise Programming Scaling Factors

The final equation for each of the alternatives is below:

$$\sum \left\{ w(i)^p \times \left(\frac{f(i^*) - f(i)}{f(i^*) - f(i^-)} \right)^p \right\}^{1/p}$$

- w (i) = weight for the criteria i
- f (i^*) = optimal value or the maximum or minimum value in the existing criteria depending on if the criteria is maximized or minimized.
- f (i^-) = least optimal value or the minimum if the criteria is maximized and the maximum if the criteria is minimized
- f(i) = criteria for the alternative being evaluated
- p = scaling factor. In this program either 1 or 2.

The criteria are summed across the plans being evaluated. The plans are then ranked according to how close they are to the ideal with a minimum value being the most desirable.

For absolute deviation, all deviations are weighted equally. For pythagorean distance, the deviations are weighted in proportion to their magnitude. As such, use of the pythagorean distance places a greater emphasis on being closer - there is a larger penalty for deviations from the ideal point.

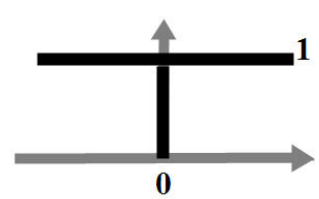
Outranking

The Outranking method used by the MCDA Module is PROMETHEE II. Promethee stands for **P**reference **R**anking **O**rganization **METH**od for **E**nrichment **E**valuations II. Outranking methods compare variables pairwise, developing a numerical matrix showing the degree to which each alternative is preferred over another alternative. The numbers in this matrix are used to develop an ordering which shows the strength of preference of one alternative over another. PROMETHEE II does not give a clear preference as the weighted scoring method and compromise programming do; rather, it gives preorders (changes in rank) and shows preference for plans based on how they compare to the criteria of other plans.

Each criteria can be assigned its own Preference Function, from the choices of Strict, Threshold, Linear Over Range, Stair-Step, and Linear with Threshold.

Preference Functions:

Strict

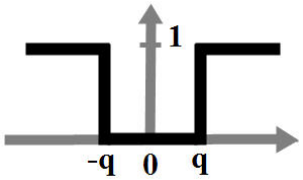


There is a strict preference for alternative A over alternative B at any level by which the rating of absolute value of A exceeds the rating of absolute value of B. Neither the Absolute Preference nor Indifference Value need be identified for this preference function. When they are equal there is no preference and the value is zero.

$$H(d) = \begin{cases} 0 \; if \; d = 0 \\ 1 \; if \; |d| > 0 \end{cases}$$

Threshold

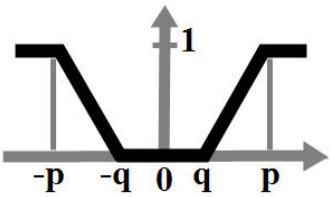
For this method an Indifference Value must be identified. Alternative A must exceed Alternative B by an amount q greater than or equal to the indifference value (q) to be preferred over B. The user defines the indifference threshold.



$$H(d) = \begin{cases} 0 \; if \; |d| \leq 0 \\ 1 \; if \; |d| > 0 \end{cases}$$

Linear With Threshold

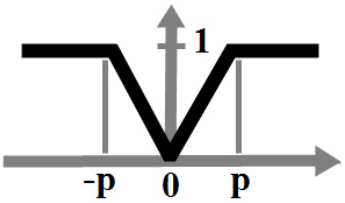
For this method an Absolute Preference value, p, and an Indifference Value, q, must be identified. This says that any two alternatives that differ by the Indifference value or less cannot be distinguished among one another. As the difference grows closer to the Absolute Preference one alternative can be said to be better than the other alternative. Once the difference reaches the Absolute Preference, one alternative can be said to be absolutely better than another alternative.



$$H(d) = \begin{cases} 0 \; if \; |d| \leq q \\ \dfrac{|d| - q}{p - q} \; if q < \; |d| \leq p \\ 1 \; if \; |d| > p \end{cases}$$

Linear Over Range

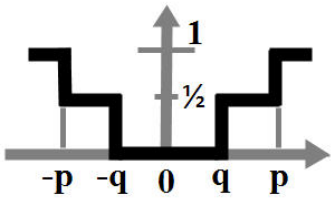
For this method an Indifference Value must be identified. This indicates that as the difference between A and B moves from a value 0 to a value p, the preference function increases linearly from zero to one over that range of differences. That is, the greater the difference past the threshold value of 0, the more that A is preferred to B.



$$H(d) = \begin{cases} \dfrac{|d|}{p} \; if \; |d| \leq p \\ 1 \; if \; |d| > p \end{cases}$$

Stairstep (Level Criterion)

For this method an Absolute Preference value, q, and an Indifference Value, p, must be identified. This says that a difference less than q gives a preference of zero, a difference between q and p gives a preference of one half, and a difference greater than p gives a preference of one.



$$H(d) = \begin{cases} 0 \; if \; |d| \leq q \\ \frac{1}{2} \; if q < \; |d| \leq p \\ 1 \; if \; |d| > p \end{cases}$$

The PROMETHEE II functions rely on four variables within this program.

d = Difference between the two criterion. Each criterion is compared to every other criterion.
q = Absolute preference. If the absolute value of the difference of the two criteria being compared is greater than q, then a preference can be shown for one criterion over another, either absolute or in decimal form. q marks the bottom boundary of the user's preference.
p = Indifference. If the absolute value of the difference of the two values being compared exceeds this number, then an absolute preference can be shown for one preference over another. Below this number, the preference is less than 1. p marks the top boundary of the user's preference.
H = preference function for the two criterion being compared. This value will range between 0 and 1.

The user chooses a performance function for each of the criteria used in the study. Each preference function has a corresponding set of equations to figure the *H* variable. Each of the plan's individual criterions is compared against each other in a preference table. For example, if you want to look at the cost of construction for a set of plans, one would set up a table similar to Table 1.

	Plan 1	Plan 2	Plan n
Plan 1	0	H(d) for Plan 2 compared to Plan 1	H(d) for Plan n compared to Plan 1
Plan 2	H(d) for Plan 1 compared to plan 2	0	H(d) for Plan n compared to Plan 2
Plan n	H(d) for Plan 1 compared to Plan n	H(d) for Plan 2 compared to Plan n	0

Table 2
Comparing Plans

If there is a preference, the preference function assigned to the criteria is used to determine H. The H variable comparing each of the plans is used to populate the preference table. After all of the criteria have been compared, the H values are added for each of the criteria into an absolute preference table.

To determine the complete preorder, the phi (Φ) values need to be determined from the absolute preference table.

$$\Phi(a) = \Phi^{+}(a) - \Phi^{-}(a)$$

$\Phi(a)$ = net outranking flow. Referred to as the score in the program
$\Phi^{+}(a)$ = positive outranking flow. In the previous chart, this is the sum down a column.
$\Phi^{-}(a)$ = negative outranking flow. In the previous chart, this is the sum across a row.

Sorting the plans by the net outranking flow gives a complete preorder of the plans. The preorder in the program gives the decision maker an idea of the plan with the stronger preference. It does not give the decision maker a gauge for determining how close the higher ranked plans are to an optimal plan. By design, PROMETHEE gives a measure of tolerances as determined by comparing every plan to another.

PROMETHEE is a useful method for setting restrictions or tolerances for error; however, it is not a tool for setting optimal limits. PROMETHEE helps the decision maker take into account variances in limitations. With this added flexibility there is, however, also more room for error.

The decision maker will rely on her team, but even with expert knowledge, the decision to use a particular parameter or criteria may be arbitrary. According to Brans et al., small deviations in the parameters used can lead to deviations in the reorder. The model can be calibrated to find the most reasonable values for the parameters, but this will add additional time and cost.

Efficient Frontier

The Efficient Frontier method is so named because it identifies a multi-dimensional frontier of cost-efficient points. The method identifies those plan alternatives that are non-dominated, meaning that there is no plan that provides more of all outputs for less of all inputs. This is a traditional step in screening alternatives in multi-criterion decision tasks. The plans that are considered dominated can be eliminated from consideration. See Figure 4 for an illustration of the Efficient Frontier. The dark dots on the lines are those solutions considered non-dominate.

Note that the concept of dominance does not imply any valuation of the inputs or outputs, only an attempt to find those plans that are unambiguously "better" than other candidate plans from the point of view of giving more output for fewer (or the same) inputs, or the same output for less input. The relative value of input and output is not considered, nor does the concept of incremental cost analysis come into play at this step.

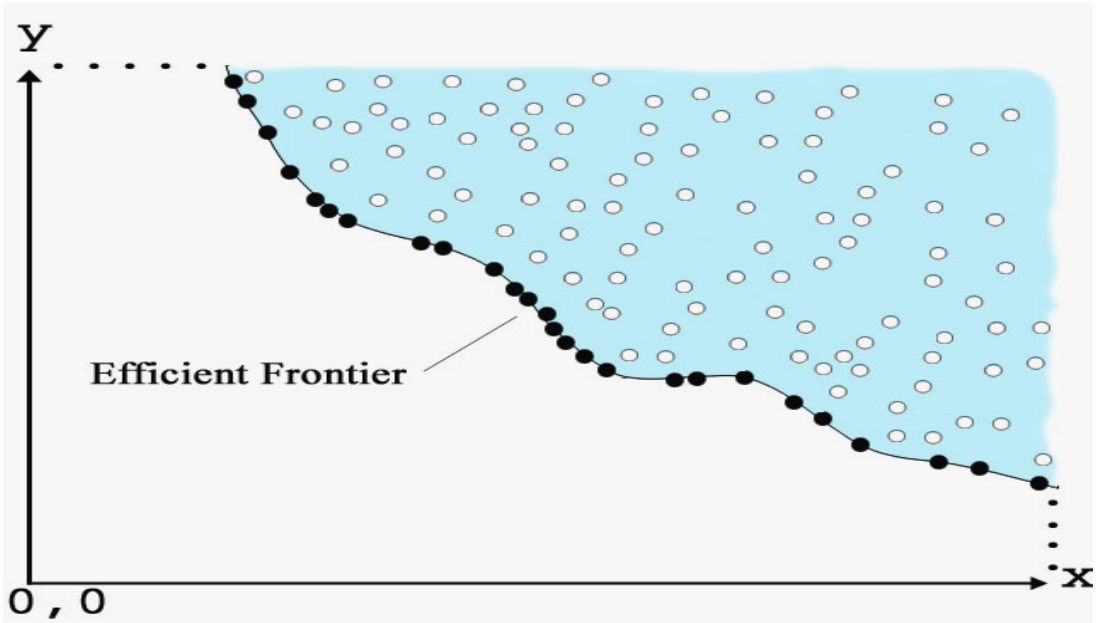


Figure 4
The Efficient Frontier of Dominant Plans

<u>Efficient frontier is not used to rank a set of plans. It simply determines dominance in a solution set. The output is a set of solutions to be further evaluated.</u>

The problem is easily understood in two dimensions, with an input (cost) and an output variable (Environmental Quality or EQ).

Plan B is dominated by Plan A because Plan B costs more, and it results in less output. There is no dominance relationship between plans A and C. Plan C costs more, but gives more output, so it is not dominated. If all plans are plotted, then the non-dominated plans are those shown below: Plans A, C, D, E, and F.

Plan	Cost	EQ Output
A	100	30
B	200	25
C	145	40
D	150	60
E	250	65
F	350	75
G	300	10
H	175	53

Table 3
Ex. of Dominate Solution

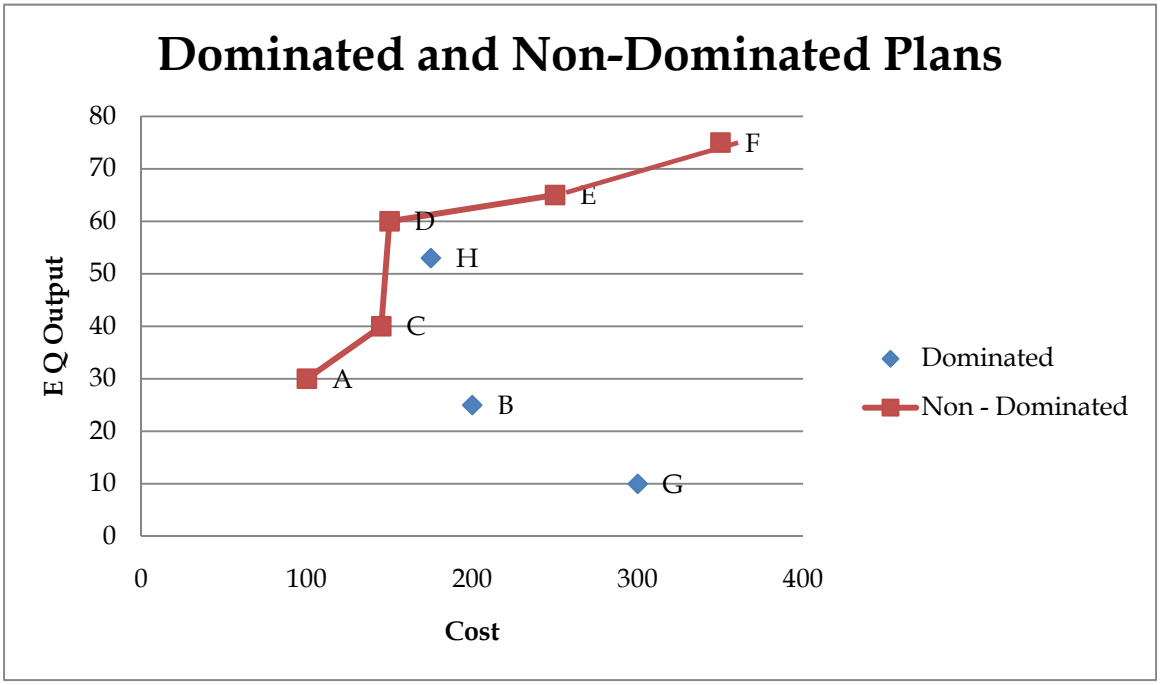


Figure 5
Graph of Dominated and Non-Dominated Plans

For multiple variables, the general concept can be extrapolated from the single-variable example outlined. That is, a pairwise comparison of plan alternatives is performed, determining which plans are dominated with the resultant non-dominated plans comprise the efficient frontier.

The program runs an algorithm developed using R Statistical package. The algorithm works by comparing pairs in each of the different columns as follows:

1: *Pre-process the decision matrix, by multiplying all output values by –1. This simplifies the definition of the dominance relationship between two rows. Row A dominates row B if, for all variables, A[i]<=B[i].*
2: *Sort the decision matrix by all columns, in ascending order.*
3: *Initialize all rows to "non-dominated".*
4: *Start at the first row of the sorted decision matrix, and check for dominance of that row against all other rows. If a row is dominated, flag it as dominated. Continue for all rows of the matrix. This constitutes one pass through the matrix.*
5: *Proceed to the next non-dominated row after the 1st pass. Repeat the same process but check only those rows that have not yet been flagged as dominated.*
6: *Continue until the decision matrix has been completely processed, i.e. until there is no further remaining non-dominated row below the row currently being processed.*
7: *The resulting set of rows that remain flagged as non-dominated (i.e. have not been flagged as dominated) represent the complete non-dominated set.*
8: *The output columns are again multiplied by –1 to restore their original values.*

(R. Males, 9)

Section 4
MCDA Software Procedures

Enabling the MCDA Module

The IWR Planning Suite MCDA Module may be enabled from the main menu. Select the "View" Menu "Modules" item (shown in Figure 6), which will list all available modules with checkboxes beside them, such as the Plan Generator Module, the CEICA Analysis Module, and the MCDA Module.

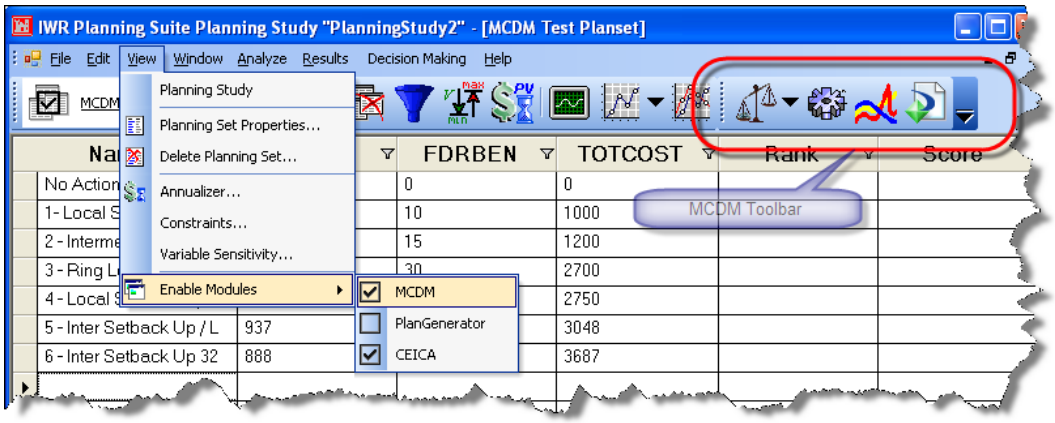


Figure 6
Enabling the MCDM Toolbar Menu

Enabled modules have their checkboxes checked. If the MCDM module checkbox is not checked, select it by hovering over it and left-clicking the mouse. This will cause the MCDM Main Menu entry "Decision Making" and the MCDM toolbar to be displayed as you see in Figure 6. You can also uncheck another module, like the Plan Generator or CEICA module, to make more room for the MCDM toolbar while you are working with MCDA. NOTE: MCDA can also be referred to as MCDM, Multi-Criteria Decision Method. In future versions of the MCDA module, the titles will be changed.Working with MCDA Planning Sets

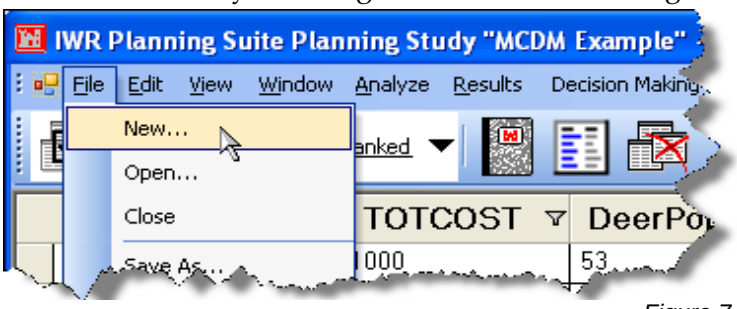


Figure 7
Creating a New MCDA Database

If it is not yet enabled, enable the IWR Planning Suite MCDM Module. First, we are going to create a new database for our MCDA application. After the program loads, select the File menu, then the New… menu item in the manner depicted by Figure 7.

If you receive the dialog in Figure 8, just select the File | Close menu item, and then reselect the File | New… menu item.

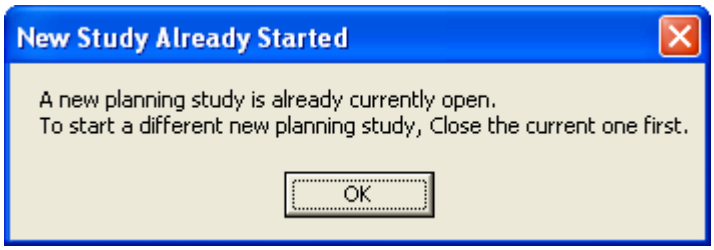


Figure 8
Planning Study is Already Open Dialog Box

After selecting File | New…, when the "New Planning Study" dialog opens (Figure 9), there will be a default file name in the "File Name" field of the dialog which you should replace as follows. Please type, "MCDA Exercise" in the "File Name" field. Click on, "Open". You have just created a new Planning Study which you

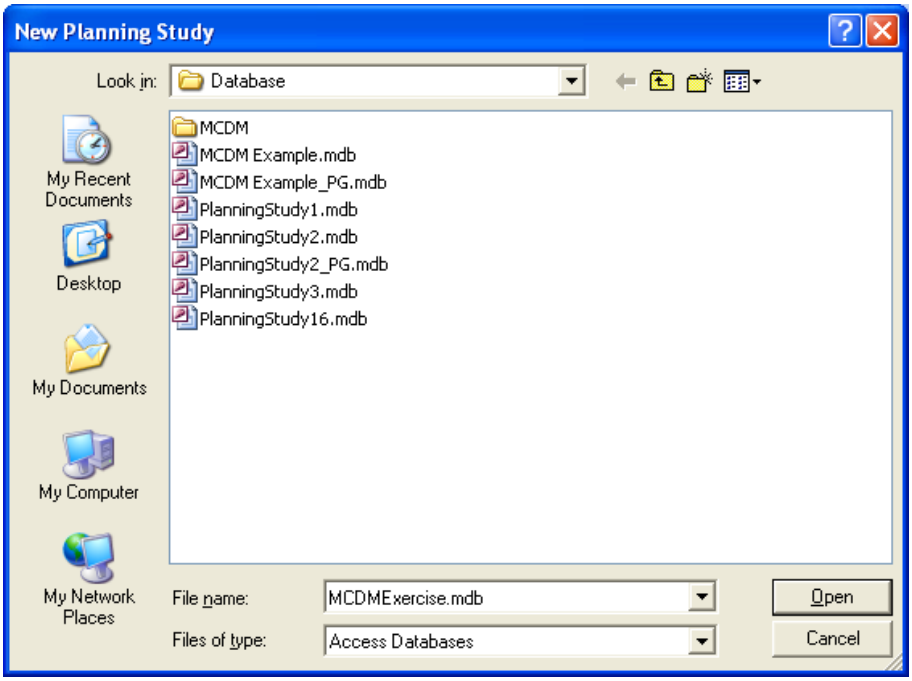
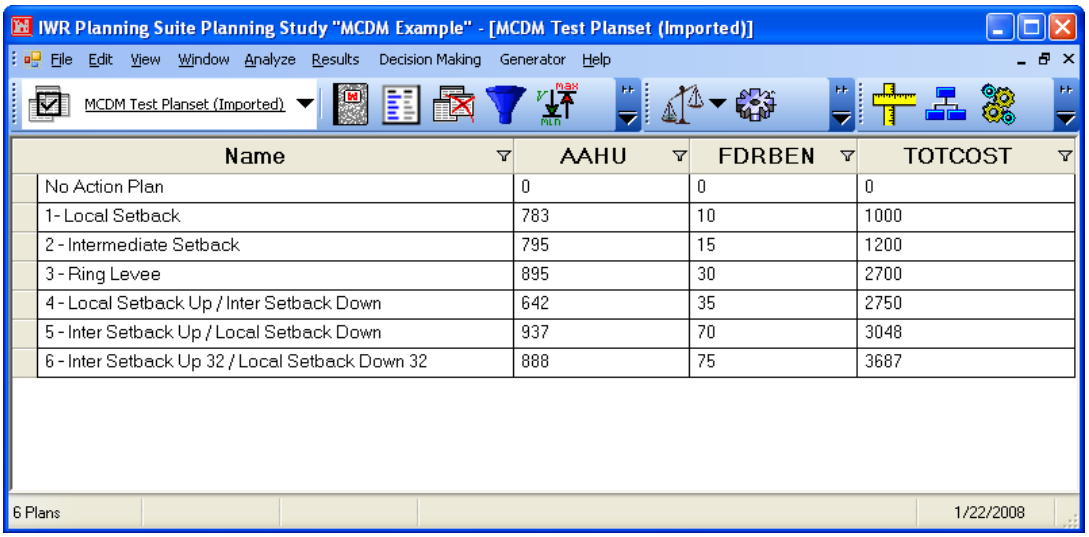


Figure 9
Creating a New MCDM Plan Study

can use for an MCDA study. If you want to open an existing MCDA file, you select the File menu Open… menu item, navigate to the location of the desired file, click on the file name of the Planning Study you wish to open, and press the Open button.

Working from Existing Planning Set Data

You can use data from an existing IWR Planning Suite database, import data from previous versions of IWR-Plan, or import from an Excel spreadsheet file. Instructions for all of these methods can be found in the IWR Planning Suite User's Guide. You can easily enter the simple planning set shown in Figure 10 on the next page.



Name	AAHU	FDRBEN	TOTCOST
No Action Plan	0	0	0
1- Local Setback	783	10	1000
2 - Intermediate Setback	795	15	1200
3 - Ring Levee	895	30	2700
4 - Local Setback Up / Inter Setback Down	642	35	2750
5 - Inter Setback Up / Local Setback Down	937	70	3048
6 - Inter Setback Up 32 / Local Setback Down 32	888	75	3687

Figure 10
Sample Planning Set

Where AAHU is Average Annual Habitat Units Gained, FDRBEN is Flood Damage, Reduction Benefits, and TOTCOST is Total Cost.

Adding New Criteria

We could at this point add new criteria to help rank these plans by other criteria deemed appropriate to assist us in choosing the 'best of the best'.

Suppose, just for example, that a new study has been conducted which concludes there to be a measurable area deer population increase related to flood damage reduction. The study also predicts that any work in the area would have an effect on that population. So, we want to add a new criterion, which will demonstrate the effect on the deer population. DeerPopIndex is a calculated value demonstrating the effect on the Deer population. We also want to add the criteria Acceptability, which is a value between 1 and 5 representing the acceptability of the particular alternative, 1 being unacceptable and 5 being most acceptable.

MCDA Criteria correspond to Plan Study variables, so we would add these new criteria as Plan Variables through the Plan Study Properties dialog as shown in Figure 11 on the next page.

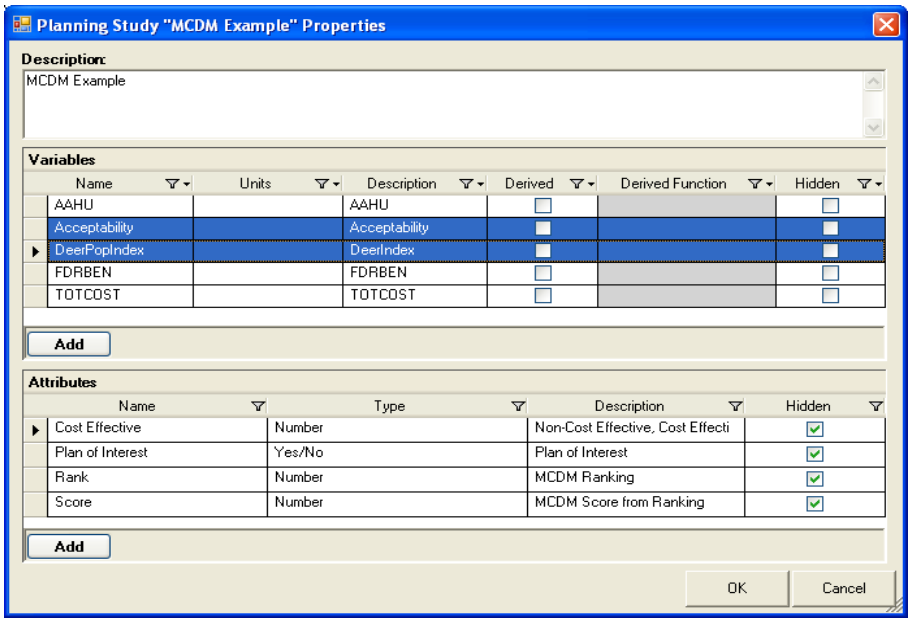


Figure 11
Plan Study Properties Dialog Box

Ensure that the Hidden checkbox in the Variables table is not checked for the two new attributes. Marking the checkbox as hidden (Figure 12), will remove the variables from the list of MCDA criteria, and we want these new variables to be available as criteria.

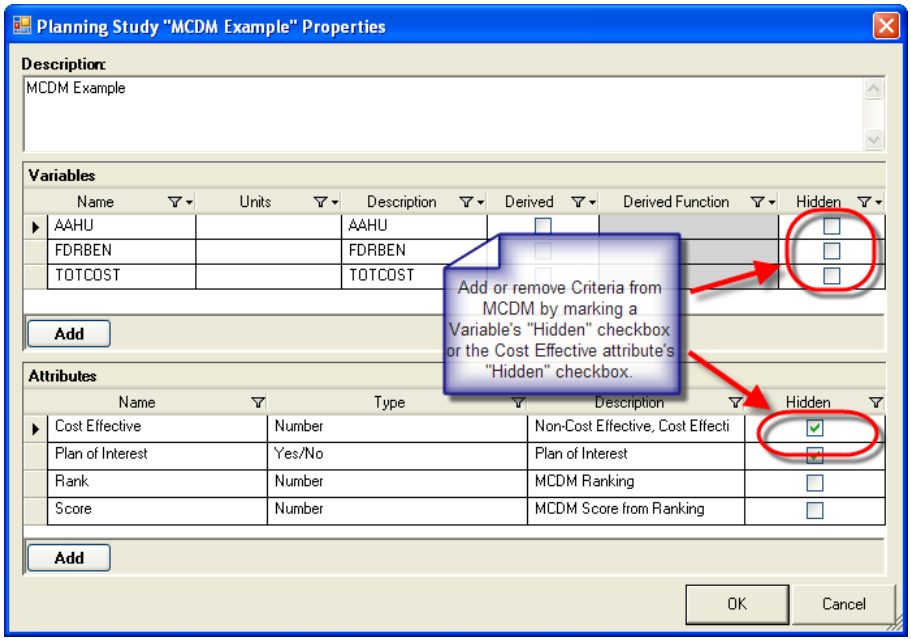


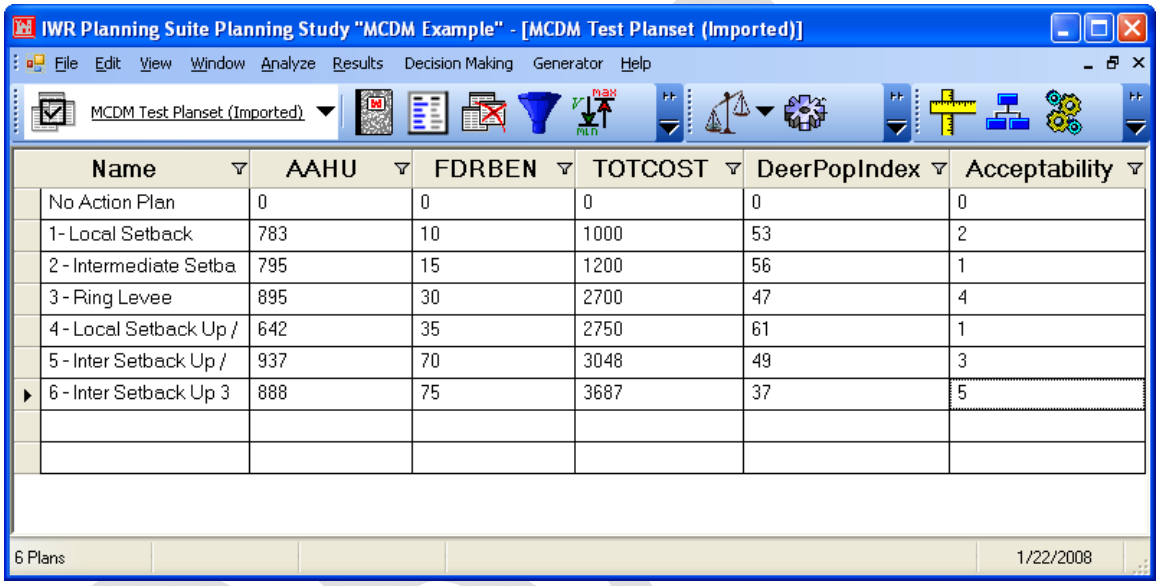
Figure 12
Add Criteria to the MCDM Set

Add these variables as new criteria, by pressing the Planning Study Properties dialog OK button to add the new variables to the plan study as MCDA criteria. NOTE: When Variables and Attributes are initially entered, they are listed in their input order.

However, when the Planning Study dialog is opened the next time, the Variables and Attributes are reorganized into alphabetical order.

Entering Criteria Values

After defining the criteria that will be used in the analysis, we now need to add some values to our new criteria to make them useful. Currently our new criteria DeerPopIndex and Acceptability have no values associated with them for each alternative. Therefore, it has no real effect on our ranking method. Enter the following information found in Figure 13 for the criterion for the corresponding alternative.



Name	AAHU	FDRBEN	TOTCOST	DeerPopIndex	Acceptability
No Action Plan	0	0	0	0	0
1- Local Setback	783	10	1000	53	2
2 - Intermediate Setba	795	15	1200	56	1
3 - Ring Levee	895	30	2700	47	4
4 - Local Setback Up /	642	35	2750	61	1
5 - Inter Setback Up /	937	70	3048	49	3
6 - Inter Setback Up 3	888	75	3687	37	5

Figure 13
Entering Criteria Values

Entering these values completes the addition of new criteria and data to the MCDA Planning Set.

Excluding Existing Criteria

We also need to exclude some variables as criteria from evaluation. MCDA Criteria correspond to Plan Study variables, so we would identify the criteria to exclude as Plan Variables through the Plan Study Properties dialog as shown in Figure 14.

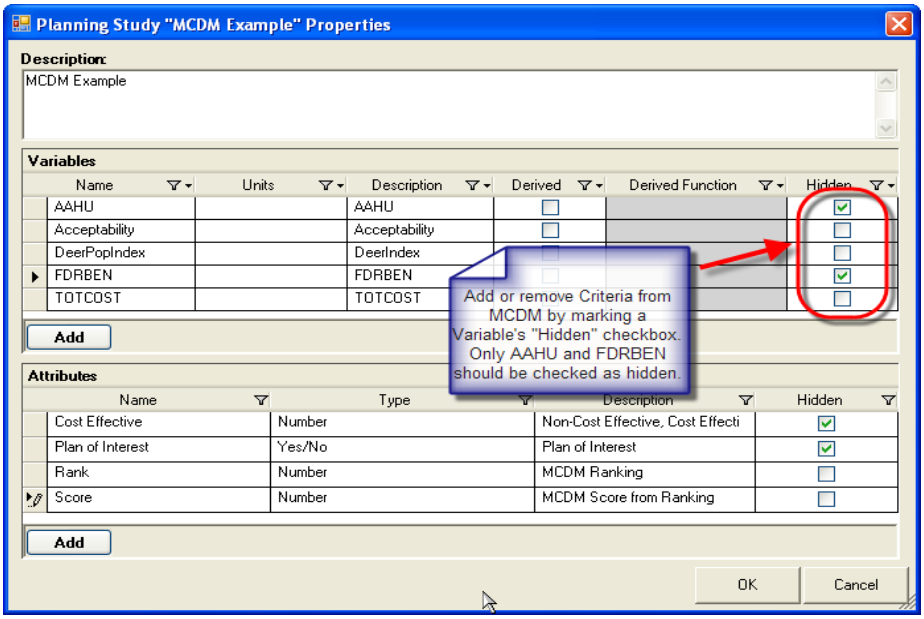


Figure 14
How to Define the Criteria to Exclude

Ensure that the Hidden checkbox in the Variables table is checked for the variables **AAHU** and **FDRBEN**. Marking the checkboxes as hidden will remove the variables from the list of MCDA criteria, and we do not want these variables to be available as MCDA criteria.

Ranking Planning Sets

Once criteria are set up properly, we can rank the planning set. Click on the Ranking Icon on the MCDA toolbar (Figure 15).

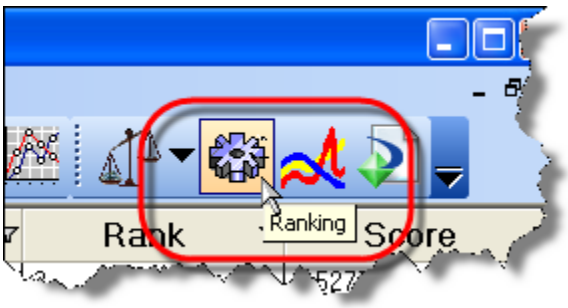


Figure 15
Toolbar Icon to Rank a Plan Set by MCDM Methods

Choose Weighted Scoring as the Rank Method (Figure 16).

You will notice the word Maximum to the right of each of the criteria. Maximum tells the program that higher values are more desirable. Minimum tells the program that

lower values are more desirable. These Min/Max are Optimization options. For more

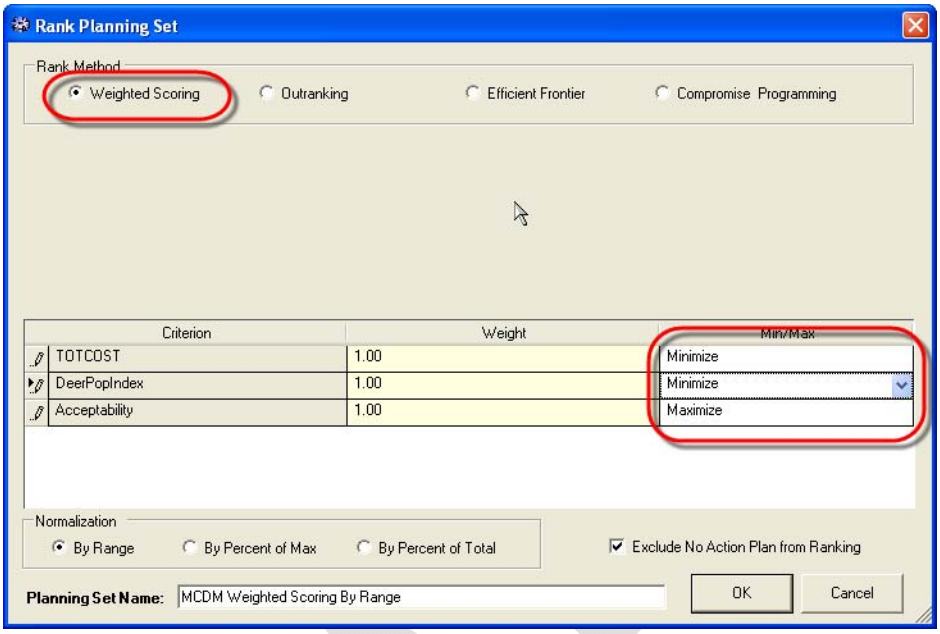


Figure 16
Rank Planning Set by Weighted Scoring

information refer to the Criteria Optimization Section on Page 5.

TotalCost should be set to Minimum, because we want the optimal alternative to have the lowest possible cost. Please recall from the initial description of the scenario that the values we entered for DeerPopIndex indicate negative effects on the Deer population, so it too is optimal when minimized. For Acceptability, the higher the number, the higher the level of acceptability, which means it should be set to Maximum. Set the optimization, labeled Min/Max, for each Criterion as shown in the dialog below.

Notice that the criteria weights are by default all one. This will become important later on when we change the weights.

Select Normalization By Range, and check the "Exclude No Action Plan from Ranking" checkbox. The default values will usually be appropriate for each ranking method for optimization and No Action plan exclusion. While a default planning set name is provided automatically based on the rank method and options selected, you can rename the MCDA set. From the planning set name text field, you may rename the default planning set name to a more specific name. Press OK to generate a new ranked planning set according to the Ranking and optimization methods defined.

Graph Ranked MCDA Planning Set Results as Bar Graph

To graph the MCDA results, click on the Graph Icon in the toolbar (Figure 17), or select Decision Making Menu Graphs Icon to display the Graph dialog.

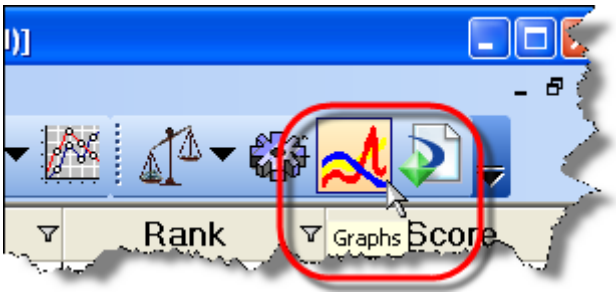


Figure 17
Icon for MCDM Graph Tool

We will now use the graphs to view the results. Select the planning set, such as "MCDA Weighted by Range" that you want to graph from the Planning Set combo box. Under

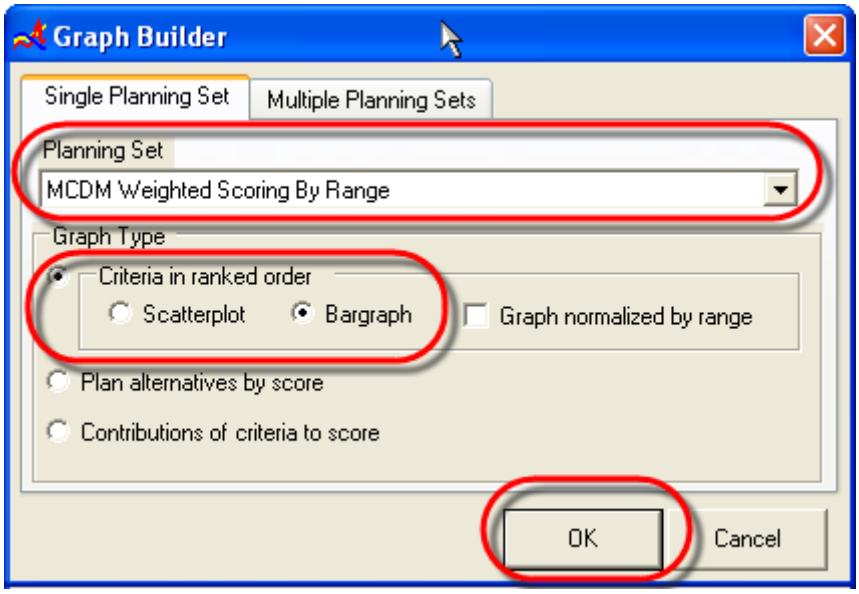


Figure 18
Select Options for MCDM Bar Graph

Graph Type choose Criteria in Rank Order (bar graph), and then click "OK", (Figure 18).

The bar graph could look like Figure 19 for the currently selected planning set, for example.

You can also access graph options by right clicking with the mouse anywhere inside of the graph. Try generating several different graphs to see what the results look like!

DRAFT

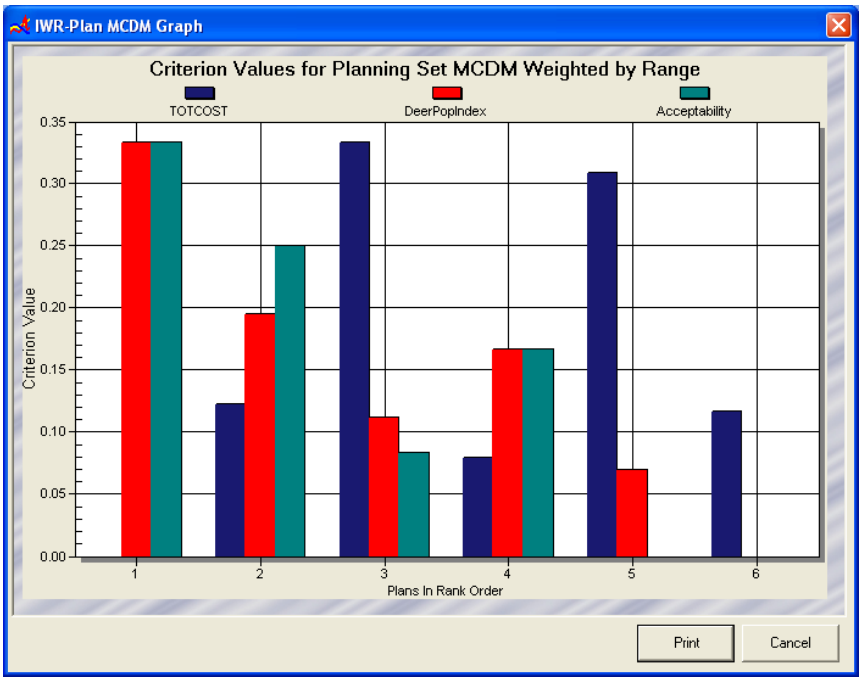


Figure 19
Graph of MCDM Criterion Value Weights

Assigning Weights Manually

We are now going to add some weights to our criteria. Weights will represent the importance of each criterion and are used in the ranking process to determine the alternative scores and ranks. Changing the weights on criteria affects the scores and therefore the rankings assigned to different plan alternatives. From the Weights popup menu icon (Figure 20) which looks like a scale, select the Weights option to display the manual dialog.

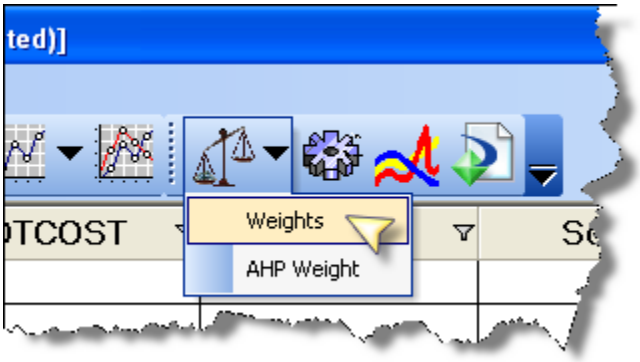


Figure 20
Manual Weights Toolbar Icon

On the Manual Creation of Weights form, you will see each of the criteria used in our study. Notice that each criterion has a weight of one. This means that all the criteria are

of equal importance to the scenario. Change your weights to match the values shown in Figure 21, and then click "OK".

Any relative weights can be entered for the various criterion, and the weights will be normalized to a standard value in the range from zero to one. This value is represented in the non-editable "Normalized Value" field.

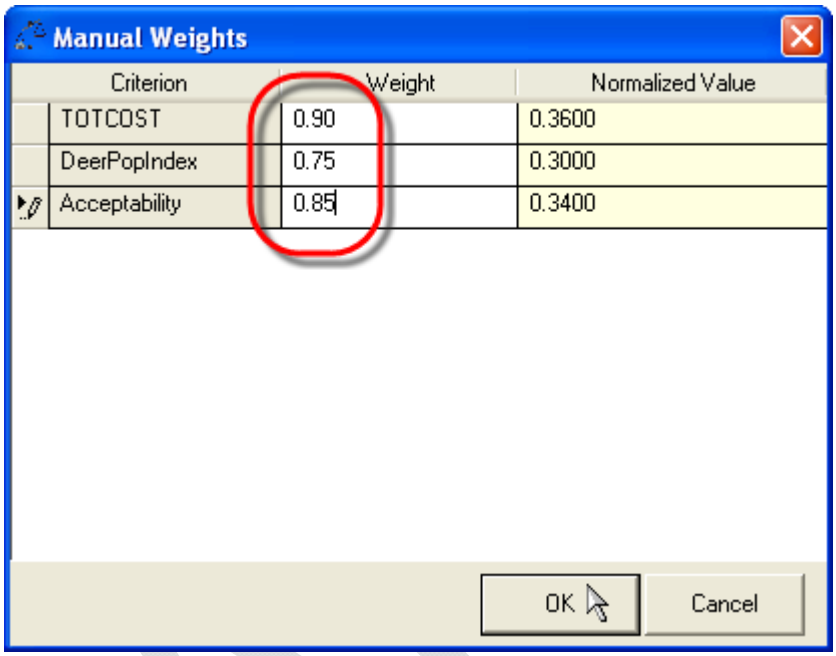


Figure 21
Manually Set Criterion Weights

Try re-ranking the original planning set using the weights and compare it to the equally weighted ranking by selecting the two planning sets and looking at their "Rank" attribute.

Bring up the Rank dialog again by clicking the Ranking Icon, and use all of the same selections as the first time ranking was done. The only difference will be in the Weights displayed, which should be the same as the weights you entered above in the Manual Weight entry dialog (Figure 22).

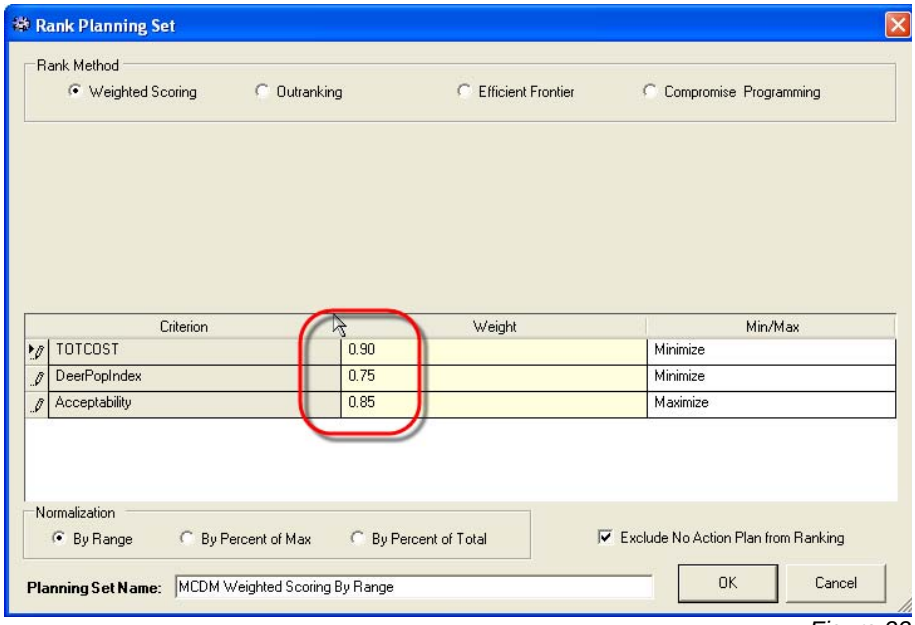


Figure 22
Rank Plan by Weighted Scoring

If the "Rank" attribute is not visible, click on the Planning Study properties icon, and in the Attributes table, uncheck the Hidden column of the Rank attribute. Uncheck the "Score" column if you want to see the underlying score from which the Plan alternative Rank is determined.

Graph Comparison of Multiple Planning Sets

Select the graph dialog Multiple Planning Sets tab, and select the MCDA sets with Weighted Scoring with and without the manual weighting, (Figure 23).

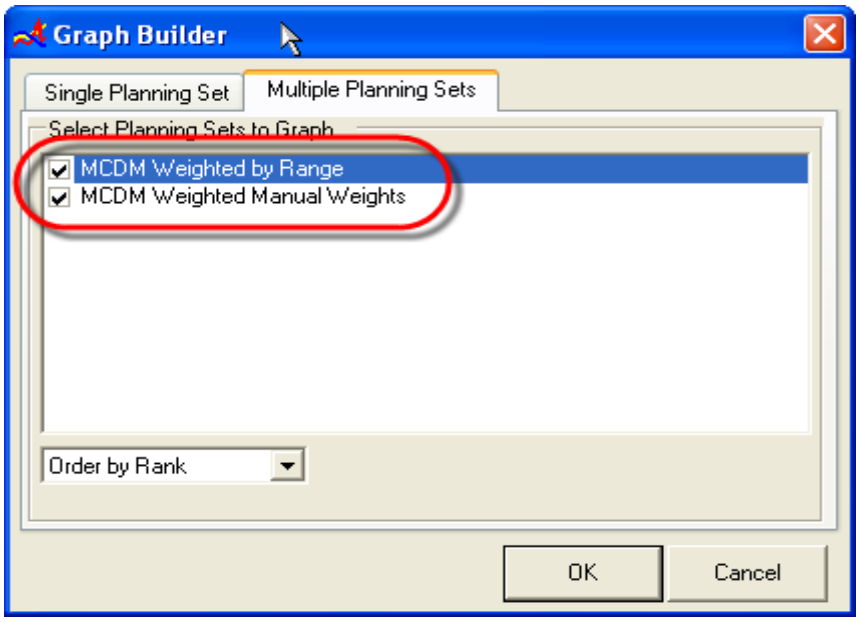


Figure 23
Selecting Multiple Plan Sets to Graph

Examine the Plan Scores, and rankings. Then, hover the mouse over the bars of Plan Alternatives so that the mouse pointer changes from an arrow to a pointing hand icon as shown on the multi-scenario Plans By Score graph, (Figure 24).

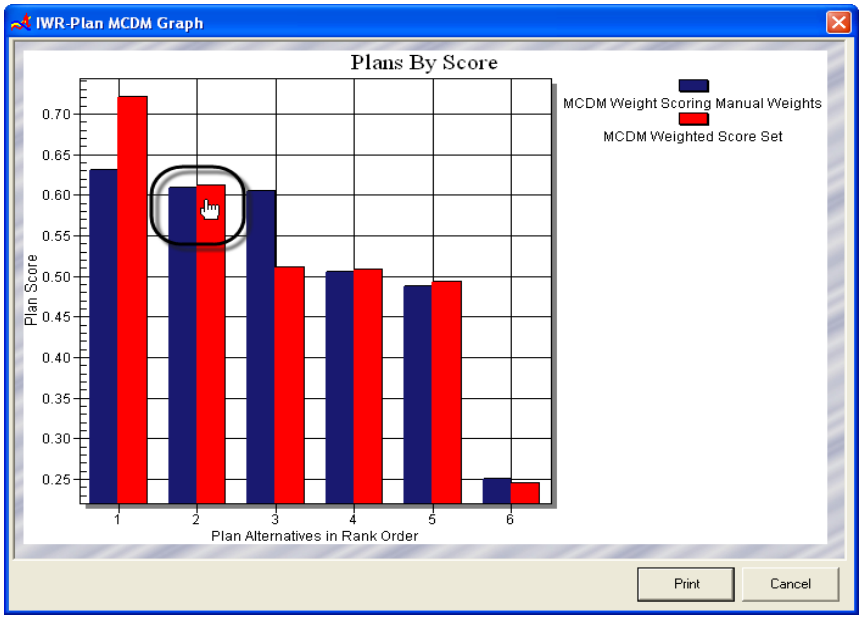


Figure 24
Multiple Plan Sets MCDM Graph of Plans by Score

Click on the bars to bring up an information dialog that shows which plans made which ranks. It should look something like Figure 25, although the specific values shown may be different from those shown here.

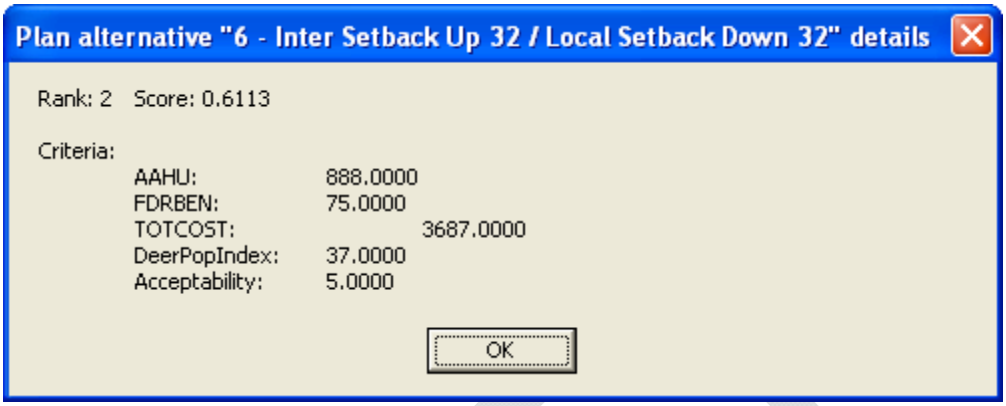


Figure 25
Plan Alternative Criterion Values

Assigning Weights with AHP

MCDA has a method of automatically assigning weights to criteria using standard English evaluative phrases. The method is called Analytical Hierarchy Process (AHP), and it uses a comparison matrix that compares the relative importance of all the criteria to one another.

When an evaluation process includes many criteria, the process of assigning appropriate weights can become confusing and unwieldy. AHP Weighting is an approach that is intended to address such situations by making the process more intuitive. AHP weighting is a useful method of involving public stakeholders in the weighting process. Because it is the product of accepted, well-established research efforts, the validity of the weighting produced by AHP may be more readily defended.

Now select AHP Weight from the Weights menu (Figure 26). Identify how important a row heading (criteria) is compared to the column heading (another criteria). For example if deer were included as a criteria in the analysis, the decision might be made that total cost is more important than the effect of Flood control on the Deer population in the project area because budgeted resources are severely limited and the impact on the size of the total deer population affected is minimal. Conversely, if financial

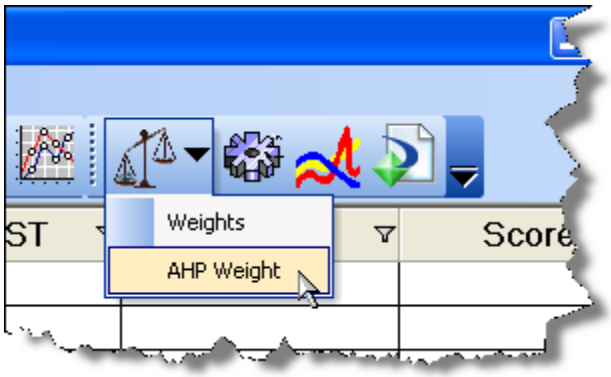


Figure 26
AHP Weight Toolbar Menu Item

resources were not a constraining factor and the percentage of the deer population affected were large, the effect on the Deer population might be considered more important than that of total cost.

The levels of importance you can choose from are natural language English phrases. See below for the phrases and their associated weights:

- Equally Important (1)
- Slightly More Important (3)
- Strongly More Important (5)
- Demonstrably More Important (7)
- Absolutely More Important (9)
- Slightly Less Important (-3)
- Strongly Less Important (-5)
- Demonstrably Less Important (-7)
- Absolutely Less Important (-9)

For the purposes of this example, fill out your table with the same selections as shown in the example AHP Weight dialog, (Figure 27).

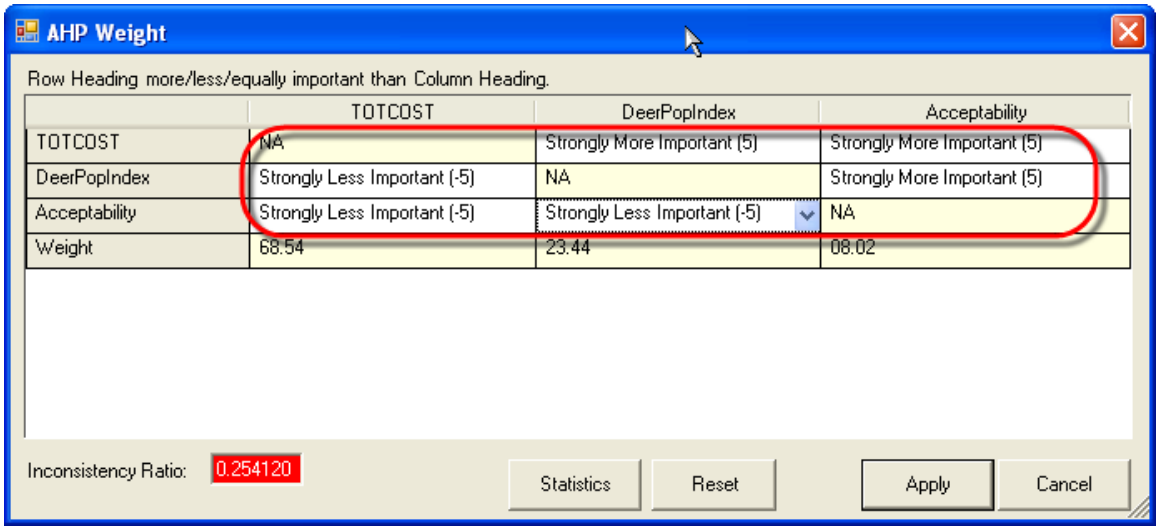


Figure 27
AHP Weight Dialog Selections

It is important to pay careful attention to the Inconsistency Ratio in the lower left corner of the form. Once the Inconsistency Ratio reaches 0.10 or above the box will become red. If this should occur, the user should examine the rankings for any inconsistencies.

Once all comparisons have been selected, click the "Apply" button to update the MCDA module to use the weights displayed in the matrix when ranking. We are now ready to see the effects or our new weighting method. Re-rank the original planning set. Examine its graphs and compare them to other MCDA planning set graphs. Notice the new rankings assigned to the plan alternatives based on the AHP Weight changes.

Now rank using the newly entered weight values for the criteria as shown in Figure 28, rename the planning set name to indicate AHP Weighting and click OK.

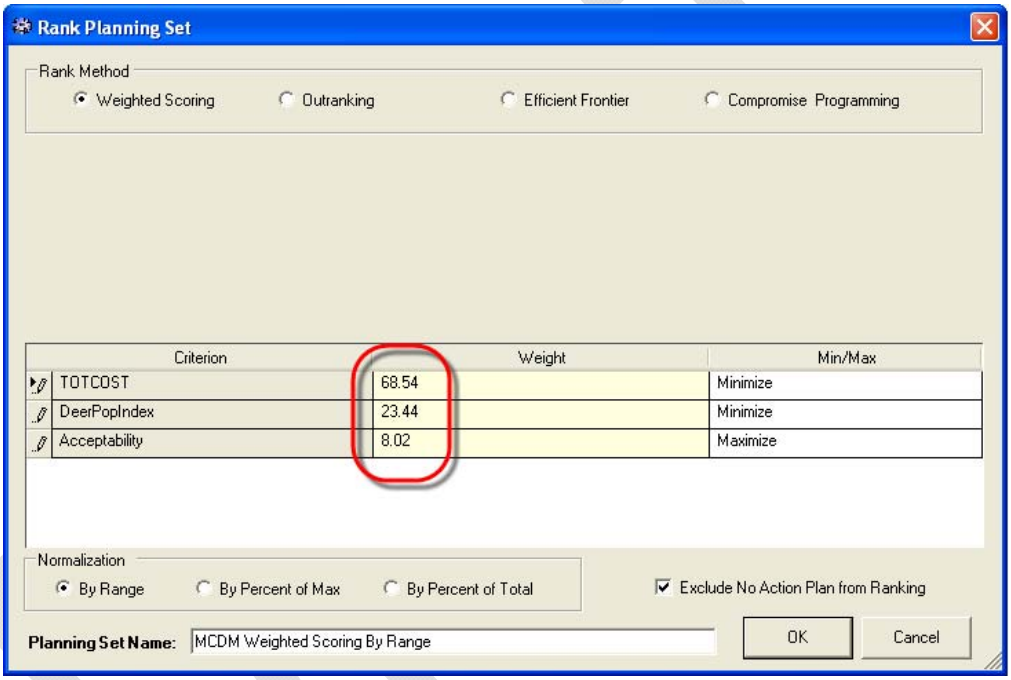


Figure28
Rank by Weighted Scoring Criterion Weights

Examine the resulting graphs and see how the ranking has been changed by the AHP Weighting selections.

Reducing Alternatives

In some cases it is necessary to reduce the size of the planning set or to eliminate those plan alternatives that do not meet the minimum requirements set for the project. This is done with the Plan Editor Constraints Filter, the purpose and use of which is described in more detail in the IWR Planning Suite manual.

Here is an example of how the constraints filter might be used to reduce a planning set for MCDA. First, select the planning set you want to constrain from the planning set list

on the plan editor. Then select the plan editor planning set constraints "funnel" icon to start the Constrain Active Planning Set dialog (Figure 29).

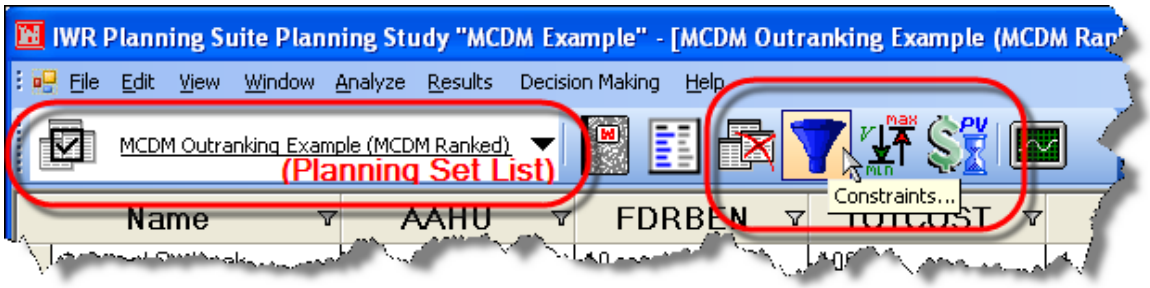


Figure 29
The Planning Set Constraint Toolbar Icon

A dialog is displayed similar to the one below, but with a default planning set name and values of -9999999999 and 9999999999 in the minimum and maximum value data fields. In the text field "Constrained Planning Set Name" please enter the new plan set name "Reduced Example Matrix" (Figure 30). (If you would like, after the constrained plan set has been generated, you may change its description to "Exclude inappropriate plan alternatives" on the planning set properties dialog.) This process allows us to make changes without altering the existing MCDA planning set. Press the OK button to close the dialog box.

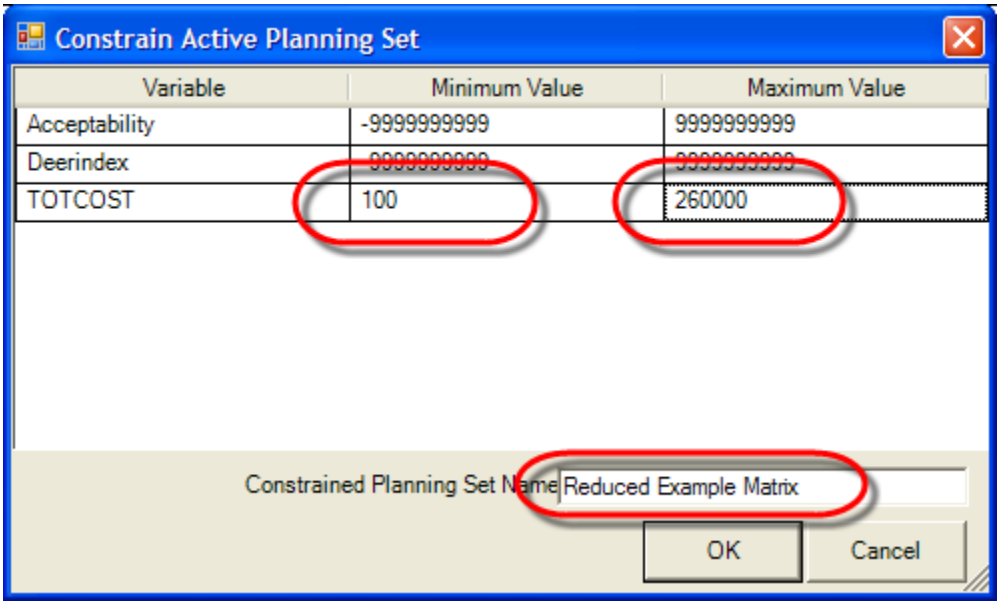


Figure 30
Constrain Total Cost

Now we will set the minimum and maximum values for our criteria. Change the minimum for Totalcost to 100, this means that alternatives total cost value must be at

least 100 to be included in the scenario. Assume we also have a $260,000 budget that we cannot exceed. For Total cost, you would set maximum to 260000 as shown, then click "OK" to generate the reduced plan set and close the Constrain Active Planning Set form.

Then select the MCDA Decision Making "Ranking" icon, and press OK to re-rank the alternatives after constraining them.

Change Ranking Method

Select the original MCDA Plan Set from the Plan Set List on the toolbar.

Click the Ranking icon to display the Rank Planning Set dialog, (Figure 31). Under method of ranking choose Outranking. A frame containing Outranking Criterion Types will appear on the dialog. These are all of the different preference functions you can choose for Promethee. Hovering over any of the types will bring up a brief definition for

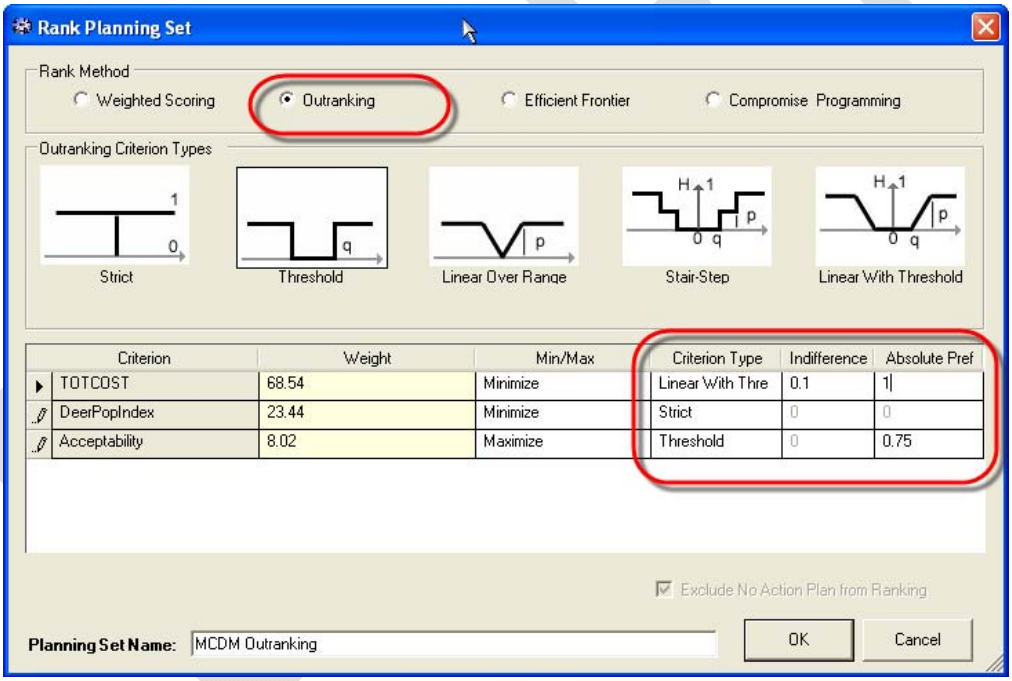


Figure 31
Rank by Outranking

that particular preference function definition.

Set the Criterion Type for DeerPopIndex to Strict. Set the Criterion Type for Totalcost to Linear With Threshold. Then set the Absolute Preference= 1 and Indifference Value=0.1. Using the Linear with Threshold performance function, an alternative (alternative A) is absolutely better than another alternative (alternative B) if its TotalCost differs by the absolute value of 1. However, as the difference between alternative A and B grows from

the Indifference Value to the Absolute Value there is a linear preference for alternative A.

Set the Outranking Criterion Type to Threshold. Set the Indifference Value to 0.75. If alternative A and Alternative B differ by only .75 then there is no preference for either A or B. Once the Acceptability differs by a value greater than 0.75 then a preference is shown. We are ready to enter a name and Click "OK" to rank the scenario. Then view the result of our ranking.

Viewing MCDA Scatterplot Graphs

View the results via the MCDA Graphs. Select the Graph Builder dialog. Under Graph Type choose Criteria in Ranked Order, Scatterplot, and click "OK" (Figure 32).

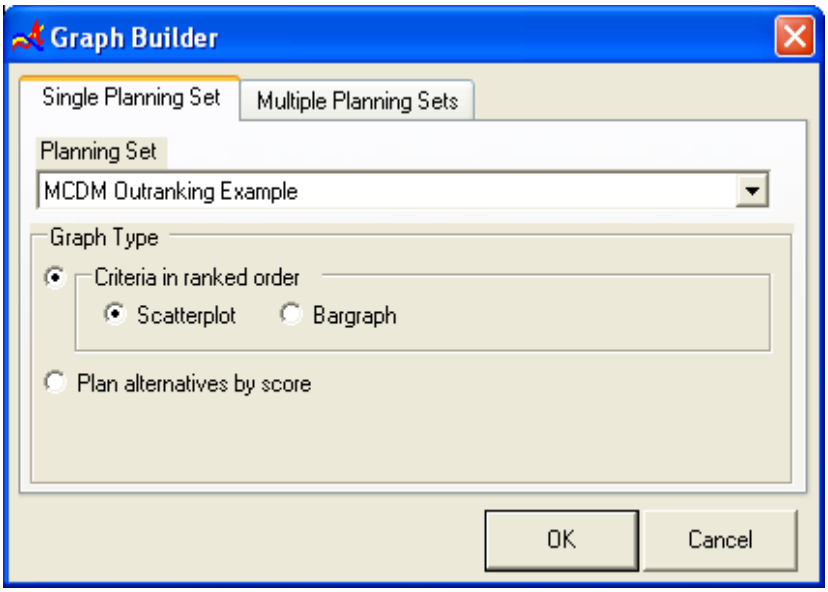


Figure 32
MCDM Graph Parameters Dialog

In all graphs (Figure 33), you are able to click on the bar to see information for that particular alternative. You can also access graph options by right clicking with the mouse anywhere inside of the graph.

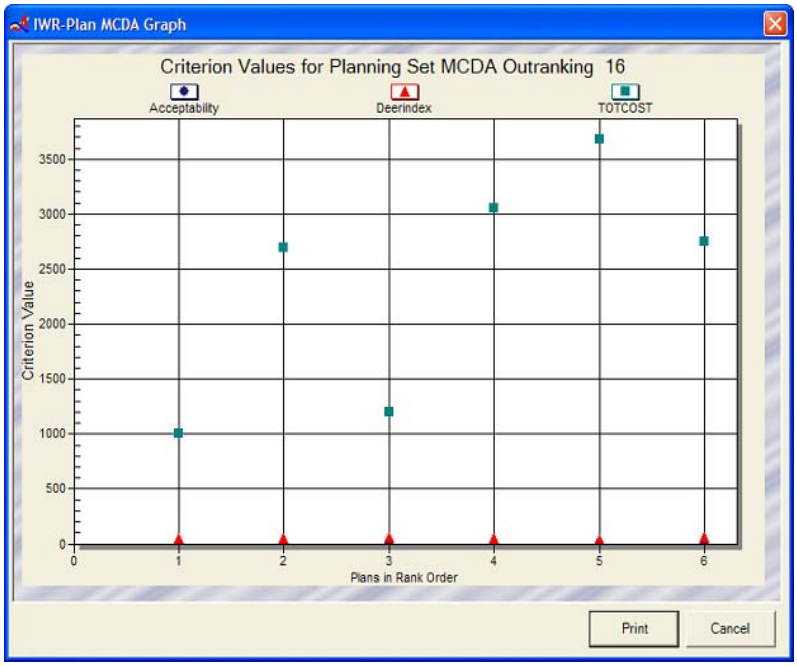


Figure 33
MCDA Criterion Values Scatterplot

Let's look at some of MCDA's additional graphing options. We'll use scenarios that we have already run.

Since we've processed the Weighted MCDA Plan Set, let's use it. We won't need to Rank again, but select the Outranked Planning Set from the list if necessary.

Now let's display the Criterion Contribution bar graph. Please select the Weighted Scoring Planning Set on the Graph Builder dialog Single Planning Set tab. The option "Contributions of criteria to score" will appear. Please select this option and click on the

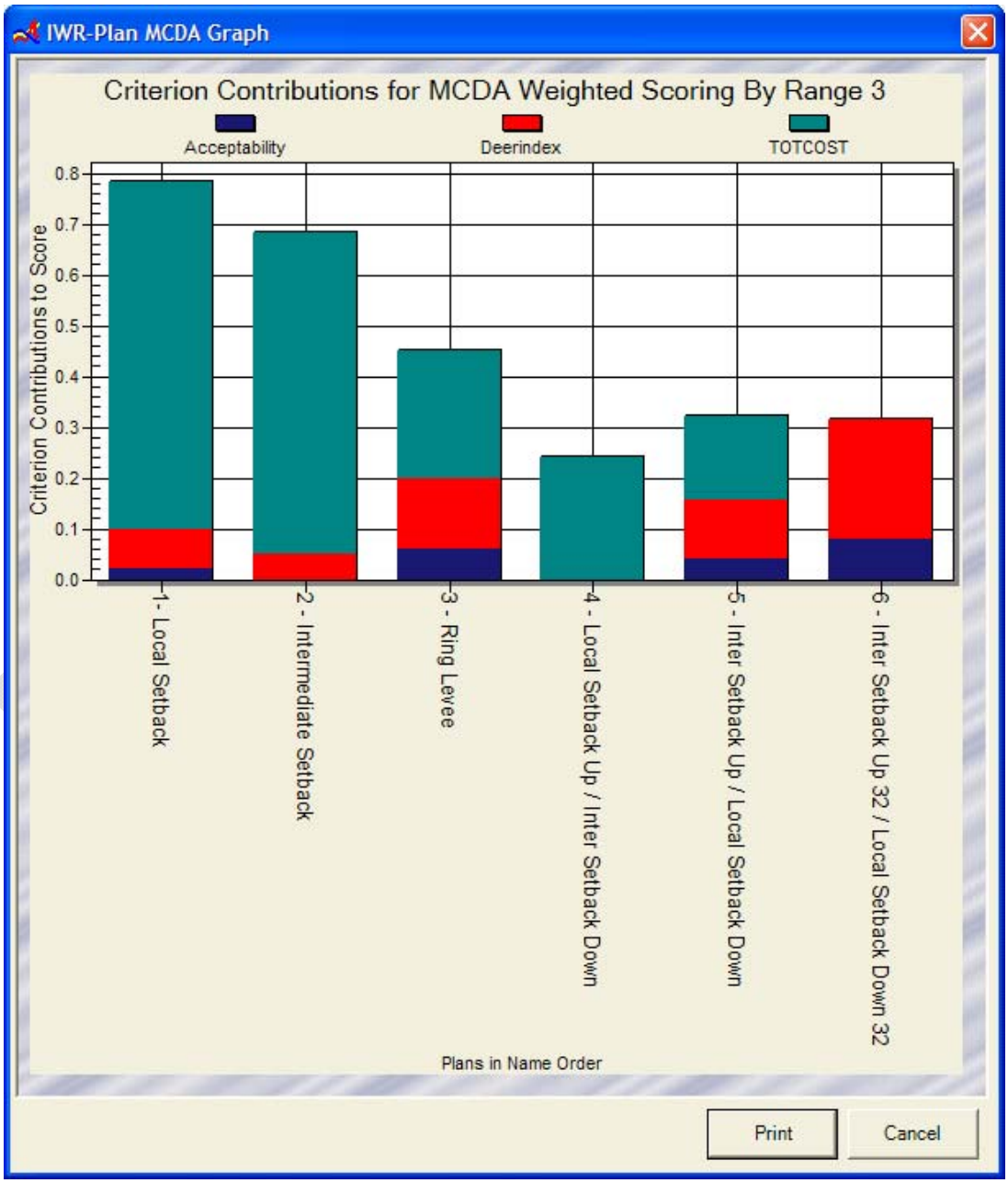


Figure 34
Criteria Contributions Graph

Figure 35
Message Box

OK button to display the graph. This graph shows how each criterion contributes to the total score for that alternative. Your graph should look like Figure 34.

If you click on one of the bars a form will appear with information about that alternative. A picture of one of these message boxes can be seen below (Figure 35). This function is available in every graph in the system. To change the way the graph looks, right click anywhere in the graph to cause the graph's popup menu to appear, Select Data Shadows and then 3D. This makes the bars appear 3D (Figure 36). This function is useful when you have data that is so small it is hard to see in the 2D view, but in the 3D view it becomes much clearer.

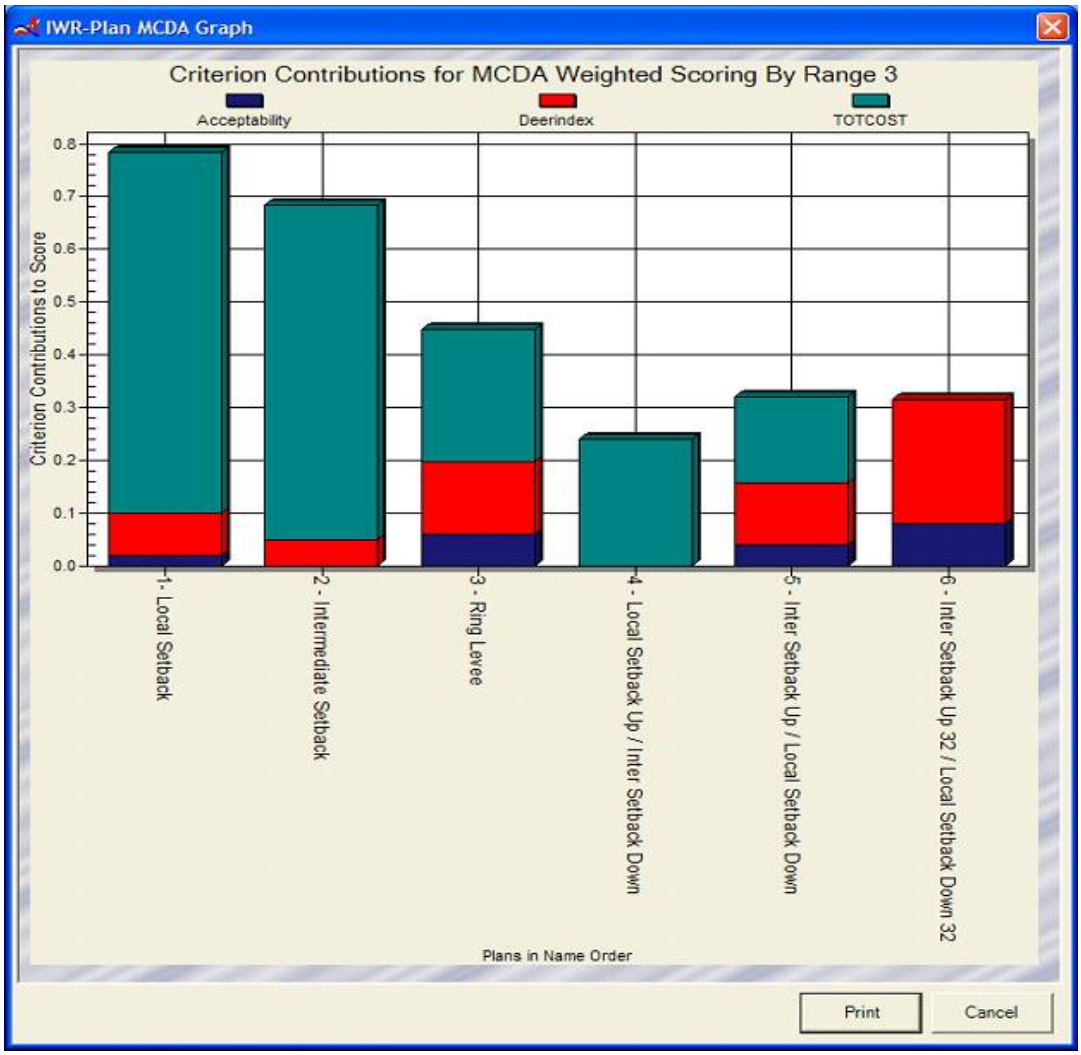


Figure 36
MCDM Graph Criterion Weighted by Range

Multiple Scenario Graphs

Planning sets from multiple scenarios generated by the same ranking method can be compared. If two such planning sets are ranked, they may be compared as follows. Choose the graph builder, and select the MCDA Weighted Scoring planning set. A similar graph of the same form as that shown in Figure 37 will be generated.

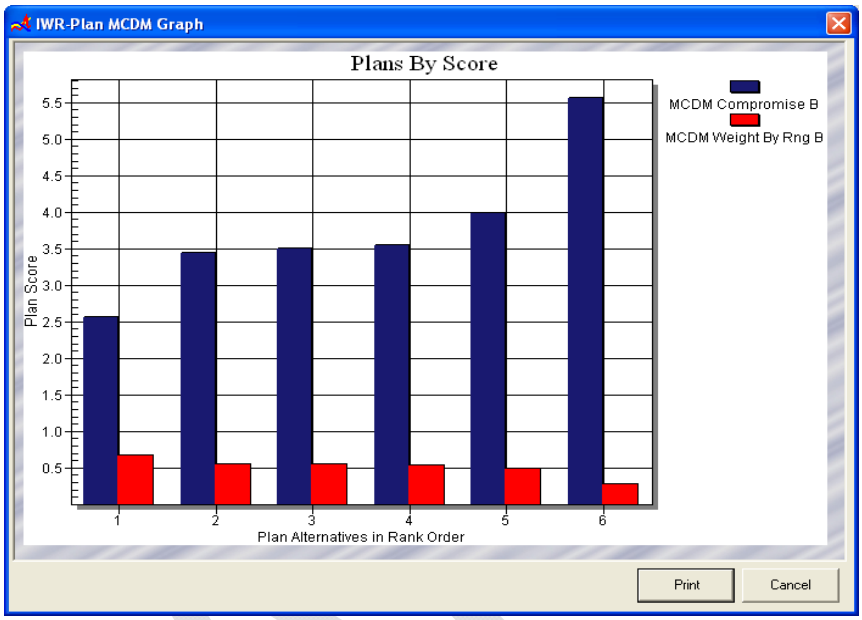


Figure 37
MCDM Multiple Scenario Graph

Graphing Options

Additional graphing options are available for all graphs types, for example, changing font types and sizes, changing plotting methods, removing grid lines, editing titles, changing graph colors, exporting graph information to another file or the computer clipboard, and other options. To access these options, simply **right-click** with your mouse placed over the graph (Figure 38).

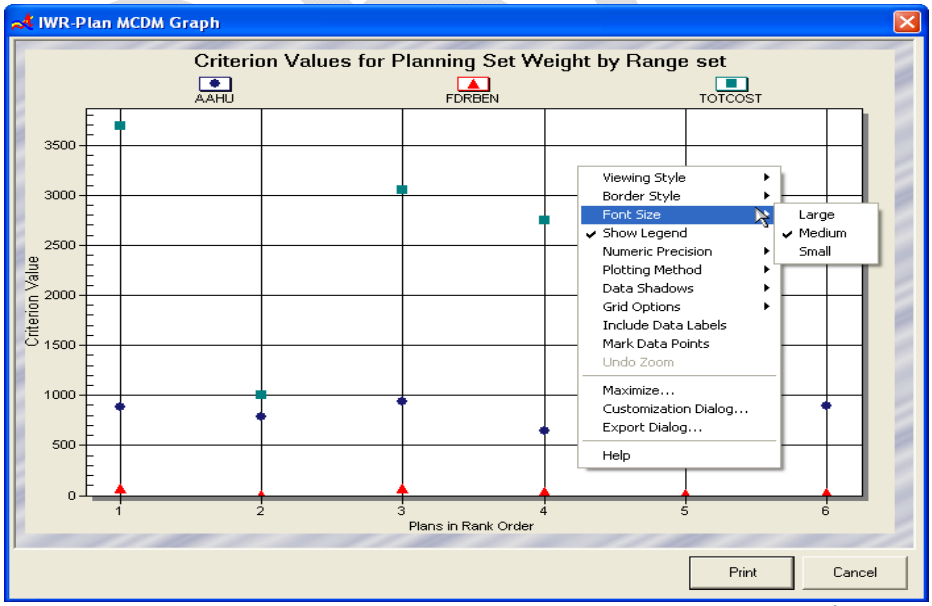


Figure 38
MCDM Criterion Values Graph

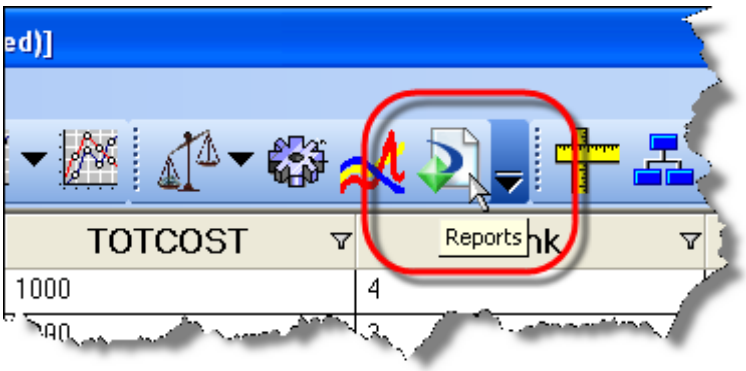


Figure39
MCDM Reports Toolbar Icon

Generating MCDA Reports

There are also several reports that can be generated. The user can create reports which sort the alternatives by plan name and by the rank after running one of the algorithms. The order of plans can also be compared across planning sets to determine if a particular set of plans rise to the top under a variety of circumstances.

Click on the reports icon, which is shown in the Figure 39. This will cause the MCDA

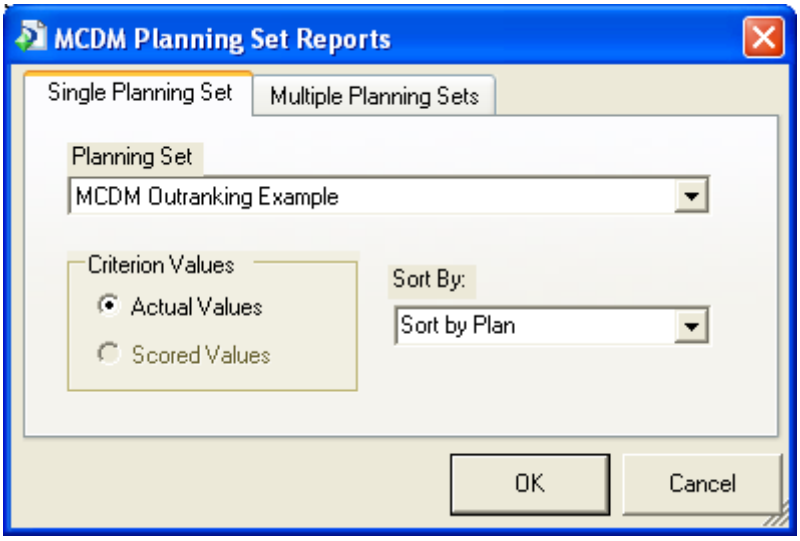


Figure 40
MCDM Rank Report Options

Planning Set Report dialog to display. Make sure the "Single Planning Set" tab is selected to report on a single planning set. Select the planning set (Figure 40) Actual Values or Scored Values (if enabled), and select how you would like the alternatives to be sorted. The Criteria Values, Actual Values will display the values for the individual criteria input by the user. The Criteria Values that are scored will display the

Figure 41
Single Scenario Rank Report

MCDM Planning Set Report - Actual Criterion Values

MCDM Outranking Example (MCDM Ranked)

Ranking Method: Outranking

Criteria	Weight	Optimization	Criterion Type	Indifference Value	Absolute Preference
HabitatUnits	1.00	Maximize	Strict	0.00	0.00
CostUnits	1.00	Minimize	Strict	0.00	0.00
Salamanders	1.00	Minimize	Strict	0.00	0.00
Cost Effective	0.00	Maximize	Strict	0.00	0.00
turbidity	1.00	Maximize	Strict	0.00	0.00

Rank	Name	Score	HabitatUnits	CostUnits	Salamanders	Cost Effective	turbidity
123	C0B0I0J0A0H0K1	0.0138	-4.1600	16.0230	0.0000	1.0000	20.0000
254	C0B0I0J0A0H1K0	-0.3799	16.4800	33.9260	732.0000	1.0000	16.0000
232	C0B0I0J0A0H1K1	-0.2923	19.2300	49.9490	732.0000	1.0000	20.0000
171	C0B0I0J0A1H0K0	-0.1093	10.0600	12.1700	0.0000	2.0000	16.0000
125	C0B0I0J0A1H0K1	0.0118	12.8100	28.1930	0.0000	1.0000	20.0000
251	C0B0I0J0A1H1K0	-0.3583	33.4500	46.0960	732.0000	1.0000	16.0000
227	C0B0I0J0A1H1K1	-0.2825	36.2000	62.1190	732.0000	1.0000	20.0000
162	C0B0I0J1A0H0K0	-0.0827	20.0200	36.0440	0.0000	2.0000	17.0000

normalized and weighted values. With both of the criterion values options, the final score will be displayed in the report.

Press the "OK" button on the dialog to view the Single Scenario Rank Report (Figure 41).

There is also a report that allows for the comparison of multiple planning sets. It requires that the planning sets that are compared be derived from the same parent planning set. All planning sets that derive from a particular parent are grouped together under that parent set as shown in Figure 42 example dialog

Comparing the Outranking and Weighted scoring planning sets produce a report similar in format to the one shown in Figure 43.

These reports and graphs provide the user with many ways to view the results for each

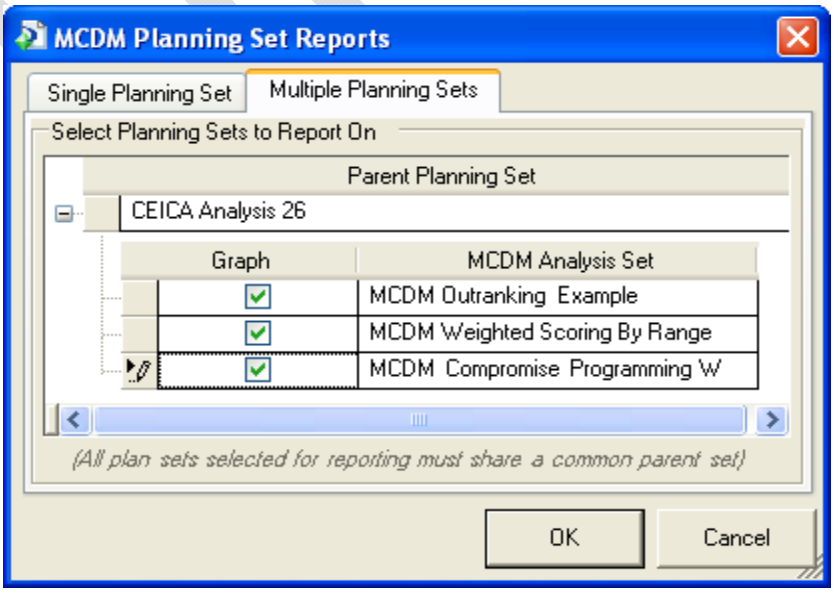
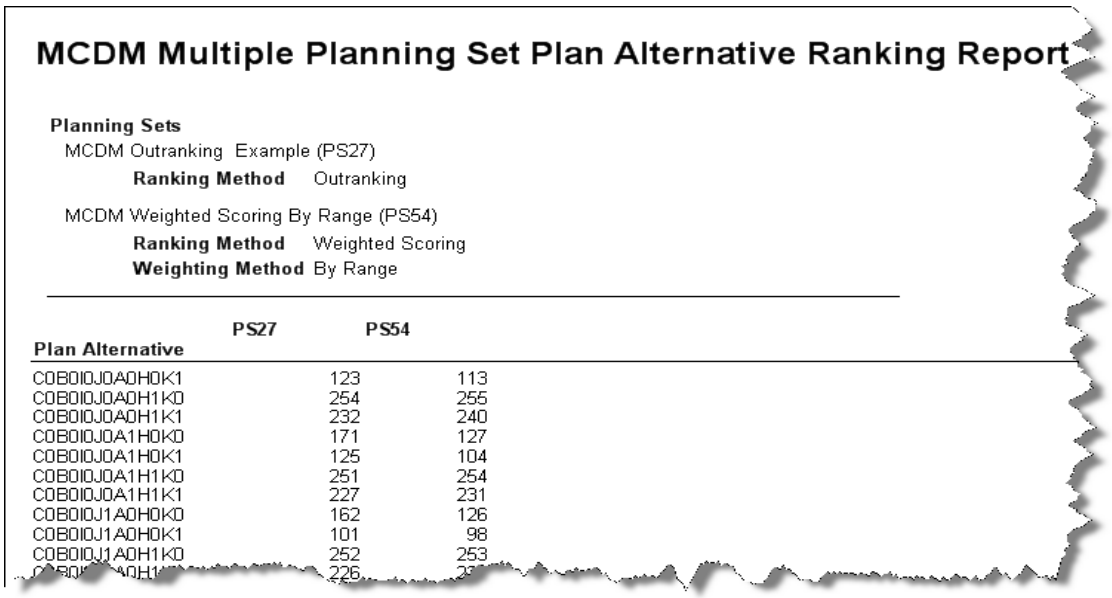


Figure 42
Multiple Planning Set Report Criteria

scenario. Try out all of the reporting and graphing capabilities to familiarize yourself with MCDA's reporting capabilities.



MCDM Multiple Planning Set Plan Alternative Ranking Report

Planning Sets
MCDM Outranking Example (PS27)
Ranking Method Outranking

MCDM Weighted Scoring By Range (PS54)
Ranking Method Weighted Scoring
Weighting Method By Range

Plan Alternative	PS27	PS54
C0B0I0J0A0H0K1	123	113
C0B0I0J0A0H1K0	254	255
C0B0I0J0A0H1K1	232	240
C0B0I0J0A1H0K0	171	127
C0B0I0J0A1H0K1	125	104
C0B0I0J0A1H1K0	251	254
C0B0I0J0A1H1K1	227	231
C0B0I0J1A0H0K0	162	126
C0B0I0J1A0H0K1	101	98
C0B0I0J1A0H1K0	252	253
[illegible]	226	[illegible]

Figure 43
Planning Set Report

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