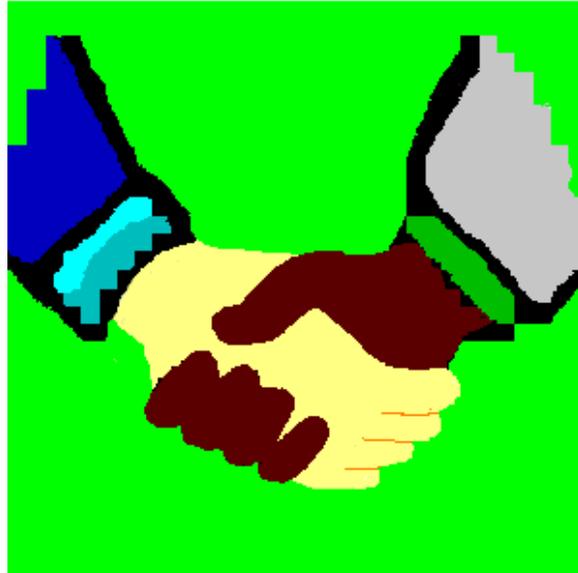# NAIADE

MANUAL & TUTORIAL

Joint Research Centre - EC, *ISPRA SITE*
Institute for Systems, Informatics and Safety

NAIADE MANUAL - Version 1.0.ENG

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1. CONCEPTS

1.1. What is NAIADE?

NAIADE (**N**ovel **A**pproach to **I**mprecise **A**ssessment and **D**ecision **E**nvironments) (Munda, 1995) is a new multicriteria evaluation method which performs the comparison of alternatives on the basis of a set of criteria. It allows the use of information affected by different types and degrees of uncertainty. The values assigned to the criteria for each alternative may be expressed in the form of either crisp, stochastic, fuzzy numbers or linguistic expressions. NAIADE is a discrete method (the set of alternatives is finite) that does not use traditional weighting of criteria. Using a pairwise comparison technique, NAIADE generates a ranking of alternatives (γ problem formulation).

NAIADE allows for two types of evaluations. The first is based on the score values assigned to the criteria of each alternative and is performed using an *impact matrix* (alternatives vs: criteria). The second analyses conflict among the different interest groups and the possible formation of coalitions according to the proposed alternatives (equity matrix: linguistic evaluation of alternatives by each group).

1.2. NAIADE: Concepts

The **multicriteria analysis**, which is performed on the impact matrix, is based on a comparison algorithm of the alternatives made up by the following steps:
>   1. completion of the *criteria/alternatives (impact)* matrix,
>   2. *pairwise comparison of alternatives* using *preference relations*,
>   3. aggregation of all criteria, and finally
>   4. ranking of alternatives.

Equity analysis is performed by the completion of an *equity matrix* from which a *similarity matrix* is calculated. Through a mathematical reduction algorithm, it is possible to build a *dendrogram of coalitions* which shows possible coalition formation, and level of conflict among the interest groups.

1.2.1 Impact Matrix

As for most of the discrete multicriteria methods, the starting point is the creation of the criteria/alternatives matrix. Firstly, the user has to input the value associated to each criteria according to each alternative. The user may assign a value in the form of a pure number (e.g.: for the cost criterion a precise number expressed in currency unit), or give a quantitative definition affected by different levels and types of uncertainty. In the case of fuzzy uncertainty, the user must define the membership function of the fuzzy number. In the case of stochastic uncertainty the user has to choose the probability density function. Lastly, it is possible to give a value using a qualitative evaluation expressed by pre-defined "linguistic variables" such as "Good", "Moderate", "Very Bad" and so on. The linguistic variables are treated as fuzzy sets (see appendix A for a complete description of stochastic, fuzzy and linguistic variables). NAIADE allows the use of all these types of information providing they are consistent for each alternative/criterion, i.e. it is not possible to assign different "types" (i.e.: linguistic, fuzzy, stochastic) to the same criteria for different alternatives (all alternatives must be evaluated for the same criteria and the types of criteria must be the same for all alternatives).

1.2.2. The Semantic Distance

In order to compare the criteria values for the alternatives, it is necessary to introduce the concept of distance. In the case of numeric evaluation, the distance is simply defined as the difference between the two numbers. In the case of fuzzy or stochastic evaluation, the concept of *semantic distance* is used. Semantic distance measures the distance between two functions: it takes into account the position and also the shape of the two functions (either for fuzzy membership functions or probability density functions). The formal definition of semantic distance is:

Given two fuzzy sets $\boldsymbol{m}_{A_1}(x)$ and $\boldsymbol{m}_{A_2}(x)$, let's define

$$f(x)=k_1\boldsymbol{m}_{A_1}(x) \qquad \text{and} \qquad g(y)=k_2\boldsymbol{m}_{A_2}(y)$$

where f(x) and g(y) are two functions obtained by scaling the ordinates of $\mu_{A_1}(x)$ and $\mu_{A_2}(x)$ through k_1 and k_2, such as:

$$\int_{-\infty}^{+\infty} f(x)dx = \int_{-\infty}^{+\infty} g(y)dy = 1$$

The semantic distance $S_d(f(x),g(y))$ between the two fuzzy sets is defined as follows:

if f(x) : X= [x_L, x_U] and g(y) : Y= [$x_{L'}$, $x_{U'}$]
(where sets X and Y can be non-bounded), then

$$S_d(f(x),g(y)) = \int_X \int_Y |x-y| f(x)g(y)dxdy$$

The same distance concept can be easily extended to stochastic measures. In this case *f(x)* and *g(y)* are the probability density functions of the measures.

1.2.3. Preference Relations and Pairwise Comparison of Alternatives

The comparison of criteria scores (values) of each pair of (alternatives) actions is carried out by means of the semantic distance described above. This comparison is based on *preference relations,* expressed by the user, for each single criterion starting from the distance between alternatives. *Preference relations* are defined by means of 6 functions that allows to express (depending on the distance between alternatives), for each criterion, an index of credibility of the statements that an alternative is *much better*, *better*, *approximately equal*, *equal*, *worse* and *much worse* than another. The credibility index goes from 0 (definitely non-credible) to 1 (definitely credible) increasing monotonically within this range. The following are the definitions of the six preference relations:
- the first two relations *much better* e *better* are defined as follows:

$$\boldsymbol{m}_{>>}(d)=\begin{cases} 0 & \text{for } d<0 \\ \dfrac{1}{\left(1+\dfrac{c_{>>}^2(\sqrt{2}-1)}{d^2}\right)^2} & \text{for } d\geq 0 \end{cases} \quad \text{and} \quad \boldsymbol{m}_{>}(d)=\begin{cases} 0 & \text{for } d<0 \\ \dfrac{1}{\left(1+\dfrac{c_{>}^2}{d^2}\right)} & \text{for } d\geq 0 \end{cases},$$

where $C_>$ and $C_{>>}$ are the crossover values (the point where the functions equal 0.5) and *d* is the distance. The preference relations are shown in the following figure:
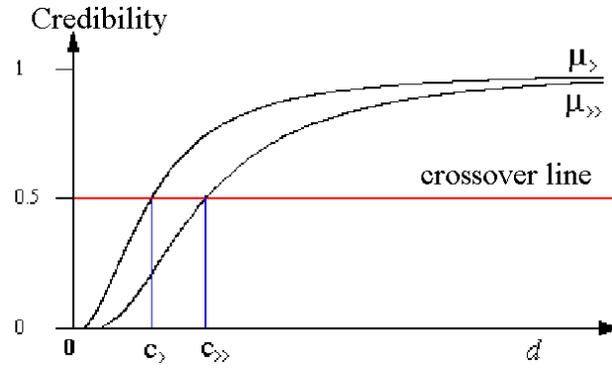
- the preference relations *approximately equal* and *equal* are defined as follows:

$$\boldsymbol{m}_{\underline{\underline{\cong}}}(d) = e^{-\left(\frac{\log 2}{C_{\underline{\underline{\cong}}}}|d|\right)} \quad \forall d \quad \text{and} \quad \boldsymbol{m}_{\underline{=}}(d) = e^{-\left(\frac{\log 2}{C_{==}^{2}}d^{2}\right)} \quad \forall d,$$

where $C_{==}$ and $C_{\underline{\underline{\cong}}}$ are the crossover values (the point where the functions equal 0.5) and d is the distance. The preference relations are illustrated in the following figure:

- finally the two preference relations *much worse* and *worse* are defined as follows:

$$\boldsymbol{m}_{<<}(d) = \begin{cases} 0 & \text{for } d > 0 \\ \dfrac{1}{\left(1+\dfrac{C_{<<}^{2}\left(\sqrt{2}-1\right)}{d^{2}}\right)^{2}} & \text{for } d \leq 0 \end{cases} \quad \text{and} \quad \boldsymbol{m}_{<}(d) = \begin{cases} 0 & \text{for } d > 0 \\ \dfrac{1}{\left(1+\dfrac{C_{<}^{2}}{d^{2}}\right)} & \text{for } d \leq 0 \end{cases}$$

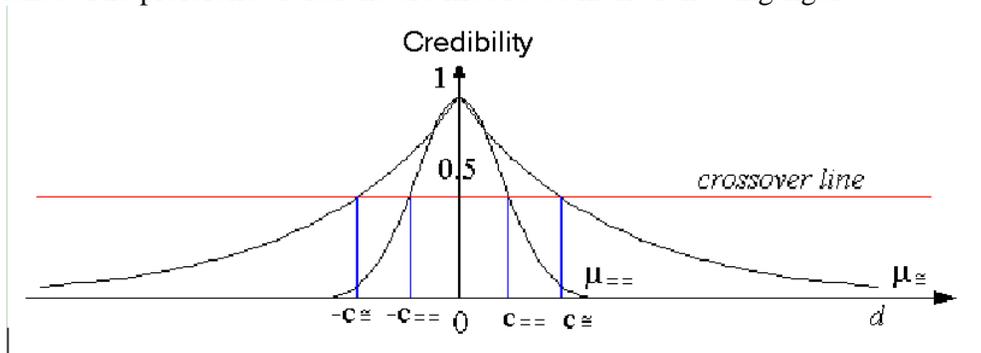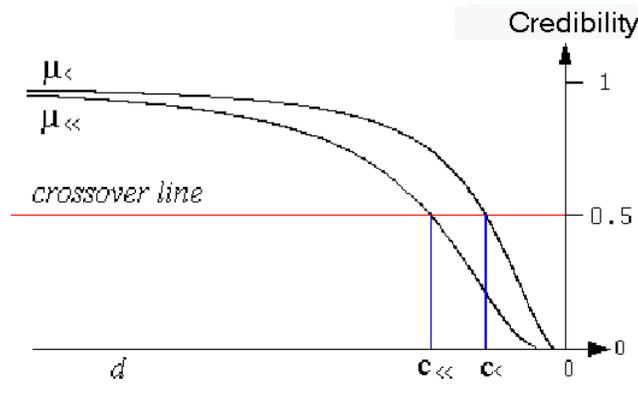where $C_{<}$ and $C_{<<}$ are the crossover values (the point where the functions equal 0.5) and d is the distance. The preference relations are illustrated in the following figure:

The following constraints apply to the preference relations:

1) $m_{>>}(d) = m_{<<}(-d)$ e $m_{>}(d) = m_{<}(-d)$ (i.e. $c_> = -c_<$ e $c_{>>} = -c_{<<}$) given two alternatives A and B at distance d, the credibility index of the statement A *is better* than B is equal to credibility index of the statement A *is worse* than B.

2) $C_{==} < C_{\cong} < C_> < C_{>>}$ The credibility index of the statement A *is equal* to B is less than the credibility index of the statement A *is approximately equal* to B increasing the distance d between A and B. The credibility index of the statement A *much better* than B is less than the credibility index on the statement A *is better* than B increasing the distance d between A and B. Moreover, the crossover value $C_{\cong}$ of the relation A *is approximately equal* to B must be less than the crossover value $C_>$ of the relation A *is better* than B crossover; in other words it is inconsistent to state that an interval of distance values exists where both the relations *better* and *approximately equal* are credible (above 0.5 credibility index).

Independently from the type of information (fuzzy, numeric or stochastic), the user has to assign the numeric value of the distance where the credibility index equals 0.5 (crossover point).

For each pair of alternatives and for each criterion, based on the 6 preference relations defined for that criterion, NAIADE calculates all the credibility indexes.

1.2.4. Criteria Aggregation

Through an aggregation algorithm of the credibility indexes, NAIADE calculates a *preference intensity index* of one alternative with respect to another. In particular the α parameter is used to express the minimum requirements on the credibility indexes. Only those criteria whose indexes are above the α threshold will be counted positively in the aggregation. The *intensity index* $m*(a,b)$ of preference * (where * stands for $>>$, $>$, $\cong$, $=$, $<<$ and $<$) of alternative a versus b is defined as follows:

$$m*(a,b) = \frac{\sum_{m=1}^{M} \max\left(m*(a,b)_m - a, 0\right)}{\sum_{m=1}^{M} \left|m*(a,b)_m - a\right|}$$

The *intensity index* $m*(a,b)$ has the following characteristics

$0 \le m_*(a,b) \le 1$

$m_*(a,b) = 0$ if none of the $m_*(a,b)_m$ is more than a

$m_*(a,b) = 1$ if $m_*(a,b)_m \ge a \; \forall$ m and $m_*(a,b)_m > a$ for at least one criterion.

In order to use information on the diversity among the assessment of the single fuzzy relations, according to each criterion, the <u>entropy</u> concept is useful. Entropy is calculated as an index varying from 0 to 1 that gives an indication of the variance of the credibility indexes that are above the threshold, and around the crossover value 0.5 (maximum fuzziness). An entropy value of 0 means that all criteria give an exact indication (either definitely credible or definitely non-credible), whereas an entropy value of 1 means that all criteria give an indication biased by the maximum fuzziness (0.5).

The information provided by the *preference intensity index* $m_*(a,b)$ and correspondent entropies $H_*(a,b)$ can be used to build the degrees of truth (τ) of the following statements:

"according to most of the criteria":

a is better than b

a and b are indifferent

a is worse than b

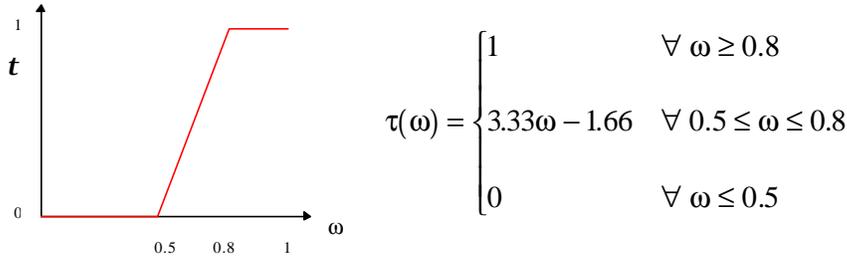The statements *a is better than b*, *a and b are indifferent*, *a is worse than b* are calculated as follows:

$$W_{better}(a,b) = \frac{m_{>>}(a,b) \wedge C_{>>}(a,b) + m_{>}(a,b) \wedge C_{>}(a,b)}{C_{>>}(a,b) + C_{>}(a,b)}$$

$$W_{indifferent}(a,b) = \frac{m_{==}(a,b) \wedge C_{==}(a,b) + m_{\cong}(a,b) \wedge C_{\cong}(a,b)}{C_{==}(a,b) + C_{\cong}(a,b)}$$

$$W_{worse}(a,b) = \frac{m_{<<}(a,b) \wedge C_{<<}(a,b) + m_{<}(a,b) \wedge C_{<}(a,b)}{C_{<<}(a,b) + C_{<}(a,b)}$$

where $C_{*}(a,b) = 1 - H_{*}(a,b)$ is the associated entropy level over the *preference intensity index* and the $\wedge$ operator can be replaced by the minimum operator which gives no compensation, and the Zimmermann-Zysno operator which allows for varying degrees of compensation γ (from 0 minimum compensation to 1 maximum compensation).

Finally the *"according to most of the criteria"* operator is implemented filtering the w_{better}, $w_{indifferent}$ and w_{worse} values as follows:

$$\tau(\omega) = \begin{cases} 1 & \forall\, \omega \geq 0.8 \\ 3.33\omega - 1.66 & \forall\, 0.5 \leq \omega \leq 0.8 \\ 0 & \forall\, \omega \leq 0.5 \end{cases}$$

1.2.5. Ranking of Alternatives

NAIADE allows for a ranking of alternatives based on the *preference intensity indexes* $m_{k}(a,b)$ and correspondent entropies $H_{*}(a,b)$. The final ranking comes from the intersection of two separate rankings. The first one $f^{+}(a)$ is based on the *better* and *much better* preference relations and with a value going from 0 to 1 indicates how *a* is "better" than all other alternatives. The second one $f^{-}(a)$ is based on the *worse* and *much worse* preference relations, its value going from 0 to 1 which indicates how *a* is "worse" than all other alternatives. $f^{+}(a)$ and $f^{-}(a)$ are calculated as follows:

$$f^{+}(a) = \frac{\sum_{n=1}^{N-1}\left(m_{>>}(a,n) \wedge C_{>>}(a,n) + m_{>}(a,n) \wedge C_{>}(a,n)\right)}{\sum_{n=1}^{N-1}C_{>>}(a,n) + \sum_{n=1}^{N-1}C_{>}(a,n)}$$

$$f^{-}(a) = \frac{\sum_{n=1}^{N-1}\left(m_{<<}(a,n) \wedge C_{<<}(a,n) + m_{<}(a,n) \wedge C_{<}(a,n)\right)}{\sum_{n=1}^{N-1}C_{<<}(a,n) + \sum_{n=1}^{N-1}C_{<}(a,n)}$$

9

where N is the number of alternatives and the ^ operator again can be chosen between the minimum operator which gives no compensation, and the Zimmermann-Zysno operator which allows for varying degrees of compensation γ (from 0 minimum compensation to 1 maximum compensation).

1.3. Equity analysis

Equity analysis starts with the creation of the equity matrix which gives a linguistic indication of the interest group judgement for each of the alternatives. Semantic distance is also used in this case to calculate the similarity indexes among interest groups. A *similarity matrix* is then computed starting from the *equity matrix*. The *Similarity matrix* gives an index, for each pair of interest groups *i,j,* of the similarity of judgement over the proposed alternatives. This index s_{ij} is calculated as $s_{ij}=1/(1+d_{ij})$ where d_{ij} is the Minkovsky distance between group *i* and group *j* which is calculated as follows:

$$d_{i,j} = \sqrt[p]{\sum_{k=1}^{N}\left(S_k(i,j)\right)^p}$$ where $S_k(i,j)$ is the semantic distance between group *i* and

group *j* in the judgement of alternative k, N is the number of alternatives and $p > 0$ is the parameter of the Minkovsky distance.

Through a sequence of mathematical reductions the *dendrogram of coalition formation* is built. It shows possible coalition formation for decreasing values of the similarity index and the degree of conflict among interest groups.

2. IMPLEMENTATION

2.1. NAIADE Implementation: Introduction

The theoretical analysis and mathematical algorithms presented so far were implemented into a software application called NAIADE. The application provides a dialogue interface which was designed according to the most modern concepts of man/machine interface, through advanced development of the typical elements that make up modern GUIs (Graphical User Interface). The application and its ways of use are presented in the reminder of this document. The present version of NAIADE is implemented "stand-alone" but its integration in more complex systems is already foreseen, in particular for automatic interfacing with other modules from whose output can be used as input to NAIADE.

2.2. Technical Characteristics

The NAIADE software is available for various platforms and operating systems; it is already available for Personal Computer Microsoft Windows 3.1, Windows 95 and Windows NT while the version for the SUN OS 4.x operating system will be available for the Sun Sparc Workstation. There are no special hardware requirements beyond the normal equipment.

2.2.1. Impact and Group Matrices

When starting up the NAIADE application the Impact (Criteria/Alternatives) matrix is presented, where the first column contains (or may contain) criteria and the first row contains (or may contain) alternatives. The *Group* and *Both* buttons allow the visualisation the groups/alternatives matrix; the *Both* button allows the simultaneous display of both matrices, criteria/alternatives and groups/alternatives, whilst the *Group* button allows the sole display of the groups/alternatives matrix.
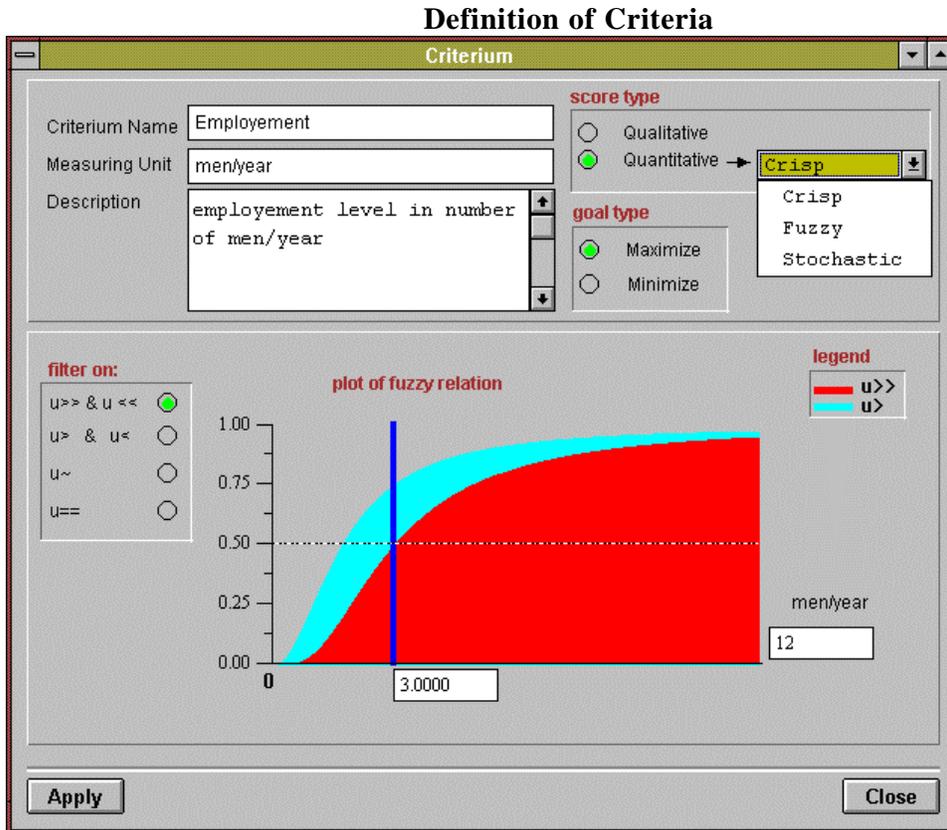
The Criteria/Alternatives matrix

The Groups/Alternatives matrix

	business as usua	optimised agriculture	flooding	ial flooding + current agricul	rtial flooding + optimised a
Farmers	good	very good	very bad	bad	moderate
Environmentalists	bad	bad	very good	moderate	moderate
Recreationers	bad	bad	good	good	good
Landless Labourers	moderate	moderate	good	good	good
Residents in the Po Area	bad	bad	good	moderate	moderate
Future Generations	bad	moderate	very good	moderate	good

2.2.2. Definition of Criteria and of Preference Relations

Clicking on the first column of the Criteria/Alternatives matrix, it activates the window where the type of criterion (fuzzy, stochastic, qualitative or quantitative) and its characteristic parameters, such as the measurement units, the optimisation criterion (maximisation or minimisation) and the crossover points of its preference relations can be defined. The latter can be defined either by directly assigning it a numerical value or by moving graphically the vertical blue line. The vertical blue line represents the crossover value or the point where the preference function intersects the crossover line (i.e. when it reaches the value of 0.5). Four preference relations have to be defined: $\mu_{>>}$ and $\mu_{>}$ which are symmetrical respectively to $\mu_{<<}$ and $\mu_{<}$. These are showed in pairs where the blue represents the "limit" for the red according to the constraints on the crossover points explained earlier (see section 1.2.4). When these constraints are not respected the user is asked to redefine the crossover points. Finally, the base scale value is displayed to remind the user of the interval values of the preference relations that will be displayed.

Definition of Criteria

2.2.3. Definition of the Alternatives

The alternatives are defined by clicking on the first row of the Criteria/Alternatives or Groups/Alternatives matrix. The name and description of the alternatives proposed are simply defined.

Dialogue Box for Definition of Alternatives
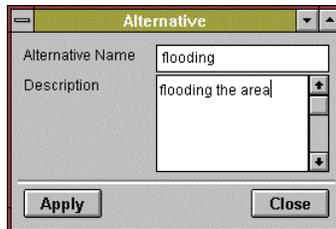
2.2.4. Definition of the Groups

The groups are defined by clicking on the first column of the Groups/Alternatives matrix. The name and description of the interest groups identified are simply defined.

Dialogue Box for Definition of Groups
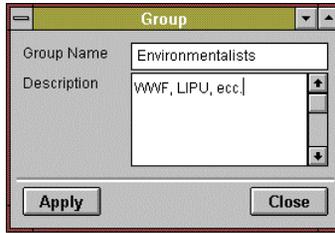
2.2.5. Filling the Matrices

The matrices are simply filled by clicking on the cell to be defined. In the Impact matrix the types of input data depend upon the type of criteria chosen for the analysis whilst in the Groups/Alternatives matrix the data are always of linguistic type. For fuzzy criteria a window is popped up from which the fuzzy set and its parameters can be defined when choosing from four possible types (see Appendix A). For stochastic criteria a window appears where the type of probability density function and its parameters can be defined. Finally when the criterion is qualitative a window appears where the user simply selects the variable. The user must assign a name to the linguistic variables which will appear in the matrix.
If the criterion is numerical the user can simply type the number in the corresponding box.

Definition of Fuzzy Criteria
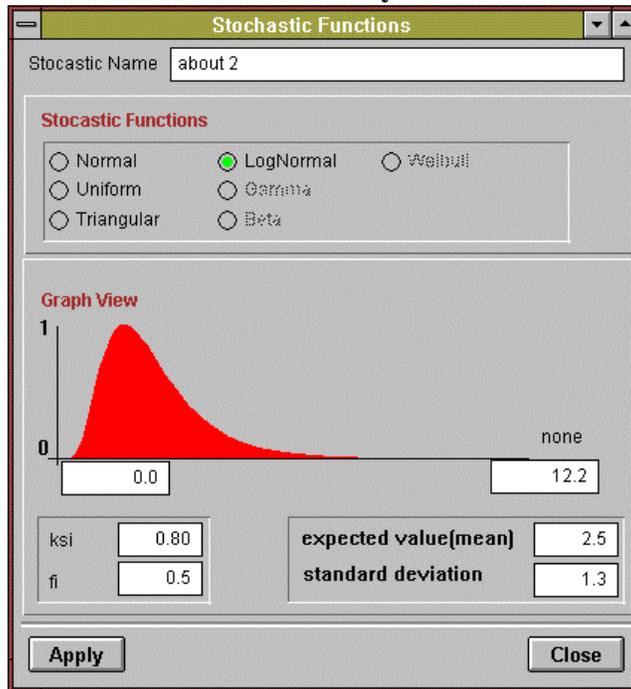
Dialogue Boxes: (1) Definiton of Stochastic Criteria and (2) Linguistic Variables
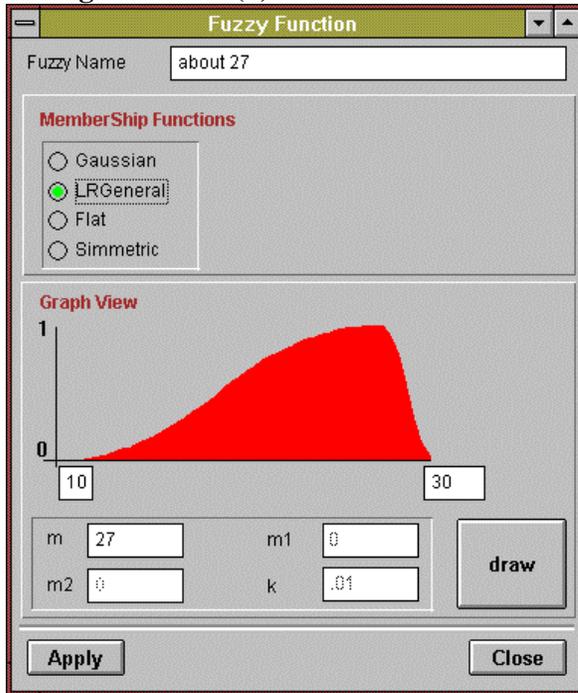
(1)
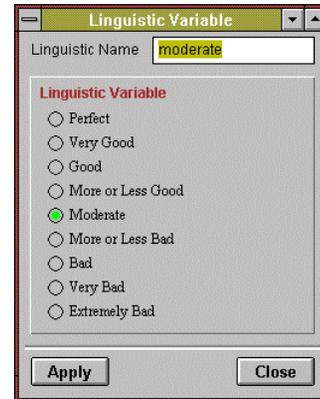
(2)

2.2.6. Parameters for Calculation

The *Calculate* button activates the analysis corresponding to one of the two types of matrix currently displayed on the main panel (multicriteria or equity). In both cases possibility is offered to the user to change the calculation parameters via the parameter dialogue box. Through the dialogue box, the following parameters can be modified:

- the number of iterations to calculate the semantic (more iterations means more precision but slower calculation)
- the expected value of the number of the semantic distance,
- the parameter *p* of the Minkovsky distance (used only in equity analysis),
- the parameter α and the ^ operator of aggregation for the multicriteria analysis.

Dialogue Box for Parameters for Calculation
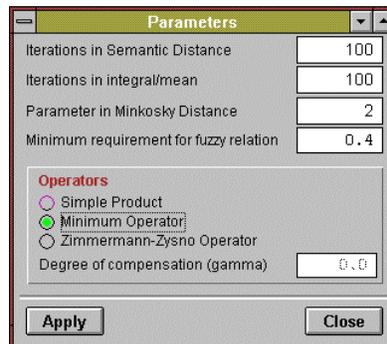
2.3. Display of the Results

The multicriteria analysis results can be consulted in two ways: on one hand, all the partial calculations are written into a file called *multicri.out* which NAIADE creates every time a new analysis is carried out, and on the other hand, the final rankings Φ+ and Φ- of the alternatives and their intersection are shown both graphically and numerically. The values of the $m_*(a,b)$ and their entropies $H_*(a,b)$, as well as the degrees of truth $\tau(\omega_{better})$, $\tau(\omega_{indifferent})$, and $\tau(\omega_{worse})$ are given for each pair of alternatives a and b.

Display of Multicriteria Analysis Results
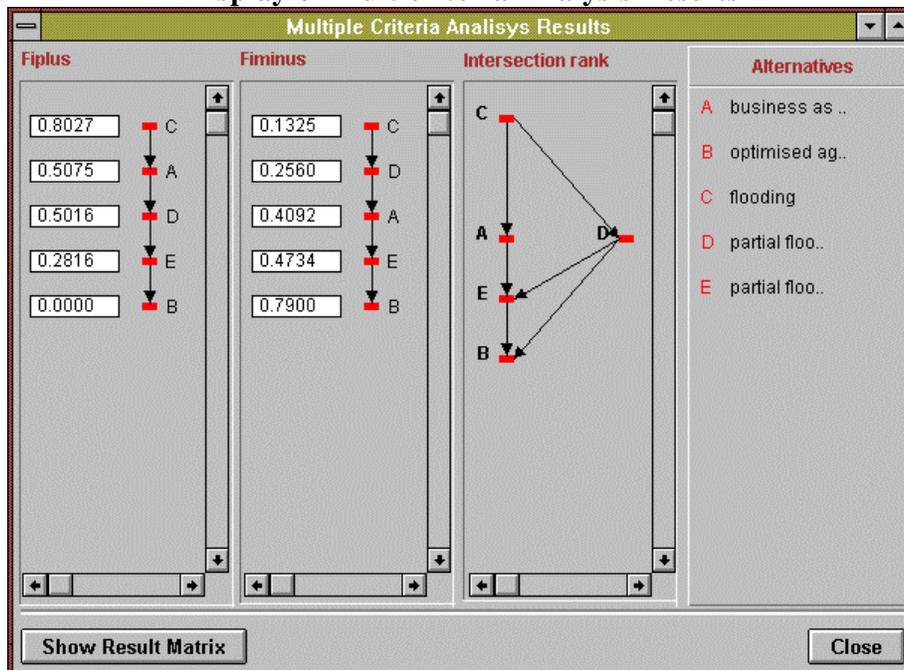
Likewise, the equity analysis results can be consulted in two ways: on one hand, all the partial calculations are written into a file called *equity.out* which is created by NAIADE at each session and on the other hand, the *coalitions dendrogram* is displayed that also gives access to the similarity matrix values.

Display of Equity Analysis Results

Equity Analysis Results

Dendrogram of the Coalition Formation Process

	Groups
B E F C D A	A Farmers
0.8237	B Environmenta..
	C Recreationers
0.6989	D Landless lab..
0.6931	E Residents
0.6907	F Future Gener..
0.4653	

Show Similarity Matrix   Close
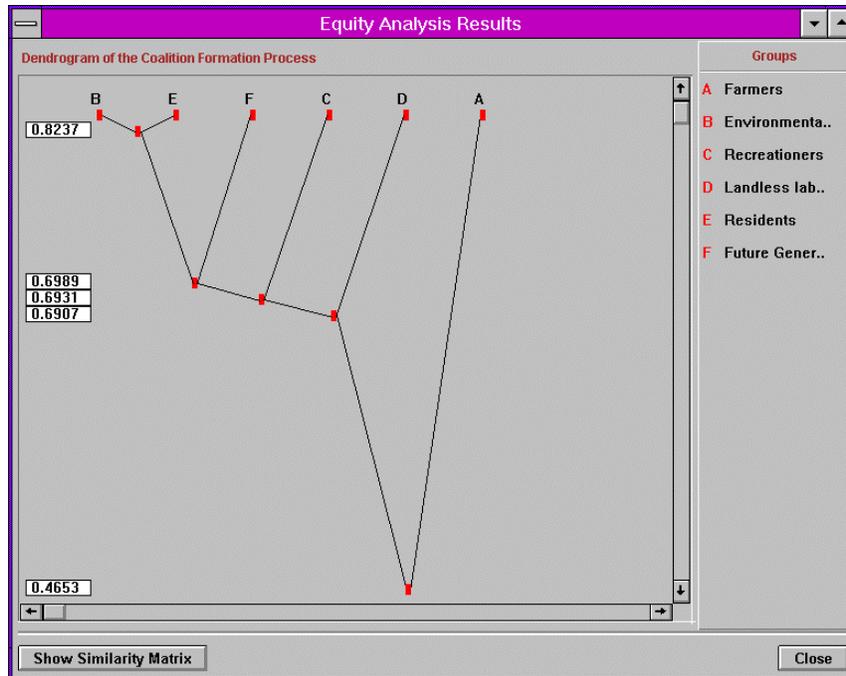
2.4. State of the Art and Further Developments

The implementation of NAIADE is complete both concerning the input/output interface and the analytical calculation part. The testing and verification phases are underway, the technical manuals being currently under preparation.
NAIADE was implemented using the C++ object-oriented language and graphic libraries to build the interface. This has allowed a highly modular architecture. Single modules of NAIADE can be reused with minimum programming effort. In particular, the code that implements the data structure and the calculation module is completely independent of the graphical interface and thus can easily be integrated into libraries or into different programming environments. Thus, one can directly interact with the current implementation, merging it with other modules or including the code in a different environment for more specific implementations

APPENDIX A

A.1. Fuzzy Sets

The following fuzzy sets, for which the user must define specific parameters, are implemented in NAIADE and described below.

A.1.1. Gaussian
Parameters: l, l,u,k,m with $k > 0$.

$$m_{Gaussian}(x) = \begin{cases} e^{-k(x-m)^2} & l \le x \le u \\ 0 & otherwise \end{cases}$$
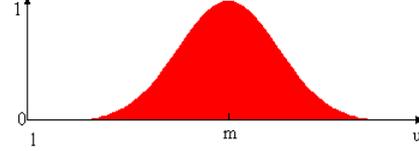
A.1.2. Flat
Parameters: $l,\ u,\ m1\ and\ m2$

$$m_{Flat}(x) = \begin{cases} 0 & x \le l \\ 2\left(\dfrac{x-l}{m1-l}\right)^2 & l < x \le b1 \\ 1-2\left(\dfrac{m1-x}{m1-l}\right)^2 & b1 \le x < m1 \\ 1 & m1 \le x \le m2 \\ 1-2\left(\dfrac{x-m2}{u-m2}\right)^2 & m2 < x \le b2 \\ 2\left(\dfrac{x-l}{m1-l}\right)^2 & b2 < x < u \\ 0 & x \ge u \end{cases}$$

where $b1 = \dfrac{l+m1}{2}$ and $b2 = \dfrac{m2+u}{2}$
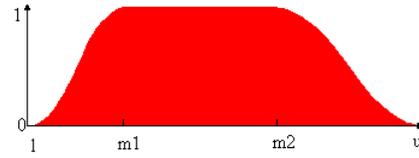
A.1.3. LRGeneral
Parameters: *l, u and m*

$$m_{LeftRigthGeneral}(x) = \begin{cases} 0 & x \le l \\ 2\left(\dfrac{x-l}{m-l}\right)^2 & l < x \le b1 \\ 1-2\left(\dfrac{m-x}{m-l}\right)^2 & b1 \le x < m \\ 1 & x = m \\ 1-2\left(\dfrac{x-m}{u-m}\right)^2 & m < x \le b2 \\ 2\left(\dfrac{x-l}{m-l}\right)^2 & b2 < x < u \\ 0 & x \ge u \end{cases}$$
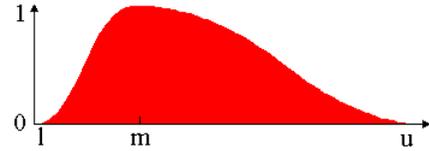
where $b1 = \dfrac{l+m}{2}$ and $b2 = \dfrac{m+u}{2}$

A.1.4. Symmetrical
Parameters: *l and m*

$$m_{SymmetricGeneral}(x) = \begin{cases} 0 & x \le l \\ 2\left(\dfrac{x-l}{m-l}\right)^2 & l < x \le b1 \\ 1-2\left(\dfrac{x-m}{m-l}\right)^2 & b1 \le x \le b2 \\ 2\left(\dfrac{x-m}{u-m}\right)^2 & b2 < x < u \\ 0 & x \ge u \end{cases}$$
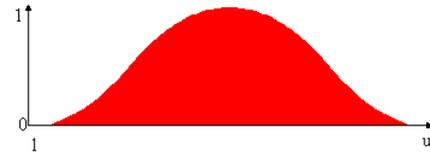
where $m = \dfrac{l+u}{2}$ and $b1 = \dfrac{l+m}{2}$ e $b2 = \dfrac{m+u}{2}$

A.2. Linguistic Variables

The linguistic variables are defined in NAIADE by means of fuzzy sets defined in the 0 - 1 scale. In the figure below illustrates the intersection points of the functions that define each fuzzy set and the respective membership values.
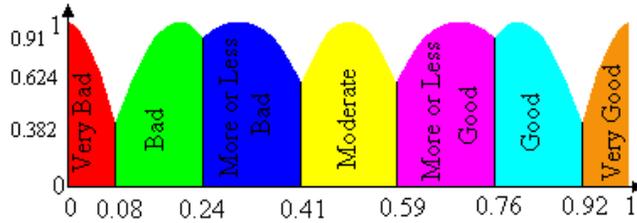
A.2.1. Perfect

$$\mu_{\text{Perfect}}(x) = \begin{cases} 1 & x = 1 \\ 0 & x \neq 1 \end{cases}$$

A.2.2. Very Good

$$m_{VeryGood}(x) = \begin{cases} 4\left(\dfrac{x-0.8}{0.2}\right)^4 & 0.8 \leq x < 0.9 \\ \left[1 - 2\left(\dfrac{1-x}{0.2}\right)^2\right]^2 & 0.9 \leq x \leq 1 \\ 0 & otherwise \end{cases}$$

A.2.3. Good

$$m_{Good}(x) = \begin{cases} 0 & otherwise \\ 2\left(\dfrac{x-0.6}{0.2}\right)^2 & 0.6 \leq x < 0.7 \\ 1 - 2\left(\dfrac{x-0.8}{0.2}\right)^2 & 0.7 \leq x \leq 0.9 \\ 2\left(\dfrac{1-x}{0.2}\right)^2 & 0.9 < x \leq 1 \end{cases}$$

A.2.4. More or less good

$$m_{MoreOrLessGood}(x) = \begin{cases} \sqrt{2}\left(\dfrac{x-0.5}{0.2}\right) & 0.5 \le x < 0.6 \\ \sqrt{1-2\left(\dfrac{x-0.7}{0.2}\right)^2} & 0.6 \le x \le 0.8 \\ \sqrt{2}\left(\dfrac{0.9-x}{0.2}\right) & 0.8 < x \le 0.9 \\ 0 & otherwise \end{cases}$$
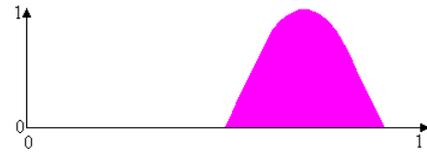
A.2.5. Moderate

$$m_{Moderate}(x) = \begin{cases} 2\left(\dfrac{x-0.3}{0.2}\right)^2 & 0.3 \le x < 0.4 \\ 1-2\left(\dfrac{x-0.5}{0.2}\right)^2 & 0.4 \le x \le 0.6 \\ 2\left(\dfrac{0.7-x}{0.2}\right)^2 & 0.6 < x \le 0.7 \\ 0 & otherwise \end{cases}$$
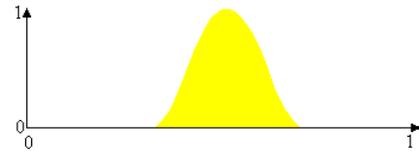
A.2.6. More or less bad

$$m_{MoreOrLessBad}(x) = \begin{cases} \sqrt{2}\left(\dfrac{x-0.1}{0.2}\right) & 0.1 \le x < 0.2 \\ \sqrt{1-2\left(\dfrac{x-0.3}{0.2}\right)^2} & 0.2 \le x \le 0.4 \\ \sqrt{2}\left(\dfrac{0.5-x}{0.2}\right) & 0.4 < x \le 0.5 \\ 0 & otherwise \end{cases}$$
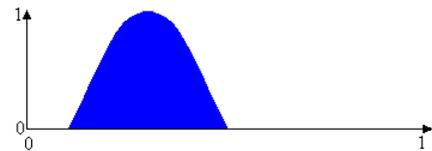
A.2.7. Bad

$$m_{Bad}(x) = \begin{cases} 0 & otherwise \\ 2\left(\dfrac{x}{0.2}\right)^2 & 0 \le x < 0.1 \\ 1-2\left(\dfrac{x-0.2}{0.2}\right)^2 & 0.1 \le x \le 0.3 \\ 2\left(\dfrac{0.4-x}{0.2}\right)^2 & 0.3 < x \le 0.4 \end{cases}$$
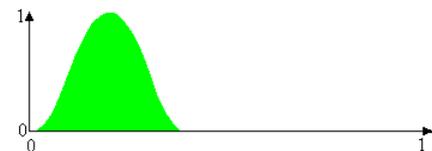
A.2.8. Very bad

$$m_{VeryBad}(x) = \begin{cases} 4\left(\dfrac{0.2-x}{0.2}\right)^4 & 0.1 < x \le 0.2 \\ \left[1-2\left(\dfrac{x}{0.2}\right)^2\right]^2 & 0 \le x \le 0.1 \\ 0 & otherwise \end{cases}$$

A.2.9. Extremely bad

$$\mu_{\text{ExtremelyBad}}(x) = \begin{cases} 1 & x = 0 \\ 0 & x \neq 0 \end{cases}$$

A.3. Stochastic Variables

Stochastic variables are defined in NAIADE by means of the following probability density functions: Uniform, Triangular, Normal, Log-Normal. In the remainder of this section each function is defined for its parameters, the operational range of the mean, μ and of the standard deviation, σ used within NAIADE

A.3.1. Uniform

Parameters: a, b

$$m = \frac{a+b}{2}$$

$$s = \sqrt{\frac{b^2 + a^2 + ab}{3}}$$

$$f_{Uniform}(x) = \begin{cases} 1/(b-a) & x \in [a,b] \\ 0 & otherwise \end{cases}$$

A.3.2. Triangular

Parameters: a, b

$$m = a$$

$$s = \frac{b}{\sqrt{6}}$$

$$f_{Triangular}(x) = \begin{cases} \dfrac{b - |x-a|}{b^2} & a - b \le x \le a + b \\ 0 & otherwise \end{cases}$$
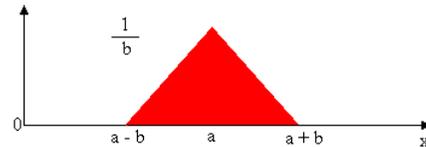
A.3.3. Normal

Parameters: m, s.

$$f_{Normal}(x) = \frac{1}{\sqrt{2ps}} e^{-\frac{(x-m)^2}{2s^2}}$$
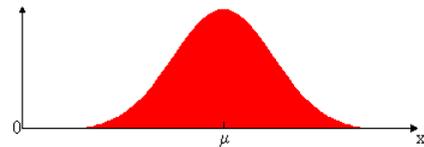
A.3.4. LogNormal

Parameters: c, f with $f > 0$.

$$m = e^{\left(c + \dfrac{f^2}{2}\right)}$$

$$s = \sqrt{e^{f^2} \cdot \left(e^{f^2} - 1\right) \cdot e^{2c}}$$

$$f_{LogNormal}(x) = \frac{1}{\sqrt{2pf} \cdot x} e^{-\dfrac{(\log(x) - c)^2}{2f^2}}$$

$\chi = 4.1$
$\phi = 1.0$

$\mu = 100$ $\sigma = 130$ 200 x
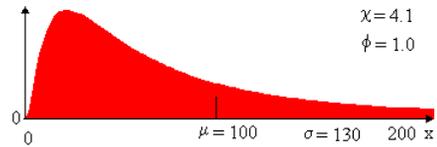
A.4. NAIADE: Format of the Input Files

NAIADE allows the input of data from ASCII files generated by any editor. In NAIADE there are two matrices: the criteria/alternatives matrix and the groups/alternatives matrix. The cells of each of these matrices can be of one of the following types, which are associated with a numerical code:

Empty	0
Alternative	1
Criterion	2
Group	3
Numeric	4
Linguistic	5
Fuzzy	6
Stochastic	7
Fuzzy and Numeric	8

A simple example is given below where the impact matrix is defined with 4 criteria (the first of which is not completely defined) and the equity matrix with 3 groups for 2 alternatives.

```
NAIADE

12 test project

PARAMETERS
100 100 2  0.6 1 0

ALTERNATIVES 2
1 5 Alt A 20 description of Alt A
1 5 Alt B 28 description of Alternative B

CRITERIA 4
0
2 5 crisp 30 description of crisp criterion 6 meters 4 0 250 180 100 30
2 5 fuzzy 30 description of fuzzy criterion 4 mc/s 2 6  4 3 0.9 0.5
2 10 stochastic 36 description of stochastic  criterion 13 N of employee 7 1  3 2 1 0.2708

GROUPS 3
3 7 group A 19 description group A
3 7 group B 19 description group B
3 7 group C 19 description group C

IMPACTMATRIX
0
0
4 305
4 250
6 6 lrg7p6 10 3.3 9.9 7.6
6 6 fda1a3 11 0 5 1 3
7 10 norm15sig3 13 15 3
7 5 tri20 16 20 30

EQUITYMATRIX
5 9 very good 1
5 8 moderate 4
5 8 moderate 4
5 9 very good 1
5 3 bad 6
5 17 more or less good 3

END
```

General note: all the strings of characters are saved as an integer followed by a string (e.g.: 35 description of linguistic criterion) where the integer indicates the number of characters which form the string, the string containing any character including spaces. Any empty strings are defined with 0 value. The only control performed in reading the file is whether key words are in the correct position. No type and value range check is performed on the input data (e.g. a value of α may be greater than 1.0). Thus although non-allowed values can be accepted as input, they would be deleterious in the calculation phase. The user is thus responsible for correct file compilation and for checking the types.

The input format is made up of a series of key words which must all be present and in the following order:

        NAIADE
        PARAMETERS
        ALTERNATIVES
        CRITERIA
        GROUPS
        IMPACTMATRIX
        EQUITYMATRIX
        END

NAIADE:
is used just to check the input file. It is followed by the project name assigned to the case study.

PARAMETERS:
is the definition key of the 6 general calculation parameters which are in the following order:
        1)   (int>0) iteration number for the calculation of the integrals of the membership functions;
        2)   (int>0) iteration number for the calculation of the semantic distance;
        3)   (int>0) coefficient p for the calculation of the Minkovsky distance;

        4)   (float ≥ 0 and ≤ 1) the coefficient α of minimum requirements on the preference relationships;
        5)   (int 0,1,2) index of the type of aggregation operator where
                        0 = produced
                        1 = minimum operator
                        2 = Zimmermann-Zysno operator
        6)   (float ≥ 0 and ≤ 1) coefficient γ of the Zimmermann-Zysno operator;

ALTERNATIVES #:
is the definition key of the alternatives where # is the number of defined alternatives. Following this each line defines an alternative by the type of cell (0 or 1). In the case the cell type is 1, the definition of the alternative is complete after giving it a name and a description, (e.g. **6 crit A 18 description crit A**)

CRITERIA #:

is the definition key of the criteria where # is the number of defined criteria. Following this each line defines a criterion for which the respective parameters are given in the following order:

    1)   (string) criterion name;
    2)   (string) criterion description;
    3)   (string) name of the measurement unit;
    4)   (int 4,5,6,7 or 8) index of the type of information associated with that

criterion where:

    4 = Numerical
    5 = Linguistic
    6 = Fuzzy
    7 = Stochastic
    8 = Fuzzy and Numeric

    5)   (int 0,1) criterion in maximisation (1) or minimisation (0);

    6)   (float ≥ 0) the crossover point $C_{>>}$ of the relationship *much better* and

much worse;

    7)   (float ≥ 0) the crossover point $C_{>}$ of the relationship *better* and *worse*;

    8)   (float ≥ 0) the crossover point $C_{\cong}$ of the relationship *about the same;*

    9)   (float ≥ 0) the crossover point $C_{=}$ of the relationship *the same*;

Example: **2 5 fuzzy 30 description of fuzzy criterion 4 mc/s 2 6 4 3 0.9 0.5**

GROUPS #:
is the definition key of the groups where # is the number of groups defined. Following this each line defines a group for which the name and the description are given - (e.g.: **3 6 Group A 18 description group A**).

IMPACTMATRIX:
is the definition key of the criteria matrix. Following this, each line defines the content of a single cell: one must define as many cells as the product of the number of criteria for the number of alternatives. The first integer of each line identifies the type of cell and the information which will be read. In particular we have:

    0 = Empty cell (if the matrix is only partly completed). No other information is required.   Note that in this case the analysis cannot be performed.

    4 = Numerical type cell, is followed just by the number (either integer or float) associated   with that cell;

    5 = Linguistic type cell. It is followed by the following information:

    1) (string) name associated with the function (only of use for display on the   ILOG interface, but it must also be supplied by those applications which do not   use this interface).

    2) (int) function type:
    - 0 through 8 are reserved for the functions used by the linguistic   variables:
    0 = **perfect**
    1 = **verygood**
    2 = **good**
    3 = **moreorlessgood**

4 = **moderate**
5 = **moreorlessbad**
6 = **bad**
7 = **verybad**
8 = **extremelybad**
These functions are defined in advance and require no further parameterisation.
Example: **5 8 moderate 4**

6 = Fuzzy type cell. It is followed by the following information:

1) (string) name associated with the function (only of use for display on ILOG interface, but it must also be supplied by those applications which do not use this interface).

2) (int) function type:

- 9 through 12 are reserved for the fuzzy set membership functions. Each number is followed by defining parameters.

9 = **Gaussian**. Is followed by: (float) lower limit of fuzzy set, (float) upper limit of the fuzzy set, the (float) centre of the Gaussian and (float) parameter K > 0.

10 = **lrgen** (left and right general). Is followed by: (float) lower limit of the fuzzy set, (float) upper limit of the fuzzy set, (float) point where the function of belonging is equal to 1 between the two limits.

11 = **flat**. Is followed by: (float) lower limit of the fuzzy set, (float) upper limit of the fuzzy set, (float) lower limit and (float) upper limit of the interval within which the function of belonging is 1.

12 = **symmetrical** Is followed by: (float) lower limit of the fuzzy set, (float) upper limit of the fuzzy set and nothing else.

Example: **6 6 lrg 7p6 10 3.3 9.9 7.6**

7 = Stochastic type cell. It is followed by the following information:

1) (string) name associated with the function (only of use for display on ILOG interface, but it must also be supplied by those applications which do not use this interface).

2) (int) function type:

- 13 through 16 are reserved for the functions used by the linguistic variables. Each number is followed by specific parameters.

13 = **normal**. Is followed by: (float) the average value μ and (float) the standard deviation $\sigma > 0$ of the normal function.

14 = **lognormal**. Is followed by: (float) the value of the coefficient χ and (float) the value of the coefficient $\phi > 0$ of the lognormal function.

15 = **uniform**. Is followed by: (float) lower limit and (float) upper limit of the uniform function.

		16 =	**triangular**. Is followed by: (float) apex point
and			(float) length > 0 of the half base of the
triangular			function.

Example: **7 10 norm15sig3 13 15 3**

GROUPMATRIX:

is the definition key of the group matrix. Following this, each line defines the content of a single cell: one must define as many cells as is the product of the number of the groups for the number of alternatives. The first integer of each line identifies the type of cell and the information which will then be read. In particular:

0 = Empty cell (if the matrix is only partly completed). No other information is required. Note that in this case the analysis cannot be performed.

5 = Linguistic type cell. This is the only type of cell allowed for the equity matrix. It is followed by the following information:

        1) (string) name associated with the function (only of use for display within the ILOG interface, it must also be supplied by those applications that do not use this interface).

        2) (int) function type:

            - numbers 0 through 8 are reserved for the functions used by the linguistic variables. These functions are completely defined in advance and require no other parameter. These are the only types of functions allowed for the equity matrix.

                0 = **perfect**
                1 = **verygood**
                2 = **good**
                3 = **moreorlessgood**
                4 = **moderate**
                5 = **moreorlessbad**
                6 = **bad**
                7 = **verybad**
                8 = **extremelybad**

Exemple: **5 8 moderate 4**

END:

is the closing key of the definition of the equity matrix without which the matrix can be correctly read.

3. TUTORIAL

3.1. Introduction

This section provides an exercise to help beginners learn how to use NAIADE software. The training exercises complement the conceptual overview and manual provided in sections 1 and 2. The exercise provided is based upon a real-world environmental policy problem, the "Boscone Della Mesola" environmental management problem. This problem presents the typical ingredients of environmental policy issues such as: several dimensions of assessment; different actors and interest groups with conflicting interests; uncertainty which together call for multi-criteria analysis in a fuzzy environment.

In this study a comprehensive economic-environmental evaluation of alternative courses of action will be carried out by means of multi-criteria analysis, using the software package NAIADE.

3.1.1. The "Boscone della Mesola" Environmental Management Problem[1]

The Mesola wood is considered as of exceptional value and of considerable environmental potential. Because of its physical and biological characteristics the "Mesola " wood has a considerable natural and ecological importance (both as forest ecosystem and as art of the agricultural context of the region). Moreover, its scientific, cultural and educational values are of high importance for it is a considerable vegetational complex, now the last remaining in the lower Po valley. A range of activities could thus be set up around it which, consistent with the environmental characteristics, could also provide considerable economic and social advantages. The human pressure exerted in some of the internal areas due to intensive exploitation of wood resources, planting crops and the use as pasture, caused the wood to degrade rapidly.

During the 1950s there were some plans to recover the Po Delta, namely that of the Po Delta Organisation set up in 1951 which affected the valleys around the Boscone. This project aimed at cleaning up the lagoon valleys in order to set up a defence system against sea storms. The drainage works were completed in 1970 but none of the forest defence works were started. These affected micro-climatic areas and the water tables. Consequently, the wood began to show some signs of stress in the areas near to the drained valley, including dry-out phenomena. Governmental and local authorities have proposed measures to restore the equilibrium of the water table. It consisted in the opening of a drainage channel along a nearby valley, cleaning up the drainage network in the wood and, the supply of water to the Boscone by means of a pumping system. Although the mortality of plants have decreased the wood still showed signs of stress. Because of this, a flooding project (in the Falce Valley) was proposed by the IDROSER (Consulting Company) technicians, whose implementation implies that new economic activities enabling the substitution of the agricultural and land-use patterns would have to be found out.

Finally, it must be noted that any alternative will have consequences to a broader problem that affects the Po basin, which is that of the eutrophication.

3.1.2. Possible Courses of Action

The alternatives taken into consideration are:
1. business as usual,

---

[1] For more information in this case study, please see: (Munda, 1995).

2. optimised agriculture,
3. flooding of the Falce Valley,
4. partial flooding in combination with business as usual,
5. partial flooding in combination with optimised agriculture.

3.1.3. Set of Evaluation Criteria

The following set of evaluation criteria can be used:

Criterion name	Description	Unit	Criterion type
Gross Profit	GP of the activities connected to the management of the area: agriculture, fishing, hunting	Millions of Lire	Fuzzy and Numeric
Employment	Employment	years/ man	Numeric
Tourist attractiveness	Recreational facilities - economical point of view	-	Linguistic
Recreational Attractiveness	Nature as source of aesthetic and spiritual comfort	-	Linguistic
Ecological equilibrium of the wood	Environmental issues	-	Linguistic
Risk of causing ecological damages	Risks to the ecosystem, e.g. due to use of fertilizers	-	Linguistic

It must be noted that investment costs were not considered since it was assumed that the society is willing to pay for the rehabilitation of the wood.

3.1.4. Interest Groups

Six main interest groups can be distinguished:
- Farmers
- Environmentalists
- Recreationers
- Landless Labourers
- Residents in the Po Delta Area
- Future Generations

3.2. Exercise

In this section it will be described possible actions to be carried out by an analyst that is planning to use NAIADE for multi-criteria analysis. The main outputs of this exercise will be:
- the analysis of the proposed alternatives in terms of their efficiency;
- the analysis of the proposed alternatives in terms of their sustainability;
- the identification of coalitions amongst groups of interest;
- the analysis of the proposed alternatives in terms of their equity.

In this framework, compromise sustainable and "defensible" solutions might be seek to reduce conflict (or to reach a certain degree of consensus) or that could have a higher degree of equity on different groups of interest.

Thus, the user is asked to:
- fill in the impact matrix for alternatives and criteria;
- carry out multi-criteria evaluation;

- fill in the group matrix;
- carry out equity analysis;
- analyse the coalitions dendrogram.

Through the exercise proposed in the remainder of this section it is intended that the user gets him/herself familiar with the NAIADE interface and the multi-criteria analysis carried out through this system.

3.2.1. Loading the Example File

From the FILE menu, choose "Load" to load the example case study of the "Bosco *mesola0.nd*. You should obtain the impact matrix as depicted in the figure below.

Impact Matrix for the "Mesola" wood management problem - partially filled

Alternatives / Criteria	business as usual	optimised agricolture	flooding		part flood + optimised agr
Employment	8	20	9		14
Tourist attractiveness	Bad	Bad	Good		Moderate
creational Attractivene	Moderate	Moderate	Good		Moderate
Ecological equilibrium	Bad	Bad	Good		Good
Risk of damage	Moderate	High	Low		High

Matrix Type: Impact   Case study:

Tools: Calculate, Equity, Both, Close

3.2.2. Filling in the Impact Matrix

3.2.2.1. Defining a new alternative

As you can see the matrix is partially filled. Start by giving a name to your project. This is done by clicking in the "Case study" field: please type in *Boscone della Mesola*.

By clicking in the first cell of the empty column you will be able to define the following alternative: *partial flooding in combination with business as usual*.

Dialogue box for defining the alternative *"partial flooding in combination with business as*

Alternative

Alternative Name: part flood + curr agr

Description: --

Apply   Close

If you choose "Apply", a new alternative is created whereas if you choose information you introduce is not saved.

Now, click in the button "BOTH" to visualise both matrices (impacts and groups). Note *partial flooding in combination with business as usual*" alternative was set up automatically in the Groups Matrix.

3.2.2.2. Defining a new criterion

In this part of the exercise you should define a criterion of fuzzy and numeric type. You can do it in the empty row of the Impact matrix, or you can alternatively select this row, delete it and use the Row menu to insert a new row where you wish to. You should call this criterion as, *Gross Profit* and choose type *Numeric and Fuzzy* when prompted with the dialogue box.

Dialogue box for defining the criterion "Gross Profit"

Criterium

Criterium Name: Gross Profit

Measuring Unit: MLit

Description:

score type
- ○ Qualitative
- ● Quantitative → Numeric & Fuzz ▼

goal type
- ● Maximize
- ○ Minimize

filter on:
- u>> & u<< ●
- u> & u< ○
- u~ ○
- u== ○

plot of fuzzy relation

legend
- u>>
- u>

1.00
0.75
0.50
0.25
0.00

0   24.6154

MLit
73.8462

Apply   Close
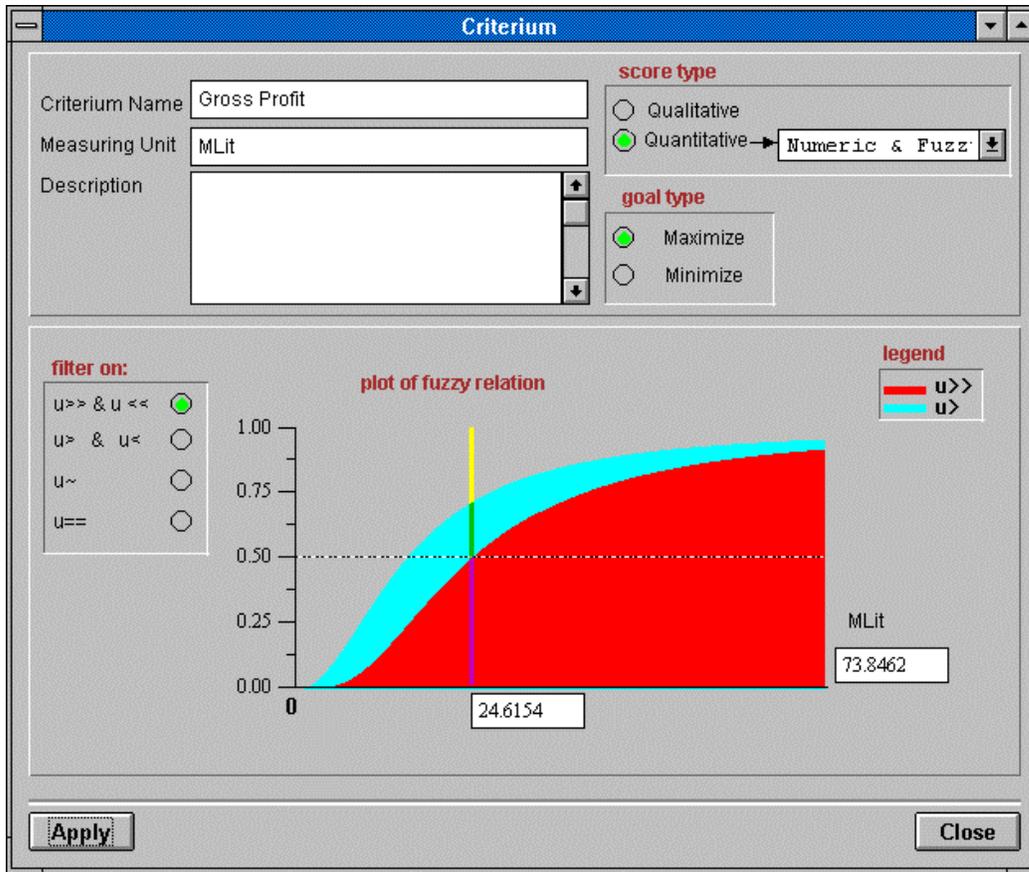
Follow the steps described below to completely define the criterion *Gross Profit* through the window depicted above:

- type in a name in the <u>Criterion Name</u> field: *Gross Profit*;
- type in the measuring unit in the <u>Measuring Unit</u> field: *MLit*;
- choose the score type in the <u>Score type</u> field: *Numeric and Fuzzy* by activating the <u>Quantitative</u> button;
- choose the goal type by activating one of the buttons of the <u>Goal Type</u> frame: choose *Maximise*;
- define in the field MLit the value 72 (MLit);
- define the crossover points for the four preference relations using the following values:

$$C_{<<} = C_{>>} = 24 \text{ Mitl}$$
$$C_{<} = C_{>} = 15 \text{ Mitl}$$
$$C_{==} = 13 \text{ Mitl}$$
$$C_{\cong} = 10 \text{ Mitl}$$

Setting the C parameters can be done either by typing them directly into the text field below the x axis or by moving the blue cursor along the x axis until the crossover point is defined for each of the preference relations that you previously chose from the <u>Filter On</u> frame. To have a better feeling of the changes on the curves' shape, try on several values. Again, if you choose "Apply", the modifications introduced are saved whereas if you choose to click on "Close" no modifications will be saved.

3.2.2.3. Filling in empty cells

In this part of the exercise you are asked to fill in the empty cells corresponding to the new alternative you have created and the scores for the criterion you have just introduced. In the table below, you have the values that you can introduce into the empty cells for the new alternative you have created[2].

When filling in the values for the "Gross profit" criterion, you will be asked whether your criterion is numeric. If you choose no, you will be prompted with a dialogue box such as that of the figure below[3].

---

[2] Note that you can clear the values that you have entered by selecting the cell and by choosing Clear from the Menu EDIT.

[3] WARNING: Your choice cannot be modified afterwards unless you delete the whole row or redefine the criterion as explained in section 3.2.2.2.

**Dialogue box for defining fuzzy criterion scores**
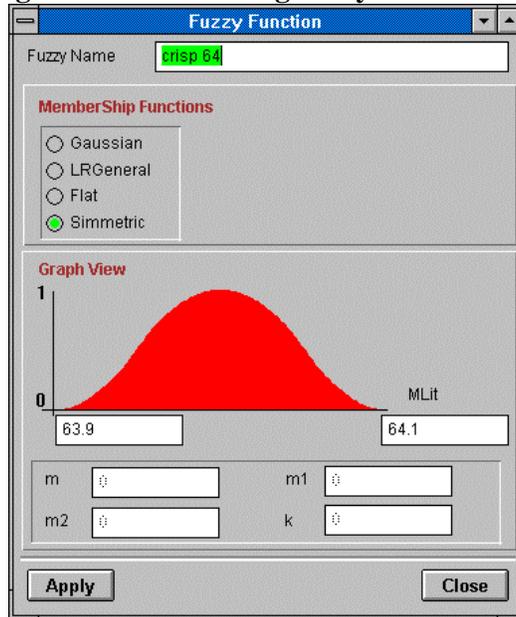
Check in the table below whether you should answer yes or no. In the table below you have the values for the "*numeric & fuzzy*" criterion you have created and you must now fill in the empty row according to the criterion scores listed in the table:

Alternative	Name	Type		Definition		Score
			Membership Function	*interval in graph view*	*parameters*	
Business as usual	crisp64	Numerical	-	-	-	64
Optimised agriculture	crisp159	Numerical	-	-	-	159
Flooding of the Falce Valley	approx143	Fuzzy	Gaussian	135-151	m=143 k=0.077	~143
Partial flooding in combination with business as usual	approx95	Fuzzy	Flat	85-107	m1=96 m2=97	~95
Partial flooding in combination with optimised agriculture	approx147	Fuzzy	LRGeneral	140-155	m=147	~147

To fill in the remaining empty cells concerning the "*partial flooding in combination with business as usual*" alternative, you should proceed as before: click in each of the cells and define the criterion score as follows:

- **Employment:** 8 years-man (numerical)
- **Tourist attractiveness:** Moderate (linguistic)
- **Recreational Attractiveness:** Moderate (linguistic)
- **Ecological equilibrium of the wood:** Good (linguistic)
- **Risk of causing ecological damages:** Bad (the risk is HIGH!) (linguistic)

Dialogue box to define linguistic variables
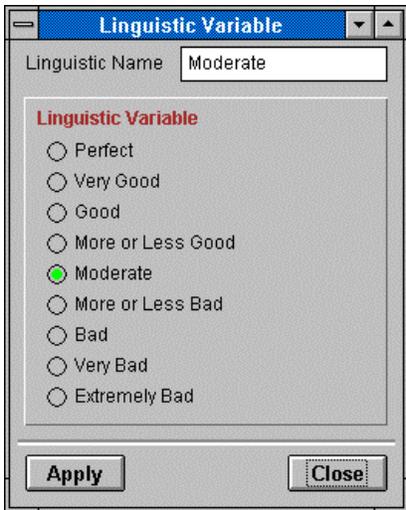
For the Linguistic Variables you should choose "Apply" if you want to save the information that you have introduced and choose "Close" otherwise, in the dialogue box.

To save the new matrix choose either from the menu FILE, "Save as" and type in a new name, for instance *mesola1.nd* or simply override the file *mesola0.nd* in which case just choose "Save" from the FILE menu.

Impact Matrix

Alternatives / Criteria	business as usual	optimised agricolture	flooding	flood+current	part flood + optimised agr
Gross Profit	64	159	appr143	appr95	appr147
Employment	8	20	9	8	14
Tourist attractiveness	Bad	Bad	Good	Moderate	Moderate
Recreational Attractiveness	Moderate	Moderate	Good	Moderate	Moderate
Ecological equilibrium	Bad	Bad	Good	Good	Good
Risk of damage	Moderate	High	Low	Bad	High

3.2.3. Multi-criteria Analysis
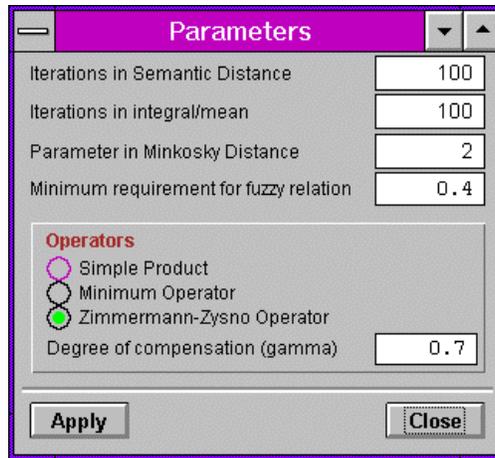
In this section you are asked to:

- change default parameters for multi-criteria analysis
- compute the multi-criteria analysis

3.2.3.1. Changing the parameters

In the window of the parameters (accessible through the EDIT menu) you can change the parameters for the multi-criteria analysis:

- Iterations in the semantic distance
- Expected value of the semantic distance
- Minimum requirement for fuzzy relation (**a**)
- Aggregation operators, including the degree of compensation (**g**) in the case of choosing the Zimmermann-Zysno operator

Dialogue box for the parameters

3.2.3.2. Calculations and display of results

In this section you are asked to fiddle with the parameters for multi-criteria analysis. In the following table we suggest you values for the parameters listed above and we invite you to answer the questions below.

Experiment	iterations	a	operator	g
1	100	0.5	min	-
2	100	0.2	min	-
3	100	0.8	Zimmermann-Zysno	0.6

To perform the calculation you can either click on the button CALCULATE or choose from the menu ANALYSIS the command "Multicriteria". Use the SHOW menu to display multi-criteria results. For each of the settings investigate the questions below.

Question 1: Which of the proposed alternatives is ranked higher in the first experiment?
_____
Question 2: What is the value of F- for alternative "flooding" in the second experiment?
_____ *and F+?* _____ .
Question 3: Which of the proposed alternatives is ranked lower in the third experiment?
_____ .
Now answer the following questions, for experiment 3. Click on the button "Show Results

Question 4: What is the final entropy for the relation $E_{>>}$ between alternatives A and C?
_____.
What does that mean? _____.
Question 5: What is the degree of truth that B is indifferent to D? _____

3.2.4. Filling in the Group Matrix

3.2.4.1. Defining a new group

In this part of the exercise you should <u>define</u> a new group. You can do it in the empty row, or you can alternatively select this row, delete it and use the Row menu to insert a new row where you wish to. You should call this group as, *Environmentalists*.

Window to define a new Group

Do not forget to save your work, using the "Save" command from the menu FILE.

3.2.4.2. Filling in empty cells

In this part of the exercise you are asked to fill in the empty cells corresponding to the preferences for the new alternative and the group's preferences over all the alternatives.. As in the case of the Impact matrix, when clicking in the empty cell the dialogue box for Linguistic Variables will be shown and you have to activate one of the radio buttons. Choose "Apply" to exit the window and actually define the value for the cell.

Below we list the groups' preferences for the "*partial flooding in combination with business as usual*" alternative:

- **Farmers:** Bad
- **Environmentalists:** Moderate
- **Recreationers:** Good
- **Landless Labourers:** Good
- **Residents in the Po Delta Area:** Moderate
- **Future Generations:** Moderate

and in the table below you can find the preferences of the "*Environmentalists*" for all proposed alternatives:

Alternative	Preference
Business as usual	Bad
Optimised agriculture	Bad
Flooding of the Falce Valley	Very Good
Partial flooding in combination with business as usual	Moderate
Partial flooding in combination with optimised agriculture	Moderate

The resulting matrix should look like this:

Groups Matrix
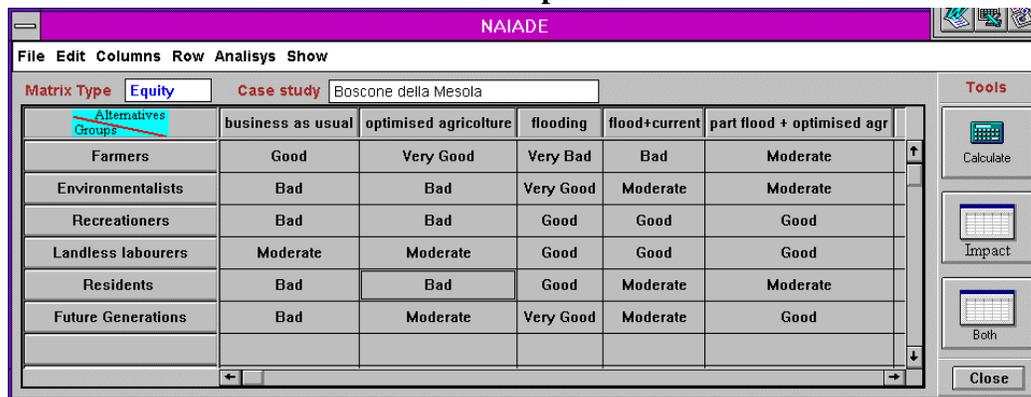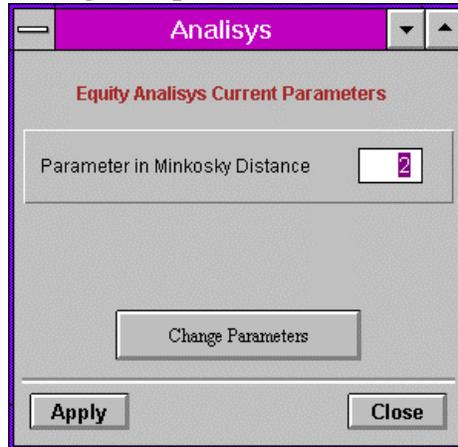
3.2.5. Equity Analysis
In this section you are asked to:
- change default parameters of equity analysis
- compute equity analysis

3.2.5.1. Changing the parameters
In the dialogue box of the parameter setting please set the parameter of the Minkovsky distance (p) to 2.

Dialogue box to change the parameter of the Minkovsky distance

3.2.5.2. Calculation and display of results
Now you can click on the button CALCULATE. Visualise the results using the Show menu and analyse the dendrogram.

Question 6: What are the basic coalitions formed when p is set to 2?

_____

_____

Question 7: Which of the solutions appear to be more "defensible" when p is set to 2?

_____

Click on the button "Show Similarity Matrix".

Question 8: What is the degree of normalised similarity between Environmentalists and Farmers when p is set to 2? _____

Now use the parameters command from the EDIT menu to change the parameter for the Minkovsky distance (p) to 10. redo the calculations.

Question 9: Which of the solutions appear to be more "defensible"?

_____

3.3. Further Analysis

If you like and have time, you can go back and change some of the criteria scores and group preferences that had been set up and repeat the whole analysis. In that way you can compare your results with those obtained earlier. Moreover, by choosing from the FILE menu, the command New, you can create a new case study.