Territorial resilience: How an MC method and SW tools can generate a robust evaluation model

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Content

Introduction

This thesis aims to be one that when we face an MCDA problem without decision maker(s), how to improve the model. Figure 1 shows the entire procedures of the thesis and the annotations are below it.

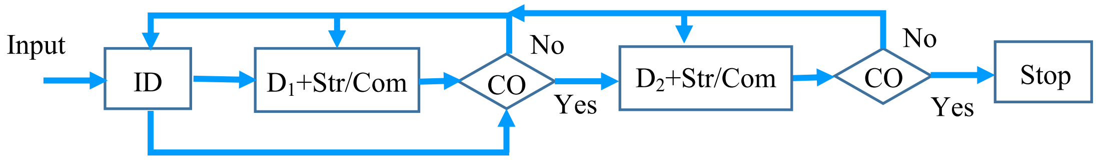


Figure 1 Structure of the thesis

ID: Result analysis and identification of its main characteristics;
D_1: Development of a sensitivity analysis of the result (first cycle);
Str/Com: Synthesis and structured visualization of results, for Communication aims;
CO: Testing of the result/model quality and, if required, proposals of model improvement and method application (CO as Control of the procedure);
D_2: Development of a robustness analysis (second cycle).

The "Input" procedure is the starting point of my thesis.Since this model is basically matured (Norese M.F.and Mustafa A. 2015), they had improved the model not only by reducing the number of criteria from14 to 6 with 3 main dimensions, but also define the parameters of it (weights, profiles and thresholds). In their work, the method they used is ELECTRE III and I will use ELECTRE Tri to improve the model. Beside the original weight distribution, we assume 5 more scenarios. Three of them are extreme weight distribution, each one places emphasis on one different dimension; the other two are potential policies. This part has been described in chapter 1.

In chapter 2, I start to analyze the result of the ELECTRE Tri according to the model, which is the "ID" procedure in figure 1. I use the figure of "comparison to profile" to determine analysis which actions. I choose the actions are incomparable or indifferent with the profile to analyze by using their visualization figure. After that, I develop a sensitivity analysis (D_1) of it to know the stability interval of cutting level and the results of different cutting level. I repeat these two procedures in the 3 extreme scenarios. Then I synthesis all the results in one table, which is procedure "Str/Com" in figure 1. I find that the results is not so satisfied, because there are too many actions are orient to the intermediate category and no one is clearly in the bad category, which is not acceptable. We realize that the model is not good enough. Therefore, we re-analysis the visualization figures of actions and profiles, and then we propose some changes in relation to the profile and veto thresholds. We propose 5 new possible veto thresholds in relation to 4 criteria and two new profiles; one is called "the marginal change" which is only with little difference and another one is called "the second change" with more

changes. This part is described in section 2.2 and it is the first “CO” procedure in figure 1.
Because the result of first “CO” is obviously not well, in chapter 3 I should re-analyze the model with new profile and veto thresholds. In section 3.1, I apply only one new veto threshold each time under the condition of original weight distribution, I find only one propose of new veto threshold is interesting, others are either have no change in the result or the result is worse than before. In section 3.2, I apply “the marginal change” profile twice, with and without the only one acceptable new veto threshold, and then I find the result is same. That means the marginal changes are not enough, therefore I should lay emphasis on the second change of the profile. In section 3.3 I analyze the model with the second changes. This time I apply the two potential policies and develop the sensitivity analysis of them. After all the analysis, I synthesis all the results of section 3.3 in one table, this time we have actions are clearly to be rejected, but more risky actions than before. In section 3.5, I compare my results with the results of ELECTRE III. There are 5 actions have different assignments. Therefore I use the figures of actions’ visualization to analysis, and I find that the comparative analysis of ELECTRE III in these cases produces results less convincing than in the sorting method. The second changes in the profile is well tested

In section 3.6, I apply the only one acceptable new veto in the second changes profile under the scenarios of original weight distribution and 2 possible policies. Then I develop a robustness analysis in relation to the weight of each criteria, each veto thresholds and the cutting level, and synthesis them in table 3.23 (D_2+Str/Com). We find there are several parts are near to the original value in the result of robustness analysis (the second CO in figure 1), therefore we propose 12 tests, each test changes a little according to one not so robust value. The results are synthesized in table 3.24 (the second cycle of D_2+Str/Com). From this table, we can say the result is generally robust with twelve actions have a clear assignment due to the robustness analysis; six actions are more difficult than those twelve actions to have a clearly assignment; the rest three actions are impossible to identify their robust assignments (Stop).

However, the analysis is based on a specific condition: without any decision maker. Therefore I have to consider all possible situations to have a general result. If there are decision makers, there may not be an action which is impossible to have a clear and robust assignment.

Chapter 1

A multi criteria approach to evaluate resilience

The word *resilience* is becoming more and more central in the environment but also in the social life. It refers to several different factors, and it has been suggested as a new multidimensional horizon of territorial control. Several aspects of resilience were studied in the ANDROID – European Lifelong learning Programme to increase society's resilience to disasters of a human and natural origin, and an MC model was elaborated in 2014 in relation to a pilot case. The original aims were to both underline the limits of the adopted resilience indices and to demonstrate, by means of the application of an MC method to a multicriteria (MC) resilience model, that MC models and methods "exist" and can be very useful in resilience increasing processes (Scarelli and Benanchi, 2014).

Starting from this study, model and results of the ELECTRE III method (Roy,1978; 1990) application, to rank twenty-two municipalities belonging to the Ombrone River hydrographic basin in the Tuscany region in Italy, where several floods events had occurred, were analyzed (Norese et al. 2016). Some criticisms emerged in relation to the original model, which had been influenced by the limited availability of adequate data and the not so consistent nature of the criteria that had been taken from literature. Some improvements were proposed, formally developed and tested by means of an iterative application of the ELECTRE III method, the same method that had been adopted in the original study.

The result of some iterations and revisions of the original model were then used to activate a new phase of study, to orient the model in relation to a possible decision process of a territorial agency that needed structured knowledge before any resource allocation could be made.

This approach and the main activities and results are described in the next sections, in order to introduce the study of this thesis, which is described in the next chapter.

1.1 Resilience and MC modelling

The term 'resilience' stems from the Latin verb *resilire* (rebound), and *resilience* was originally used to refer to the pliant or elastic quality of a substance. In the last few decades, the concept of 'resilience' has gained much ground in a wide variety of academic disciplines. Research is conducted not only in engineering and ecological sciences pertaining to climate change and disaster management (the potentiality of a system to return to the equilibrium which was present before a natural or unnatural disaster), but also in psychology (the capacity to react and to face the adversities of life), medicine (the patients' reaction to a treatment of therapy), or law (a community's capacity to react and integrate new rules or proceedings of the local authorities). Each definition includes different concepts, such as flexibility, adaptation or reaction. Resilience would seem to be the answer to a wide range of problems and threats.

Resilience has therefore garnered the attention of policymakers. It could be useful to design a reflexive management process that guides policymakers or other actors through the steps of understanding which factors they can influence to strengthen the resilience property of the system (Duijnhoven and Neef, 2014).

The resilience definition that is used here was originally proposed in the ANDROID Programme (http://www.disaster-resilience.net). *Resilience is something we can grow in ourselves, in our family and in our communities*, as the result of an educational activity addressed to the prevention and minimization of negative effects of adversities, natural events, disasters and so on. Therefore, resilience, in this context, can be seen as the capacity of the administrators to face the risk of a catastrophe, their level of interest, resources and efforts devoted to it (the social life sphere). The resilience concept should be considered as the result of interactions between the environmental, socio-political and economics factors that influence the various spheres of social life and activate the actors' awareness and involvement that are required to prevent and manage the effects of a disaster event.

A large numbers of indicators have been proposed in the literature and some resilience indices, which aggregate indicators, have been adopted. Scarelli and Benanchi (2014) proposed a different approach to the problem. As an alternative to the indices that combine different factors in a single synthetic value, they developed an MC model in which all the components would be transparent, and they applied a multicriteria method, ELECTRE III, to synthesize the evaluations and rank the analysed territorial units from the most to the least resilient. The main reason for the choice of this MC method was its ability to pay particular attention to the uncertainty level that could have been associated to each indicator and the related evaluation.

The results of this first MC approach to resilience were analysed, in relation to the data used for the evaluations and the model structure (main aspects, or model dimensions, and criteria that analytically make each dimension operational) and parameters (Norese et al. 2016). Some parameters of an MC model directly express the decision makers' points of view. They are the relative importance of the criteria (which only the decision makers can express, in order to verify whether a *concordance* of heavy criteria exists and may facilitate a decision) and the veto thresholds, which model the need for controlling the risk of a high *discordance* between evaluations (complementary principle to the concordance principle in the ELECTRE methods and all the outranking methods). Other parameters (the indifference and preference thresholds) are used to reduce the uncertainty that may be associated to the data and the expressions of decision preference (see Roy, 1996).

The criteria of the Scarelli and Benanchi model (2014) were taken from literature, as also their relative importance (the weights), because of the absence of decision makers in this pilot case. While the indifference and preference thresholds were elaborated in relation to the quality of the used data. The structure of the model is shown in table 1.1 and consists of only two strategic aspects, or dimensions, and fourteen criteria: the first six criteria of the table are related to the environmental dimension, with almost the same importance as the other eight criteria that are related to the socio-economic dimension (as indicated in the literature). Index of demographic dependency, as ratio between the population on 0-14 age and over 65 ages, respects the active one (15-64). A young population has a reaction and recovery times shorter than an older population.

Table 1.1 - The model structure in (Scarelli e Benanchi, 2014)

Criteria/ indicators	Analysed aspects
CO2 emissions	Contamination risk as a sign of limited environmental awareness
% of urbanized area	Limited rainfall absorption
Electricity domestic use	Alternative energy use (environmental awareness)
% of differentiated waste	Environmental awareness
Drinkable water use	Safeguarding aquifer layers
Certified firms	Environmental awareness
Demographic density	Anthropic impact on the environment
Unemployed men	Anthropic impact on the environment
Unemployed women	Progress in the social life
Accidents in workplace	Awareness of safety and risk
Territorial desirability	Awareness of environment safeguarding
Reaction time limits	Young + old population /Active population ratio
Employees /residents	Resource consumption and waste creation
Spendable income	Economic resources from citizens to prevent disasters

A careful analysis of the ELECTRE III application and results was considered essential to verify whether this resilience evaluation was accurate enough, could give suitable explanations to the different situations in the Ombrone basin and could be used to facilitate improvement actions. The study started with an analysis of the results of the ELECTRE III application and of its possible limits, and continued with an examination of the model elements that could negatively influence the result. Some change hypotheses were made and a sequence of ELECTRE III applications to the original model and the proposed variants was provisionally planned, because the analysis of each new result could orient the sequence of changes. The comparative visualization of the results facilitated the identification of possible limits in the model parameters, evaluations and/or structure.

This analysis is described in (Norese et al., 2016) and here is synthesized by means of a framework (see figure 1.1) that had been proposed in (Lendaris, 1980) and used in several applications of the methodology MACRAME (Norese, 1994).

In figure 1.1, we can see that the original model is with 2 dimensions, 14 criteria and 22 actions. After the result analysis by using ELECTRE III, Siena is eliminated because it is a total different one among all actions. Then, with the introduction and modification of thresholds, the result of every change or change combination is worse; therefore the model should be re-structured instead of being improved. After the analysis of the model, it becomes 3 dimensions with only 6 criteria and 21 actions, in 4 scenarios. The result analysis shows that always the same best and worst actions and the others change their relative positions but always in the middle part of the ranking. After that, there is a deep analysis of the strange actions, the conclusion is the actions are so different that at the can be classified in 3 types.

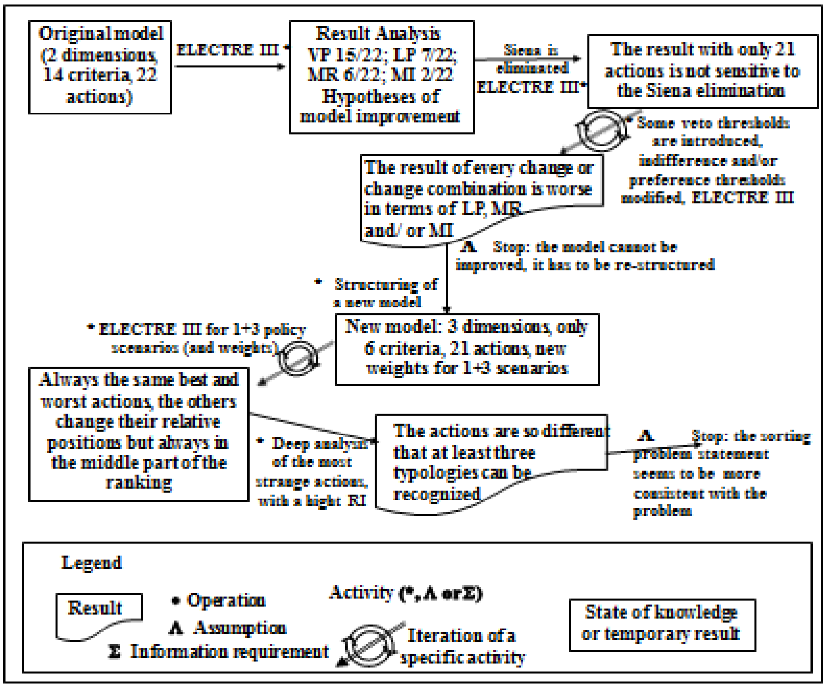


Figure 1.1 Frameworks of ELECTRE III

The result of an ELECTRE III application is a classification of compared actions, from "best to worst", which is represented by a *final partial graph*, i.e. a pre-order that is developed as the intersection of the two complete pre-orders resulting from two distillation procedures, that is, the descendant procedure and the ascendant one (Figueira et al, 2005). The final partial graph can include different paths, the longest of which can be visualized as the vertical and considered the main path, while each lateral path indicates a situation of incomparability and underlines a distance (of one or more classes and sometimes even of several ones) between some action positions in the two distillations. The presence of different paths is more frequent when several actions are compared, and the lateral paths may be visualized above all in the intermediate part of the graph. The number of lateral paths grows if the comparability of some actions is not so high, but a high number of paths can sometimes be the sign of a difficult definition of some model parameters and above all of the veto thresholds.
In the resilience case, the model included not a few actions (22 municipalities) and could have presented some elements of uncertainty, because it was not created for a

specific decision problem, but only to improve future decision processes, and because it synthesized logical inputs from literature and analytical inputs from the few available but not so reliable and consistent data.

The final partial graph that resulted from the ELECTRE III application to the model is presented in figure X, with fifteen actions in the vertical path and seven actions in the lateral paths, which are only present in the intermediate part of the graph. It can be observed that the municipality that is incomparable with the maximum number (6) of other municipalities is Trequanda (TREQU) and there are a maximum number of only two actions in the same class. Some indices can be used to describe this result: VI=15/22 is the vertical index; LI =7/22 is the lateral index that measures the presence of incomparability; II=2/22 is the indifference index, the maximum number of actions in the same class; RI=6/22 is the incomparability index, in relation to TREQU, the action that is incomparable with 6 other actions. The only element that caught our attention was the presence of Siena in the last positions. Siena is the main city in the county, with more than 50,000 inhabitants, while the population of the other twenty-one municipalities is always less than 5,000, except for five municipalities which have populations of about 7,000 or 9,000 inhabitants. For this reason, Siena is not easily comparable with the other municipalities. As a consequence, Siena was eliminated from the set of actions, and it was believed that this measure would have changed the result to a great extent. However, the result without Siena was not so different, with 15 actions always being present in the vertical path and six in the lateral ones. Some small changes occurred only in the intermediate part. Essentially, the ELECTRE III result seemed to be not so sensitive to the Siena elimination.

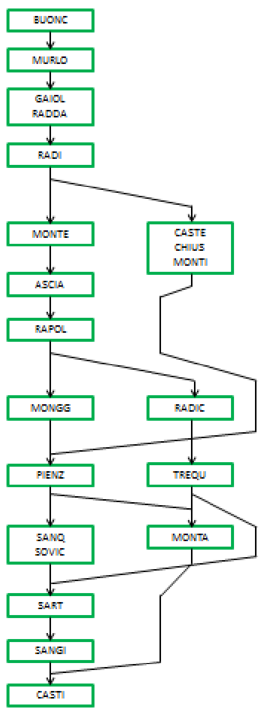


Figure 1.2 Results

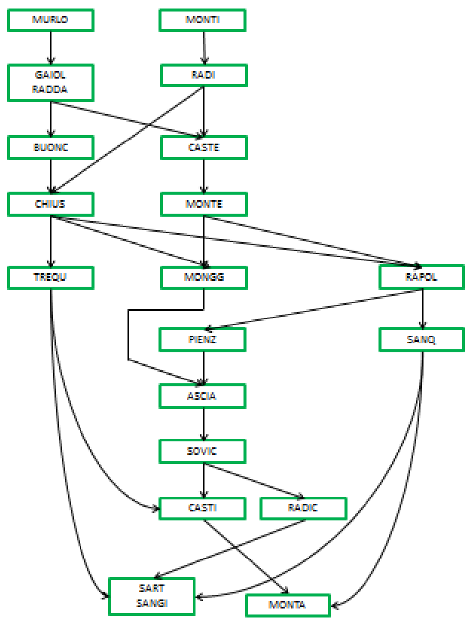


Figure 1.3 Results

At this point, some small changes were introduced to improve certain thresholds of indifference and preference that were too large, and the result changed the situation considerably in relation to each small change. When some veto thresholds were introduced, because the original model had not included any veto threshold, the result became disastrous (see figure 1.3). This result is a clear sign that something was wrong in the model and small changes in its parameters only underlined that the structure and contents of the model should be analyzed.
A careful reading of the meaning of all the criteria and the data that had been used in the original model for the evaluations indicated that the structure of the model might only apparently have been be consistent with the multidimensional definition of resilience and that the quality of the evaluations was not always acceptable. The problem was formulated in relation to a possible decision process of a territorial agency that needed structured knowledge before any resource allocation could be made. The structure of the model was changed in relation to the problem formulation (see figure 1.4) and only some of the original criteria were associated to the new structure.

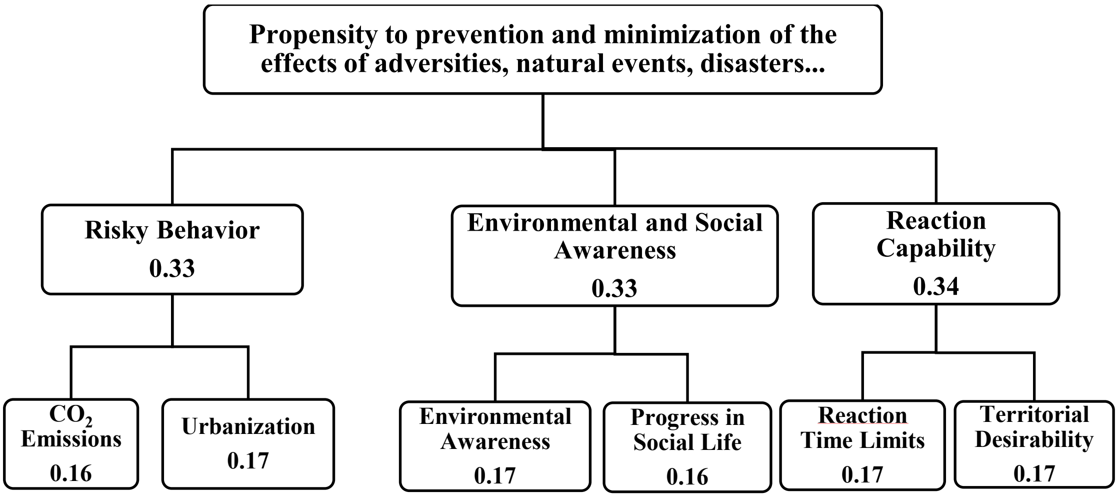


Figure 1.4: New model structure

The problem is analyzed in the model by means of three main dimensions, which are Risky Behavior, Environmental & Social Awareness and Reaction Capability, and each dimension shares nearly equal importance. Each dimension is made operational by means of two criteria that share nearly equal weight. The total weight of the criteria is one. This definition of the weights is connected to the problem situation, which was formulated in relation to a possible decision process of a territorial agency, without the involvement of decision makers. The weights start from the structure of the model where all the dimensions are strategic and a preference system is not declared. Therefore the dimensions have the same importance and the relative importance of the criteria that are connected to each dimension is the same. Different scenarios of weights, which represent different policies and related preference systems, can be created to test the sensibility of the results in relation to the different policies.
The criteria that were associated to the logical structure of the three dimensions were extracted from the original model and are:

- CO2 emission, as indication of a risky behavior that produces contamination and alteration of the atmosphere (decreasing preference);
- Urbanized area, because it limits the rainfall absorption and contributes to generate flood (decreasing)
- Differentiated waste as a sign of the environmental awareness of municipalities and citizens (increasing);
- Presence of women in the job seeker's list respect to the total population, as a sign of the progress in the social life (increasing)

- Index of demographic dependency as an indicator of limit to the reaction time (decreasing).
- Territorial desirability, as ratio between the touristic flows and resident population, which is an expression of interest for the territory safeguard (increasing).

A sequence of ELECTRE III applications to this new model showed more understandable results, with a reduced incomparability in the rankings, although the not so reliable evaluations. A clear and robust presence of the same four head actions, plus other four in almost the same position, and of the same five actions at the end of the ranking was evident in several tests of robustness analysis and in relation to four different weight scenarios of different possible policies. While the other actions changed positions but always in the intermediate part of the ranking, between the head and the end.

The idea of applying the ELECTRE Tri-B method (Yu, 1992; Mousseau et al., 2000; Figueira et al., 2013) to the new model started from an evident situation of incomparability between some actions/cities, also in relation to the new model, and a clear distinction of the actions in three stable categories of resilience propensity. The ELECTRE Tri-B method does not compare actions, as ELECTRE III does, while compares the actions with a reference system, to assign actions into ordered categories. This methodological approach was considered more consistent with the situation and the problems in which decision makers or policy makers have to assign budget to the municipalities. The ELECTRE Tri method is described in Annex 1. The procedure aims to formally analyze the quality of its results, in relation to internal criteria, and external ones, in relation to the results of the ELECTRE III applications to the new model. The model for the application of ELECTRE Tri-B is described in section 1.2. The results of the ELECTRE III applications, which could be used to be compared with the results of the ELECTRE Tri applications, are described in the section 1.3.

1.2 The model for the application of ELECTRE Tri-B

The multi criteria model for sorting uses the same criteria, weights and evaluations as the last model for ranking (see table 1.2, with the actions, i.e. the analyzed municipalities, their abbreviated names in parenthesis and the evaluations in relation to each criterion), plus the definition of two reference actions that characterize three categories. The original preference, indifference, and veto parameters can be the same or they can be marginally modified.

Categories can be defined to distinguish situations in which “funds from a territorial agency can be effectively used”, situations in which “funds could only partially improve resilience” and others in which “funding risks to be useless”.

A category should include cities/towns with a limited risky behavior and good Environmental and social awareness and Reaction capability. This category will be shown by “Good” (funds definitely assigned to this category action). Another category should include cities with evaluations on the three main aspects that are intermediate, or some are good and the others intermediate or bad. This category will be shown by “Intermediate” (it means funds only in case of existing extra budget). The last category should include cities/towns whose performances on one or more aspects are critical. This category will be shown by “Bad” (no funds).

In order to define each category, some characterizing reference actions are necessary in ELECTRE Tri-B method. They are used as bounds of a category and the method assigns an action to a specific category by comparing the action with the reference actions. Table 1.3 shows the criteria, with the used scale that are associated and the other required parameters (preference (p), indifference (q) and veto (v) thresholds), and the values of the reference actions (B_1 and B_2) that separate the three categories Bad, Intermediate and Good, where B_1 is the high profile, between Good and Intermediate categories, and B_2 is the low one, that separates Intermediate and Bad categories.

For instance, for the “Environmental awareness” criterion, the evaluations are included in the interval [14.9-54.2], where 54.2 is the preferred evaluation, the indifferent threshold is q=0.5, the preference threshold is p=2 and the veto threshold is v=25, the reference values of the criterion are 35, which separates the Bad from the Intermediate category, and 45, which separates the Intermediate from the Good category.

Table 1.2: Action performance

Criteria / Actions	CO_2 emission	Urbanization	Environmental awareness	Progress in social life	Reaction time (Index from ISTAT)	Territory desirability
Versus of preference	**Decreasing**	**Decreasing**	**Increasing**	**Increasing**	**Decreasing**	**Increasing**
Unit of measure/ Used scale	**Level [7-1]**	**% [2 - 0.1]**	**% [14.9 -54.2]**	**% [0.38 - 0.52]**	**Index [0.76-0.49]**	**% [1.39 -19.29]**
RADICOFANI (RADI)	1	0.44	35.4	0.45	0.58	1.91
SARTEANO (SARTE)	3	2	39	0.42	0.63	2.77
PIENZA (PIENZ)	1	1	41.4	0.41	0.69	13.68
SAN QUIRICO D'ORCIA (SANQ)	5	1.8	45.9	0.45	0.62	19.29
CASTIGLION D'ORCIA (CASTI)	1	0.1	18	0.4	0.7	3.8
MANTALCINO (MONTA)	3	0.2	47.8	0.43	0.63	3.99
MURLO (MURLO)	1	0.9	35.4	0.5	0.58	5.3
BUONCONVENTO (BUONC)	1	1	54.2	0.44	0.6	3.13
SAN GIOVANNI D'ASSO (SANGI)	1	0.26	25.8	0.39	0.76	8.94
TREQUANDA (TREQU)	1	0.1	30.7	0.42	0.65	5.8
ASCIANO (ASCIA)	5	0.7	48	0.43	0.59	5.3
MONTERONI D'ARBIA (MONTE)	3	1	52.8	0.52	0.53	1.39
RAPOLANO TERME (RAPOL)	3	0.6	42.1	0.46	0.61	5.62
CASTELNUOVO BER. (CASTE)	3	0.1	34.2	0.52	0.49	4.43
GAIOLE IN CHIANTI (GAIOLE)	1	0.3	34.5	0.52	0.58	6.39
RADDA IN CHIANTI (RADDA)	1	0.15	33.5	0.43	0.59	12.97
MONTERIGGIONI (MONGG)	3	0.05	52.9	0.44	0.55	4.66
OVICILLE (SOVIC)	4	0.3	45.4	0.49	0.54	3.11
RADICONDOLI (RADIC)	7	0.12	38.6	0.41	0.63	3.22
CHIUSDINO (CHIUS)	1	0.1	23.5	0.44	0.62	12.23
MONTICIANO (MONTI)	1	0.15	14.9	0.45	0.68	4.98

Table 1.3: Scales, thresholds and reference actions

Criteria [used scales], thresholds v, q and p	**Profiles that separate the three categories**			
CO_2 Emission [7-1], v=5	7	5	3	1
Urbanization [2-0,1],v=1.2, q=0.1,p= 0.2	2	1	0.4	0.1
Environment.aw. [14.9-54.2], v=25,q=0.5, p=2	14.9	35	45	54.2
Progress social life [0.38-0.519], q=0.01, p=0.02	0.38	0.42	0.47	0.519
Reaction time lim.[0.76-0.49],v=0.19, q=0.02, p=0.04	0.76	0.68	0.58	0.49
Territorial des. [1.39 -19.29], v=9, q=0.4, p=1.5	1.39	4	10	19.29

1.2.1 Scenarios of weights

The decision maker(s) may place emphasis on one or another particular dimension, in relation to a policy. If it is *Improving resilience by educating people***,** Awareness will be improved by education (0.4), Reaction time can be poorly improved (0.25), Risky behavior may be improved (0.35). If the policy is *Improving resilience by training on how to react in case of disaster (Civil protection)* Reaction capability has to be grown (0.40), Risky behavior (0.30) and Awareness (0.30) are less important. In this case, without decision maker(s), three scenarios of weights are proposed to take to extremes.

In scenario 1, the dimension Risky Behavior has a prominent importance compared with the other two dimensions. So the weight of this dimension is 0.5 and the criteria, CO_2 emissions and Urbanization, share this weight equally, with a relative importance equal to 0.25. The weights of other two dimensions, Environmental & Social Awareness and Reaction Capability, are equal to

0.25. In relation to the dimension Environmental & Social Awareness, the criterion Environmental Awareness has a weight of 0.13 and the criterion Progress in Social Life has a weight of 0.12. In relation to the dimension Reaction Capability, Reaction time limits has a weight of 0.12 and Territorial Desirability has a weight of 0.13.

In scenario 2, the dimension Environmental & Social Awareness has a prominent importance compared with the other two dimensions. So the weight of this dimension is 0.5 and the criteria Environmental Awareness and Progress in Social Life share the weight equally, with a weight equal to 0.25. The weights of other two dimensions, Risky Behavior and Reaction Capability, are equal to 0.25. The criteria in relation to the dimension Risky Behavior have a weight equal to 0.12 (CO_2 Emission) and 0.13 (Urbanization). Criteria in relation to the dimension Reaction Capability have a weight equal to 0.12 (Reaction time limits) and 0.13 (Territorial Desirability).

In scenario 3, the dimension Environmental & Social Awareness has a prominent importance. So the weight of the dimension Reaction Capability is 0.5 and the criteria of this dimension, Reaction Time Limits and Territorial Desirability, share the weight equally, with a relative importance of 0.25. The weights of other two dimensions, Risky Behavior and Environmental & Social Awareness, are equal to 0.25. In relation to the dimension Risky Behavior, the weight of the criterion CO_2 Emission is 0.12 and of the criterion Urbanization is 0.13. In relation to the dimension Environmental & Social Awareness, the weight of the criterion Environmental Awareness is 0.13 and of Progress in Social Life is 0.12.

1.3 The results of the ELECTRE III applications

The ELECTRE III results, which are shown in figure 1.5, are related to the four different scenarios of weights. The analysis of these results underlines that some actions are always in the best four positions and they are indicated in figure with the codes RADDA, GAIOL, MONGG and CASTE. Other four actions are always in the first positions, except for only one scenario, and their codes are: CHIUS, BUONC, PIENZA and SOVIC.

Four actions are always in the last positions and their codes are: SART, RADIC and CASTI. Other two actions are near to the last and their codes are: ASCIA and RADI.

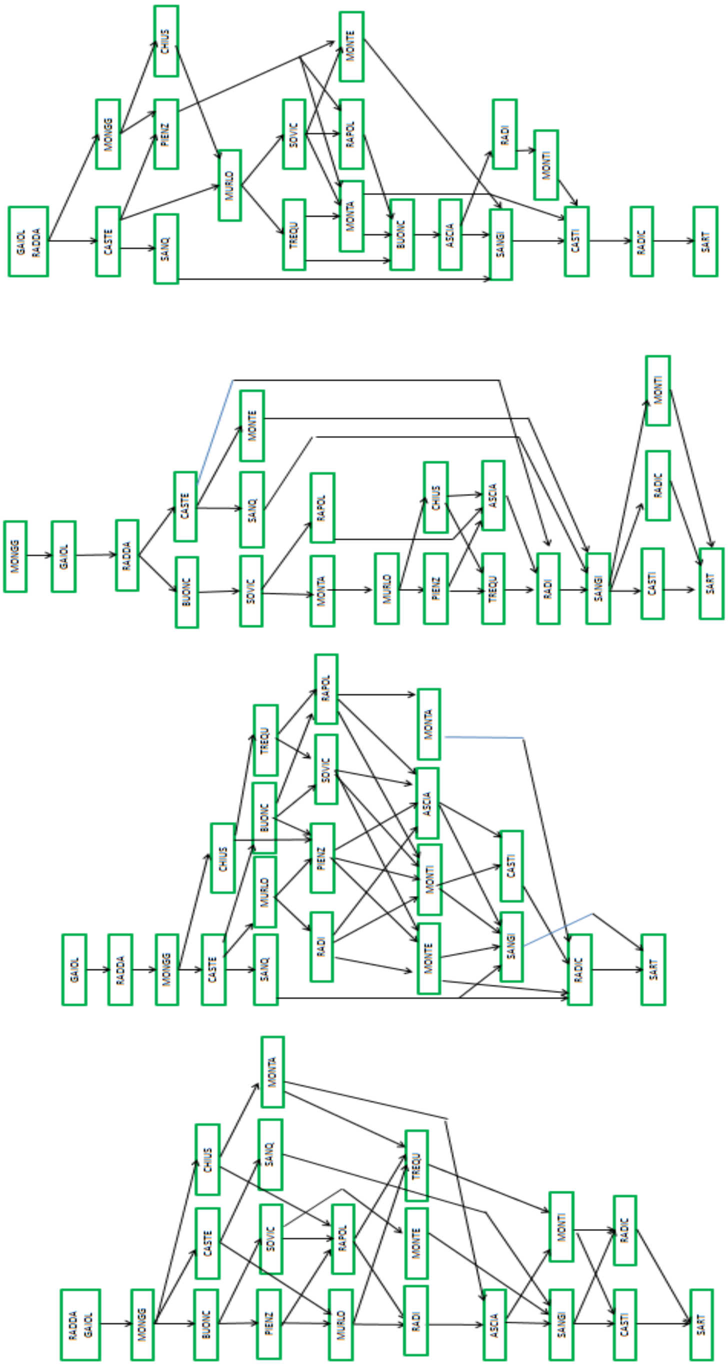


Figure 1.5 Results of ELECTRE III

Chapter 2

The ELECTRE Tri application to a resilience model

Two are the ambits and aims of this analysis: an integrated use of two different SW tools to test their compatibility and possible synergy, and to underline limits and possible improvements of the tools; a structured analysis of how the method ELECTRE Tri can be applied to a model and used to test the result, in order to identify limits in the model, which could be reduced or eliminated, and to propose a clear documentation of this analysis and an easy reading of the results, for present or future decision makers.
A result analysis includes several steps, in general not linear, that aim to test quality in several terms (understandability, consistency with elements of knowledge external to the model, presence of strange and/or critical elements,…). This analysis can produce a more effective clarification and/or interpretation of the result and some proposals of each unexpected element of the result investigation, of testing its sensitivity to some specific parameters and of parameter re-calibration or model structure improvement.
In the first section of this chapter, the ELECTRE Tri software tool from the French laboratory of LAMSADE is used to apply the method to the first version of the model and to visualize the result and the possible impact of some specific parameters (above all weights and veto thresholds). After this result analysis, the Canadian software tool MCDA-Ulaval is above all used to identify the stability interval of the result in relation to the parameter cutting level and to facilitate the sensitivity analysis of the result.
In the second section, the results of the previous analysis are synthesized and some proposals of tests and model improvements discussed, for their development in chapter 3.

2.1 Result analysis

The result of the ELETRE Tri software tool application to the model is shown in table 2.1 and synthesized in table 2.2, where the assignment of each action is indicated for both the pessimistic and the optimistic assignment procedures.
The starting cutting level, without any indication from the decision maker(s), was chosen equal to 0.65. This is the intermediate value of the interval 0.60-0.70, where the cutting level is not too high to generate incomparability in several comparisons, or too low in order to verify the presence of a significant majority of reasons to have outranking. Other values will be tested during the analysis.

Table 2.1: Assignments of the ELECTRE Tri application to the model

λ=0.65		
Candidate action	Pessimistic	Optimistic
RADICOFANI (RADI)	Intermediate	Intermediate
SARTEANO (SARTE)	Bad	Intermediate
PIENZA (PIENZ)	Intermediate	Intermediate
SAN QUIRICO D'ORCIA (SANQ)	Intermediate	Good
CASTIGLION D'ORCIA (CASTI)	Intermediate	Intermediate
MONTALCINO (MONTA)	Intermediate	Intermediate
MURLO (MURLO)	Intermediate	Intermediate
BUONCONVENTO (BUONC)	Intermediate	Intermediate
SAN GIOVANNI D'ASSO (SANGI)	Bad	Intermediate
TREQUANDA (TREQU)	Intermediate	Intermediate
ASCIANO (ASCIA)	Intermediate	Intermediate
MONTERONI D'ARBIA (MONTE)	Intermediate	Good
RAPOLANO TERME (RAPOL)	Intermediate	Intermediate
CASTELNUOVO BERARDENGA (CASTE)	Good	Good
GAIOLE IN CHIANTI (GAIOLE)	Good	Good
RADDA IN CHIANTI (RADDA)	Good	Good
MONTERIGGIONI (MONGG)	Good	Good
SOVICILLE (SOVIC)	Intermediate	Intermediate
RADICONDOLI (RADIC)	Intermediate	Intermediate
CHIUSDINO (CHIUS)	Intermediate	Good
MONTICIANO (MONTI)	Intermediate	Intermediate

Table 2.2: Synthesis of the assignments of 21 actions (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG (4/21)	CASTE, GAIOLE, RADDA, MONGG, SANQ, MONTE, CHIUS (7/21)
Intermediate	(15/21)	(14/21)
Bad	SARTE, SANGI (2/21)	

Only four actions are good in both the procedures and no one is Bad in both the procedure. There are 3 Intermediate-Good actions, 12 Intermediate-Intermediate actions and 2 Bad-Intermediate actions. If we look into the window Comparison to profile (Figure 2.1), symbols and letters are proposed for each action: the symbols of preference between actions a and profiles B, or B and a (≻ ≺), the letter R, which represents a relation of incomparability between action and profile, and the letter I that represents a relation of Indifference between action and profile. There are five incomparable situations, in relation to Sarteano and San Giovanni d'Asso, both incomparable with B_2 while B_1 is preferred to themselves, San Quirico d'Orcia, Monteriggioni and Chiusdino, which are incomparable with B_1 and preferred to B_2. Gaiole in Chianti is preferred to B_2 and is indifferent to B_1.

Comparison to Profile

	B2	B1
RADI	>	<
SARTE	R	<
PIENZ	>	<
SANQ	>	R
CASTI	>	<
MONTA	>	<
MURLO	>	<
BUONC	>	<
SANGI	R	<
TREQU	>	<
ASCIA	>	<
MONTE	>	R
RAPOL	>	<
CASTE	>	>
GAIOLE	>	I
RADDA	>	>
MONGG	>	>
SOVIC	>	<
RADIC	>	<
CHIUS	>	R
MONTI	>	<

Figure 2.1: Comparison to Profile

We can get a better understanding of the actions that present incomparability through the windows "Visualization of Alternative". In figure 2.2, the evaluations of the action Sarteano are showed. Each horizontal grey line represents the used evaluation scale for a specific criterion. The blue lines represent the profiles that separate the three categories and connect their performances (the reference model). The left one indicates the low profile B_2 and the right one the high profile B_1. The category C_1 (bad) is on the left side of the profile B_2. On the right side of the profile B_1 there is the category C_3 (good). The category C_2 (intermediate) is between the two blue lines. The red line connects the performances of a specific action in the different criteria and it visualizes the action position in relation with the profiles.

Sarteano and San Giovanni d'Asso

These two actions are incomparable with B_2 and B_1 is preferred to them. They are the only two Bad-Intermediate actions. They may be in the same situation, but it is visualized that the actions are different.

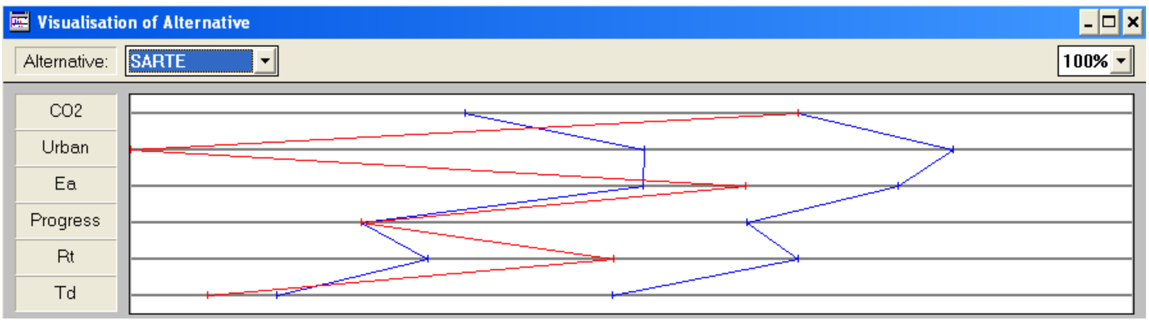


Figure 2.2: Visualization of Alternative – Sarteano

B_1 is clearly preferred to action Sarteano because B_1 is better or equal in each criterion (dominance). Sarteano is preferred to B_2 in 3 of the 6 criteria, it is indifferent in 1 and therefore it could outrank

B_2. But the action has the lowest performance of the used scale in the criterion Urbanization. Its evaluation is 2, the veto threshold for both the profiles is 1.2 and the evaluation of B_2 is 1. So a high discordance index reduces the degree of credibility of outranking that becomes less than the cutting level. Therefore, the action does not outrank the profile B_2. The profile B_2 does not outrank the action and therefore they result incomparable. For this reason Sarteano is assigned to the Bad category in the pessimistic procedure. It is assigned to the Intermediate category in the optimistic procedure. The assignment of Sarteano can change (new assignment Intermediate-Intermediate) if the veto threshold for the profile B_2, in the criterion Urbanization, becomes bigger than 1.2 **(proposal of a possible parameter change).**

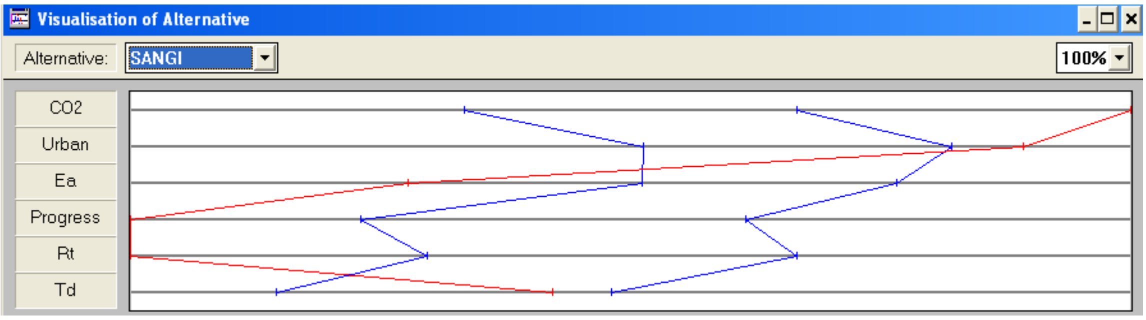


Figure 2.3: Visualization of Alternative – San Giovanni d'Asso

The situation of the action San Giovanni d'Asso is different. As for Sarteano, this action has a very bad performance (in this case in two criteria, Progress Social Life and Reaction Time Limits), but at the same time its evaluation in the criterion CO_2 Emissions is very good (the best on the used scale). Its evaluation is 1, the evaluation of B_2 is 5 and the veto threshold for the criterion is 5. B_1 is better in 4 criteria and it outranks the action. B_2 is better in 3 of the 6 criteria and could outrank the action, but a high discordance index for the criterion CO_2 Emissions reduces the degree of credibility of outranking that becomes less than the cutting level. Therefore, the action does not outrank the profile B_2 and the profile does not outrank the action: they result incomparable.
This action is different from the previous one and its behavior should be analyzed in some details. The incomparability can be considered a useful sign of a risky situation with contradictory evaluations, some of them very good and others very bad.

San Quirico D'Orcia, Monteroni D'Arbia and Chiusdino
I put these three actions together because they are incomparable with B_1 and preferred to B_2. They are also the only three Intermediate-Good actions. They could be in the same situation, but it is visualized that the actions are different. San Quirico D'Orcia is an interesting action but not a Good action. Monteroni D'Arbia is a risky action. Chiusdino is an interesting action that could become a Good action with a small change of the model.

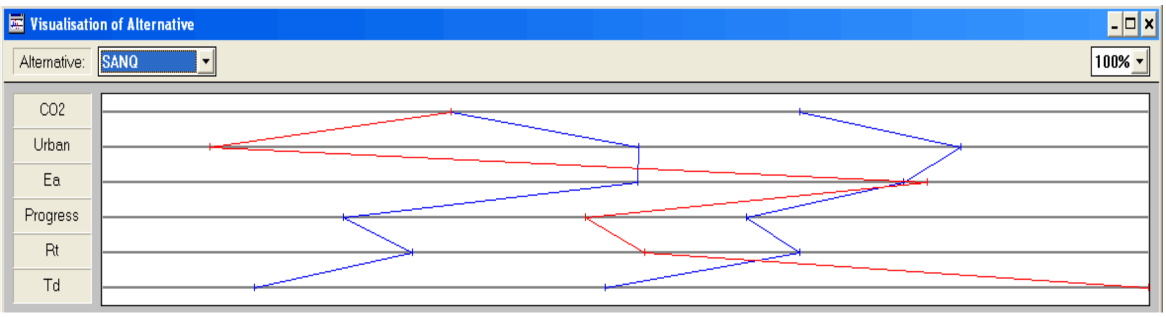


Figure 2.4: Visualization of Alternative – San Quirico D'Orcia

San Quirico D'Orcia does not outrank B_1 and it outranks B_2 (it is preferred to B_2 in 4 of the 6 criteria and indifferent in 1). Therefore it is Intermediate in the pessimistic procedure. B_2 is not preferred to the action. B_1 is preferred to it in 4 of the 6 criteria; however, the action has the best performance of the used scale in the criterion Territory Desirability. Its evaluation is 19.29 and the veto threshold for both the profiles is 9 and the evaluation of B_1 is 10. So a high discordance index reduces the degree of credibility of outranking that becomes less than the cutting level. Therefore, the action and B_1 are incomparable and the action is assigned to the Good category in the optimistic procedure.

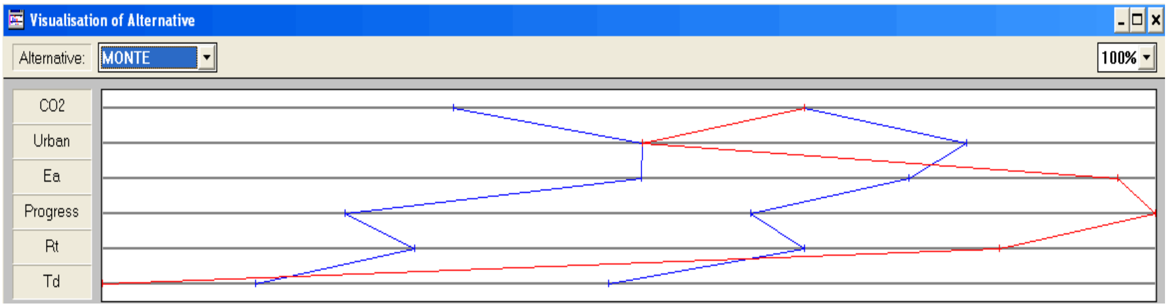


Figure 2.5: Visualization of Alternative – Monteroni D'Arbia

Monteroni D'Arbia outranks B_2 (it is preferred or equal to B_2 in 5 of the 6 criteria) and it could outrank B_1 (preferred or equal in 4 of the 6 criteria), but the action has the lowest performance of the used scale in the criterion Territory Desirability. Its evaluation is 1.39 and the veto threshold for both the profiles is 9 and the evaluation of B_1 is 10. So a high discordance index reduces the degree of credibility of outranking that becomes less than the cutting level. B_1 does not outrank the action (also if there is no veto threshold for the criterion Progress in Social Life) and therefore, action and B_1 are incomparable. This is a risky action, with contradictory evaluations, and its behavior should be analyzed in some details.

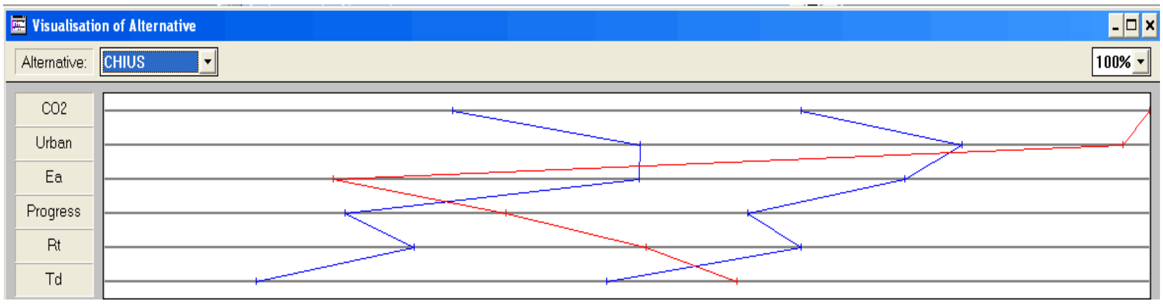


Figure 2.6: Visualization of Alternative – Chiusdino

Chiusdino does not outrank B_1. It is preferred in three criteria that are not the most important and there is discordance. The evaluation of the action for the criterion Environmental Awareness is 23.5, the veto threshold for both the profiles is 25 and the evaluation of B_1 is 45. A high discordance index reduces the degree of credibility of outranking that becomes less than the cutting level. Chiusdino outranks B_2 and is assigned to the Intermediate category. B_1 could outrank the action (it is preferred in 3 of the 6 criteria that are the most important), however there is discordance. The action has the best performance of the used scale in the criterion CO_2 Emissions. Its evaluation is 1 and the veto threshold for both the profiles is 5 and the evaluation of B_1 is 3. So a high discordance index reduces the degree of credibility of outranking that becomes less than the cutting level. As the result, the action and B_1 are incomparable and the action is a Good action in the optimistic procedure. A change of the veto threshold for the criterion Environmental Awareness in relation to B_1 (30 and not 25) could produce a Good-Good assignment. Another change could be in the veto of CO2 emissions in relation to B_2 (6 and not 5) **(proposals of possible parameter calibration and model improvement).**

Gaiole in Chianti

This is one of the four Good-Good actions. However, the other three actions are all preferred to B_1, only action Gaiole in Chianti is indifferent with B_1. The visualization of this action (figure 2.7) underlines that it is preferred or equal to B_2 in all the criteria, so it obviously outranks (and dominates) B_2. It is also preferred or equal to B_1 in 4 of the 6 criteria, so it can outrank B_1. B_1 is preferred or equal to it in 4 of the 6 criteria (the indifference threshold of Urbanization makes the action and B_1 indifferent) and then also B_1 can outrank the action. Therefore, the action and B_1 are indifferent.

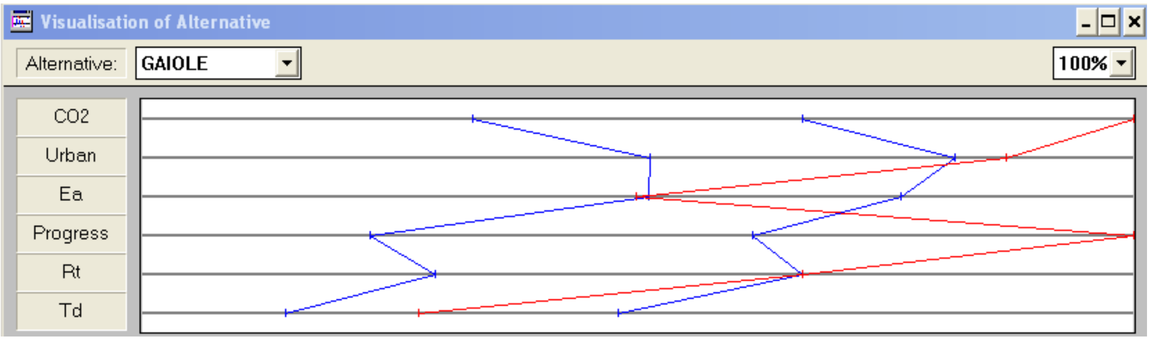


Figure 2.7: Visualization of Alternative – Gaiole in Chianti

Project : Original Project - Result : <Configuration, Tabl...

::

RESULT <Configuration, Table, *, 0>

::

Statistics :

<min, max>	#	%
<1, 2>	2	9.5238%
<2, 2>	12	57.1429%
<2, 3>	3	14.2857%
<3, 3>	4	19.0476%

ACTION	Pessimist (pseudo-conjunctive)	Optimist (pseudo-disjunctive)
RADI	C_2 Intermediate	C_2 Intermediate
SARIE	C_1 Bad	C_2 Intermediate
PIENZA	C_2 Intermediate	C_2 Intermediate
SANQ	C_2 Intermediate	C_3 Good
CASTI	C_2 Intermediate	C_2 Intermediate
MONTA	C_2 Intermediate	C_2 Intermediate
MURLO	C_2 Intermediate	C_2 Intermediate
BUONC	C_2 Intermediate	C_2 Intermediate
SANGI	C_1 Bad	C_2 Intermediate
TREQU	C_2 Intermediate	C_2 Intermediate
ASCIA	C_2 Intermediate	C_2 Intermediate
MONTE	C_2 Intermediate	C_3 Good
RAPOL	C_2 Intermediate	C_2 Intermediate
CASTE	C_3 Good	C_3 Good
GAIOLE	C_3 Good	C_3 Good
RADDA	C_3 Good	C_3 Good
MONGG	C_3 Good	C_3 Good
SOVIC	C_2 Intermediate	C_2 Intermediate
RADIC	C_2 Intermediate	C_2 Intermediate
CHIUS	C_2 Intermediate	C_3 Good
MONTI	C_2 Intermediate	C_2 Intermediate

::

Figure 2.8: Assignment by Alternative for cutting level λ=0.65 (New model, MCDA-Ulaval)

2.1.1 Stability intervals and sensitivity analysis

The result by the software MCDA-Ulaval is synthesized in figure 2.8. If we compare the result to table 2.1, we can see that there is no difference between them. This software can determine the interval of stability of the result in relation to changes of the parameter cutting level (see figure 2.9). The lower bound of the stability interval is very low (λ = 0.5712036) and the upper bound is very near to the original value (λ = 0.6599487). The result of the assignment does not change if the cutting level λ has any value in the interval, but changes for λ=0.66. Therefore it could be interesting the use this new value of the parameter, in order to see which is the change and if it is marginal or big enough.

The result of the assignment when cutting level is 0.65 is shown in table 2.3a. There are 4 Good-Good actions, which are CASTE, GAIOLE, RADDA and MONGG, 3 Intermediate-Good actions, SANQ, MONTE and CHIUS. SARTE and SANGI are two Bad-Intermediate actions. The other 12 actions are Intermediate-Intermediate actions. , but changes for λ=0.65995

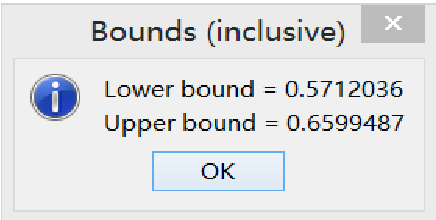


Figure 2.9: Stability analysis by MCDA-Ulaval

When the cutting level is 0.66, U-laval shows the stability interval is [0.659939, 0.66006106], and the two SWs show different results (see table 2.3 b and 2.3 c) because they have different approximation rules. The result of U-laval includes only two Good-Good actions, RADDA and MONGG, and not 4.

Table 2.3a: Synthesis of the assignments of 21 actions (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG (4/21)	SANQ, MONTE, CASTE, RADDA, GAIOLE, MONGG, CHIUS (7/21)
Intermediate	(15/21)	(14/21)
Bad	SARTE, SANGI (2/21)	

Table 2.3b: Synthesis of the assignments of 21 actions (cutting level λ=0.66) LAMSADE

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG (4/21)	SANQ, MONTE, CASTE, RADDA, GAIOLE, MONGG, CHIUS (7/21)
Intermediate	(15/21)	(14/21)
Bad	SARTE, SANGI (2/21)	

Table 2.3c: Synthesis of the assignments of 21 actions (cutting level λ=0.66) U-laval

Categories	Pessimistic	Optimistic
Good	RADDA, MONGG (2/21)	SANQ, MONTE, CASTE, RADDA, MONGG, CHIUS (6/21)
Intermediate	(17/21)	(15/21)
Bad	SARTE, SANGI (2/21)	

In order to homogenize the results of the two SWs we can use two different cutting levels, the first equal to 0.65995 and the second equal to 0.661. In relation to the first the result is identical to the result of table 2.3a, and the stability interval becomes [0.5712049, 0.66001105]. In relation to the second cutting level, equal to 0.661, the result presents two Good-Good actions (see table 2.4a) and a stability interval [0.6600513, 0.67006105].
The result of cutting level equal to 0.671 is synthesized in table 2.4b. The stability of this new interval, [0.6700513, 0.68006104], is small and a new application of the method with a cutting level equal to 0.681 produces result in table 2.4c. The stability interval of this last result is [0.68005127, 0.7719702].
When the cutting level becomes 0.671 the result heavily changes: there is not any action assigned to the Good category in pessimistic procedure. The assignments of PIENZA, BUONC, TREQU, SOVIC and MONTI are better than before. CASTI becomes a Bad-Good action and then a potentially risky action. When the cutting level increases to 0.681, two more actions, MURLO and GAIOLE, become Intermediate-Good actions.

Table 2.4a: Synthesis of the assignments of 21 actions (cutting level λ=0.661)

Categories	Pessimistic	Optimistic
Good	RADDA, MONGG (2/21)	SANQ, MONTA, MONTE, CASTE, RADDA, MONGG, CHIUS (7/21)
Intermediate	(17/21)	(14/21)
Bad	SARTE, SANGI (2/21)	

Table 2.4b: Synthesis of the assignments of 21 actions (cutting level λ=0.671)

Categories	Pessimistic	Optimistic
Good		PIENZA, SANQ, ***CASTI***, MONTA, BUONC, TREQU, MONTE, CASTE, RADDA, MONGG, SOVIC, CHIUS, MONTI (13/21)
Intermediate	(18/21)	(8/21)
Bad	SARTE, SANGI, ***CASTI*** (3/21)	

Table 2.4c: Synthesis of the assignments of 21 actions (cutting level λ=0.681)

Categories	Pessimistic	Optimistic
Good		PIENZA, SANQ, ***CASTI***, MONTA, MURLO, BUONC, TREQU, MONTE, CASTE, GAIOLE, RADDA, MONGG, SOVIC, CHIUS, MONTI (15/21)
Intermediate	(18/21)	(6/21)
Bad	SARTE, SANGI, ***CASTI*** (3/21)	

In table 2.4 d and 2.4 e, no one Good-Good action is present, there are 12 (for 0.671) and 13 (for 0.681) Intermediate-Good actions and 2 Bad-Intermediate actions, but in this case there is an action, CASTI, is Bad in the Pessimistic procedure and Good in the Optimistic one. The behavior of this “strange” action is visualized in figure 2.10. CASTI has the best performance in the criterion CO_2 emission (this is the upper bound of the used scale) and a very good performance in the criterion Urbanization. On the contrary, its performance in the other criteria is quite bad. The small change of the cutting level underlined a strange and perhaps critical situation that the previous assignment (Intermediate-Intermediate) had not made evident.

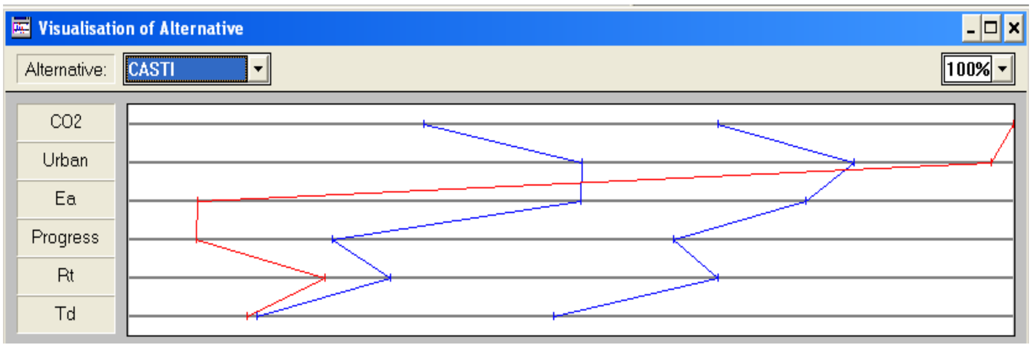


Figure 2.10: Visualization of Castiglion d'Orcia (CASTI)

As a general trend, we can see that the pessimistic assignment of the actions becomes worse when the cutting level increases; on the contrary, the optimistic assignment becomes better, except for action GAIOLE. This behavior is strange and the reasons are not so clear.
A Comparison to profiles window underlines that the number of the incomparability situations is strongly bigger (see table, where this number was 5 with the original cutting level and becomes 18 with the last ELECTRE Tri application).

Table 2.5: Number of situations in all cutting level (new model)

	0.65	0.661	0.671	0.681
Incomparable	5	7	16	18
Indifferent	1			

2.1.2 Scenario 1: result analysis

Scenario 1 heavily changes the weights: the dimension Risky Behavior is much more important than the other two. After changing the weighs of each criterion, the result is synthesized in table 2.6, where the assignment of each action is indicated for both the pessimistic and the optimistic assignment procedures. In order to improve the visual of the result, I summarize the result in table 2.7.

Table 2.6: Assignment by Alternative for cutting level λ=0.65 of scenario 1

λ=0.65		
Candidate action	Pessimistic	Optimistic
RADICOFANI (RADI)	Intermediate	Intermediate
SARTEANO (SARTE)	Bad	Intermediate
PIENZA (PIENZA)	Intermediate	Good
SAN QUIRICO D'ORCIA (SANQ)	Intermediate	Good
CASTIGLION D'ORCIA (CASTI)	Intermediate	Good
MONTALCINO (MONTA)	Intermediate	Good
MURLO (MURLO)	Intermediate	Good
BUONCONVENTO (BUONC)	Intermediate	Good
SAN GIOVANNI D'ASSO (SANGI)	Bad	Intermediate
TREQUANDA (TREQU)	Intermediate	Good
ASCIANO (ASCIA)	Intermediate	Intermediate
MONTERONI D'ARBIA (MONTE)	Intermediate	Good
RAPOLANO TERME (RAPOL)	Intermediate	Intermediate
CASTELNUOVO BERARDENGA (CASTE)	Good	Good
GAIOLE IN CHIANTI (GAIOLE)	Good	Good
RADDA IN CHIANTI (RADDA)	Good	Good
MONTERIGGIONI (MONGG)	Good	Good
SOVICILLE (SOVIC)	Intermediate	Intermediate
RADICONDOLI (RADIC)	Intermediate	Intermediate
CHIUSDINO (CHIUS)	Intermediate	Good
MONTICIANO (MONTI)	Intermediate	Good

Table 2.7: Synthesis of the assignments of 21 actions of scenario 1 (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG (4/21)	CASTE, GAIOLE, RADDA, MONGG, SANQ, MONTE, PIENZA, CASTI, TREQU, MONTA, MURLO, BUONC, CHIUS, MONTI (14/21)
Intermediate	(15/21)	(7/21)
Bad	SARTE, SANGI (2/21)	

Comparing table 2.6 with table 2.1 and table 2.7 with table 2.2, we can find there is no difference in the result of pessimistic assignment. There are 7 actions shift from intermediate to good in the optimistic assignment. From table 3 we can find that 4 actions present an assignment Good-Good, which is the same as the original model, 10 Intermediate-Good actions, 5 Intermediate-Intermediate actions, 2 Bad-Intermediate actions.

In the Comparison to profile window (Figure 2.11), the number of the incomparable situations is became higher (12), only two (Sarteano and San Giovanni d'Asso) incomparable with B_2, but 10 incomparable with B_1. There are changes in relation to 7 actions, Pienza, Castiglion d'Orica, Mantalcino, Murlo, Buonconvento, Trequanda and Monticiano, which were outranked by B_1 in the original model and now become incomparable with B_1. This set of action generates the shift from Intermediate-Intermediate to Intermediate-Good assignment. And Gaiole in Chianti is preferred to B_2 and B_1 while it was indifferent with B_1.

In conclusion, in scenario 1 the result is very similar to the original one. Still Castelnuovo Berardenga, Gaiole in Chianti, Radda in Chianti, Monteriggioni are the best, Sarteano and San Giovanni d'Asso are the worst, but some actions have a tendency of having a better assignment.

Comparison to Profile

	B2	B1
RADI	>	<
SARTE	R	<
PIENZ	>	R
SANQ	>	R
CASTI	>	R
MONTA	>	R
MURLO	>	R
BUONC	>	R
SANGI	R	<
TREQU	>	R
ASCIA	>	<
MONTE	>	R
RAPOL	>	<
CASTE	>	>
GAIOLE	>	>
RADDA	>	>
MONGG	>	>
SOVIC	>	<
RADIC	>	<
CHIUS	>	R
MONTI	>	R

Figure 2.11: Comparison to Profile of scenario 1

Scenario 1: sensitivity analysis

There is no difference between the result of table 2.6 and the result by the software MCDA-Ulaval. Then this software is used to know the stability interval of the result in relation to the parameter λ. The lower bound is not so low (λ = 0.63001096), the upper bound is close to the original value (λ = 0.650061). It means that the result changes for λ=0.63 or 0.651. Therefore, it could be interesting the analysis of the result sensitivity to these changes of the cutting level (see tables 2.8a and b).

When the cutting level is reduced (λ=0.63) in Scenario 1, the Good-Good actions become 5, with MONTA that was not present with λ=0.65, and SARTE is the only one Bad-Intermediate action. The interval of stability of this result in relation to the cutting level is [0.62005126, 0.63006103]. The result of cutting level with 0.62 is synthesized in table 2.7 d. The interval of stability of this result in relation to the cutting level is [0.5000049, 0.62006104].

When the cutting level becomes λ=0.651, there is only but relevant change (see table 2.7c), in relation to λ=0.65: SANGI becomes a Bad-Good action. The interval of stability of this result in relation to the cutting level is [0.6500513, 0.705044].

Table 2.8a: Scenario 1, synthesis of the assignments of 21 actions (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG (4/21)	CASTE, GAIOLE, RADDA, MONGG, SANQ, MONTE, PIENZA, CASTI, TREQU, MONTA, MURLO, BUONC, CHIUS, MONTI (14/21)
Intermediate	(15/21)	(7/21)
Bad	SARTE, SANGI (2/21)	

Table 2.8b: Scenario 1, synthesis of the assignments of 21 actions (cutting level λ=0.63)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG, MONTA (5/21)	PIENZA, SANQ, CASTI, MONTA, BUONC, TREQU, CASTE, GAIOLE, RADDA, MONGG, CHIUS, MONTI (12/21)
Intermediate	(15/21)	(9/21)
Bad	SARTE (1/21)	

Table 2.8c: Scenario 1, synthesis of the assignments of 21 actions (cutting level λ=0.651)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG (4/21)	CASTE, GAIOLE, RADDA, MONGG, SANQ, MONTE, PIENZA, CASTI, TREQU, MONTA, MURLO, BUONC, CHIUS, MONTI, ***SANGI*** (15/21)
Intermediate	(15/21)	(6/21)
Bad	SARTE, ***SANGI*** (2/21)	

Table 2.8d: Scenario 1, synthesis of the assignments of 21 actions (cutting level λ=0.62)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG, MONTA (5/21)	SANQ, CASTI, MONTA, TREQU, CASTE, GAIOLE, RADDA, MONGG, CHIUS, MONTI (10/21)
Intermediate	(15/21)	(11/21)
Bad	SARTE (1/21)	

In Scenario 1, we can summarize that CASTE, GAIOLE, RADDA and MONGG are always Good-Good actions and SARTE is always a Bad-Intermediate action. The action SANGI is a Bad-Intermediate action when the cutting level is λ=0.65, a Bad-Good action when the cutting level is bigger than 0.65, and it becomes an Intermediate-Intermediate action when the cutting level decreases to λ=0.63.

2.1.3 Scenario 2: result analysis

Scenario 2 heavily changes the weights: the dimension Environmental and Social Awareness is much more important than the other two. After changing the weighs of each criterion, the result is presented in table 2.9, where the assignment of each action is indicated for both the pessimistic and the optimistic assignment procedures synthesized, and synthesized in table 2.10

Table 2.9: Assignment by Alternative for cutting level λ=0.65 of scenario 2

Candidate action	Pessimistic	Optimistic
RADICOFANI (RADI)	Intermediate	Intermediate
SARTEANO (SARTE)	Intermediate	Intermediate
PIENZA (PIENZA)	Intermediate	Intermediate
SAN QUIRICO D'ORCIA (SANQ)	Intermediate	Good
CASTIGLION D'ORCIA (CASTI)	Bad	Intermediate
MONTALCINO (MONTA)	Intermediate	Good
MURLO (MURLO)	Intermediate	Good
BUONCONVENTO (BUONC)	Intermediate	Good
SAN GIOVANNI D'ASSO (SANGI)	Bad	Intermediate
TREQUANDA (TREQU)	Intermediate	Intermediate
ASCIANO (ASCIA)	Intermediate	Intermediate
MONTERONI D'ARBIA (MONTE)	Intermediate	Good
RAPOLANO TERME (RAPOL)	Intermediate	Intermediate
CASTELNUOVO BERARDENGA (CASTE)	Intermediate	Good
GAIOLE IN CHIANTI (GAIOLE)	Intermediate	Good
RADDA IN CHIANTI (RADDA)	Intermediate	Good
MONTERIGGIONI (MONGG)	Intermediate	Good
SOVICILLE (SOVIC)	Good	Good
RADICONDOLI (RADIC)	Intermediate	Intermediate
CHIUSDINO (CHIUS)	Intermediate	Good
MONTICIANO (MONTI)	Bad	Intermediate

Table 2.10: Synthesis of the assignments of 21 actions of scenario 2 (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	SOVIC (1/21)	SOVIC,CASTE, GAIOLE, RADDA, MONGG, MONTE, CHIUS, SANQ, MONTA, MURLO, BUONC (11/21)
Intermediate	(17/21)	(10/21)
Bad	SANGI, CASTI, MONTI(3/21)	

There is only 1 Good-Good action, 10 Intermediate-Good actions, 7 Intermediate-Intermediate actions and 3 Bad-Intermediate actions.
If we look into the window Comparison to profile (Figure 2.12), we will find that there are 13 incomparable situations. Only three actions (Catiglion d'Orcia, San Giovanni d'Asso and Monticiano) are incomparable with B_2, but ten (San Quirico d'Orcia, Mantalcino, Murlo, Buonconvento, Monteroni d'Arbia, Castelnuovo Berardenga, Gaiole in Chianti, Radda in Chianti, Monteriggioni and Chiusdino) are incomparable with B_1. There is not any indifferent situation in scenario 2.

Comparison to Profile

	B2	B1
RADI	>	<
SARTE	>	<
PIENZ	>	<
SANQ	>	R
CASTI	R	<
MONTA	>	R
MURLO	>	R
BUONC	>	R
SANGI	R	<
TREQU	>	<
ASCIA	>	<
MONTE	>	R
RAPOL	>	<
CASTE	>	R
GAIOLE	>	R
RADDA	>	R
MONGG	>	R
SOVIC	>	>
RADIC	>	<
CHIUS	>	R
MONTI	R	<

Figure 2.12: Comparison to Profile of scenario 2

Sovicille, Castiglion d'Orcia and Monticiano can be strange actions. The assignment of Sovicille was intermediate-intermediate twice, now suddenly it becomes the only one good-good action. Castiglion d'Orcia and Monticiano are assigned to the bad category in pessimistic assignment. So these three actions are analyzed by means of the windows Visualization of Alternative.

Sovicille

B_2 is outranked by Sovicille because the action is better in five criteria and only in one criterion action and profile are indifferent. The result shows that the action is also preferred to B_1, because in scenario 2 the criteria where the action has a good performance (Environment Awareness and Progress in Social Life) have a higher weight than the original ones. In addition, the discordance in relation to the bad performance in the criterion Territory Desirability does not reduce the outranking degree heavily. So it is assigned in good category according to both pessimistic and optimistic procedure. If the veto threshold for the criterion Territory Desirability, in relation to both the profiles, becomes stricter (from 9 to 8) or softer (from 9 to 10), the result could change. **(Proposal of veto threshold change)**

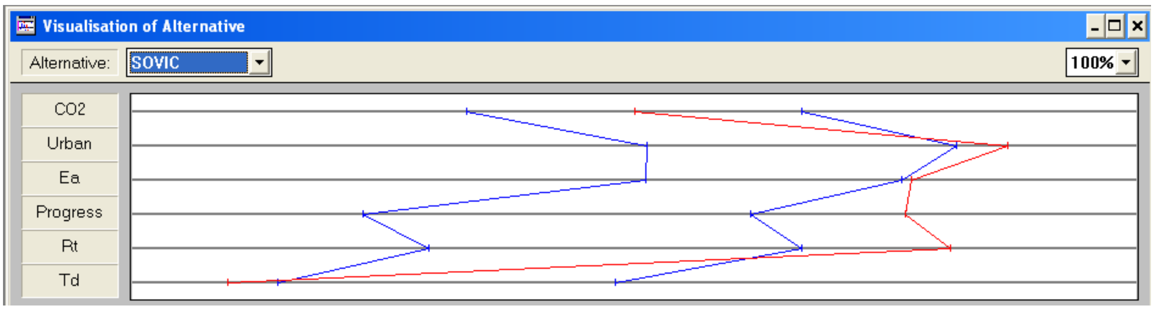


Figure 2.13: Visualization of Alternative – Sovicille

Castiglion d'Orcia and Monticiano

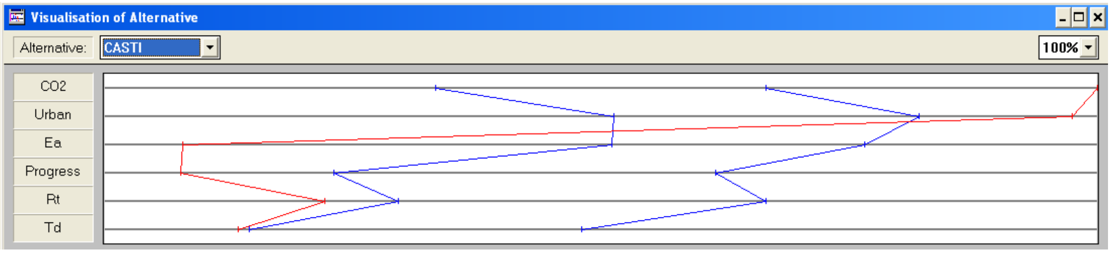


Figure 2.14: Visualization of Alternative – Castiglion d'Orcia

Castiglion d'Orcia was visualized for the first time in figure 2.10 when it resulted a Bad-Good action in the sensitivity analysis of the original model. In scenario 2, Environmental Awareness and Progress in Social Life are the two most important criteria, so it is assigned in a bad category according to the pessimistic assignment procedure, but in the optimistic one it is Intermediate (figure 2.14).
In figure 2.15, the action Monticiano results similar to the action Castiglion d'Orcia and it is assigned to the Bad category, according to the pessimistic assignment procedure.

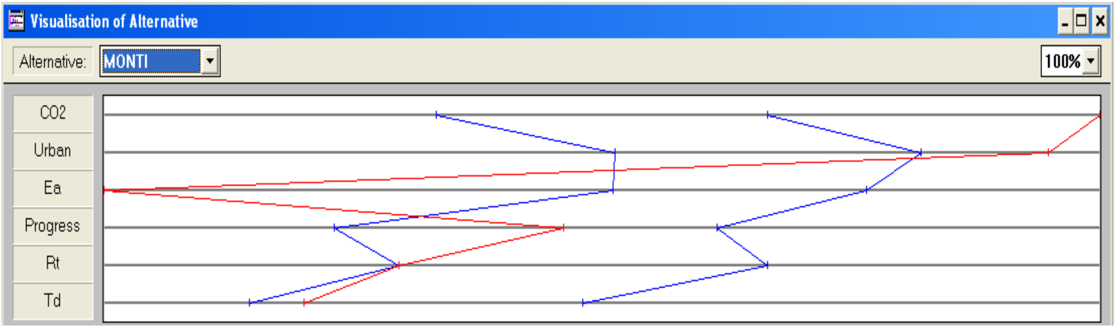


Figure 2.15: Visualization of Alternative – Monticiano

Scenario 2: sensitivity analysis

The software MCDA-Ulaval generates the same result and it is used to identify the stability interval of the result in relation to the parameter λ. The lower bound is not too low, $\lambda = 0.6391357$, the upper bound is not too high, $\lambda = 0.6768249$. It means that result changes for λ=0.639 or 0.677. Therefore it could be interesting the analysis of this change, in order to see which element changes and if this change is marginal or not.

Table 2.11: Scenario 2, synthesis of the assignments of 21 actions (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	<u>SOVIC</u> (1/21)	<u>SOVIC</u>,CASTE, GAIOLE, RADDA, MONGG, MONTE, CHIUS, SANQ, MONTA, MURLO, BUONC (11/21)
Intermediate	(17/21)	(10/21)
Bad	SANGI, CASTI, MONTI(3/21)	

In the table 2.11, SOVIC is the only one Good-Good action and there are 3 Bad-Intermediate actions, which are SANGI, CASTI and MONTI. The interval of stability of this result is very limited [0.6391357, 0.6768249], so the values 0.639 and 0.677 of the cutting level are tested in this sensitivity analysis. In the table 2.11b, the only difference refers to λ=0.65 is that MONTI is no longer a Bad-Intermediate action; it is an Intermediate-Intermediate action. The interval of stability of this result is very limited [0.63002783, 0.63912207], so the result will change when the value of cutting level is 0.63 (see table 2.12a).
SOVIC is the only Good-Good action in the case of λ=0.63 and 0.677. The number of Intermediate-Good action has decreased from 10 to 7, with λ=0.63. CASTI and SANGI are Bad-Intermediate

actions, in both the cases, MONTI and SARTE only with λ=0.677.
The interval of stability with λ=0.63 is [0.62005126, 0.63006103], the result will change when λ=0.619; with λ=0.677 is [0.6768872, 0.7499768], that is large enough and for any cutting level in this interval, the result will not change.
In table 2.12d, the result is much different with other situations. There are 3 more Good-Good actions, which are CASTE, GAIOLE and MONGG. There are fewer actions assigned in good category in optimistic procedure refers to λ=0.63. There are only two actions are Intermediate-Good actions, SANQ and MONTE. The interval of stability with λ=0.619 is [0.6000181, 0.61999766].

Table 2.12a: Scenario 2, synthesis of the assignments of 21 actions (cutting level λ=0.639)

Categories	Pessimistic	Optimistic
Good	SOVIC (1/21)	SOVIC,CASTE, GAIOLE, RADDA, MONGG, MONTE, CHIUS, SANQ, MONTA, MURLO, BUONC (11/21)
Intermediate	(17/21)	(10/21)
Bad	SANGI, CASTI (3/21)	

Table 2.12b: Scenario 2, synthesis of the assignments of 21 actions (cutting level λ=0.63)

Categories	Pessimistic	Optimistic
Good	SOVIC (1/21)	SANQ, MONTA, MONTE,CASTE, RADDA, MONGG, CHIUS, SOVIC (8/21)
Intermediate	(18/21)	(13/21)
Bad	CASTI, SANGI (2/21)	

Table 2.12c: Scenario 2, synthesis of the assignments of 21 actions (cutting level λ=0.677)

Categories	Pessimistic	Optimistic
Good	SOVIC (1/21)	SANQ, MONTA, MURLO, BUONC, MONTE,CASTE, GAIOLE, RADDA, MONGG, CHIUS, SOVIC (11/21)
Intermediate	(17/21)	(10/21)
Bad	CASTI, SANGI, MONTI, SARTE (4/21)	

Table 2.12d: Scenario 2, synthesis of the assignments of 21 actions (cutting level λ=0.619)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, MONGG, SOVIC (4/21)	SANQ, MONTE,CASTE, GAIOLE, MONGG, SOVIC (6/21)
Intermediate	(15/21)	(15/21)
Bad	CASTI, SANGI (2/21)	

In scenario 2, SOVIC is always a Good-Good action; SANQ and MONTE are always an Intermediate-Good action; CASTI and SANGI are always a Bad-Intermediate action. When the cutting level is lower than 0.62, there becomes 3 more Good-Good actions yet. When the cutting level is high, there are two more actions becomes Bad-Intermediate, which are MONTI and SARTE.

2.1.4 Scenario 3: result analysis

Scenario 3 heavily changes the weights: the dimension Reaction Capability is much more important than the other two. After changing the weighs of each criterion, the result is synthesized in table 2.13, where the assignment of each action is indicated for both the pessimistic and the optimistic assignment procedures. The result is synthesized in table 2.14. There is only 1 Good-Good action, 7 Intermediate-Good actions, 11 Intermediate-Intermediate actions and 2 Bad-Intermediate actions. The incomparable situations this time are only 9 (window Comparison to profile of Figure 2.16).

Table 2.13: Assignment by Alternative for cutting level λ=0.65 of scenario 3

Candidate action	Pessimistic	Optimistic
RADICOFANI (RADI)	Intermediate	Intermediate
SARTEANO (SARTE)	Bad	Intermediate
PIENZA (PIENZA)	Intermediate	Good
SAN QUIRICO D'ORCIA (SANQ)	Intermediate	Good
CASTIGLION D'ORCIA (CASTI)	Intermediate	Intermediate
MONTALCINO (MONTA)	Intermediate	Intermediate
MURLO (MURLO)	Intermediate	Intermediate
BUONCONVENTO (BUONC)	Intermediate	Intermediate
SAN GIOVANNI D'ASSO (SANGI)	Bad	Intermediate
TREQUANDA (TREQU)	Intermediate	Intermediate
ASCIANO (ASCIA)	Intermediate	Intermediate
MONTERONI D'ARBIA (MONTE)	Intermediate	Good
RAPOLANO TERME (RAPOL)	Intermediate	Intermediate
CASTELNUOVO BERARDENGA (CASTE)	Intermediate	Good
GAIOLE IN CHIANTI (GAIOLE)	Intermediate	Intermediate
RADDA IN CHIANTI (RADDA)	Good	Good
MONTERIGGIONI (MONGG)	Intermediate	Good
SOVICILLE (SOVIC)	Intermediate	Good
RADICONDOLI (RADIC)	Intermediate	Intermediate
CHIUSDINO (CHIUS)	Intermediate	Good
MONTICIANO (MONTI)	Intermediate	Intermediate

Table 2.14: Synthesis of the assignments of 21 actions of scenario 3 (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	RADDA (1/21)	SOVIC,CASTE, RADDA, MONGG, MONTE, CHIUS, SANQ, PIENZ (8/21)
Intermediate	(18/21)	(13/21)
Bad	SARTE, SANGI (2/21)	

Comparison to Profile

	B2	B1
RADI	>	<
SARTE	R	<
PIENZ	>	R
SANQ	>	R
CASTI	>	<
MONTA	>	<
MURLO	>	<
BUONC	>	<
SANGI	R	<
TREQU	>	<
ASCIA	>	<
MONTE	>	R
RAPOL	>	<
CASTE	>	R
GAIOLE	>	<
RADDA	>	>
MONGG	>	R
SOVIC	>	R
RADIC	>	<
CHIUS	>	R
MONTI	>	<

Figure 2.16: Comparison to Profile of scenario 3

Radda in Chianti, Gaiole in Chianti, Castenuovo Berardenga and Monteriggioni

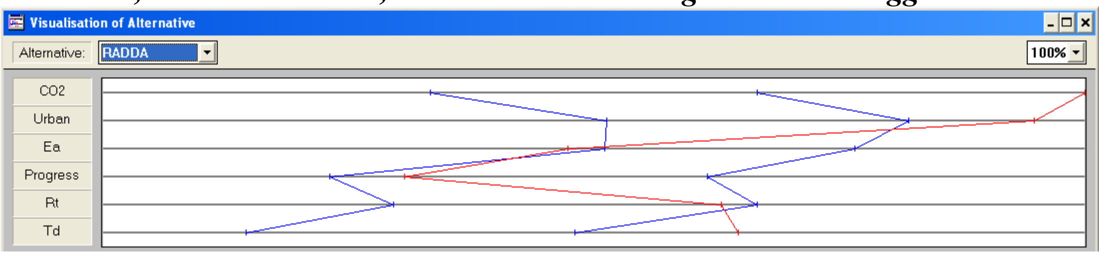


Figure 2.17: Visualization of Alternative – Radda in Chianti

In the original model and scenario 1, action Radda in Chianti is always in the Good-Good categories with other three, Castelnuovo Berardenga, Gaiole in Chianti and Monteriggioni. However in scenario 3, it becomes the only Good-Good action (see figure 2.17). The other three actions (figures 2.18, 2.19 and 2.20) present a common character: B_1 is clearly better than them in the criterion Territory Desirability that in this scenario is very important.

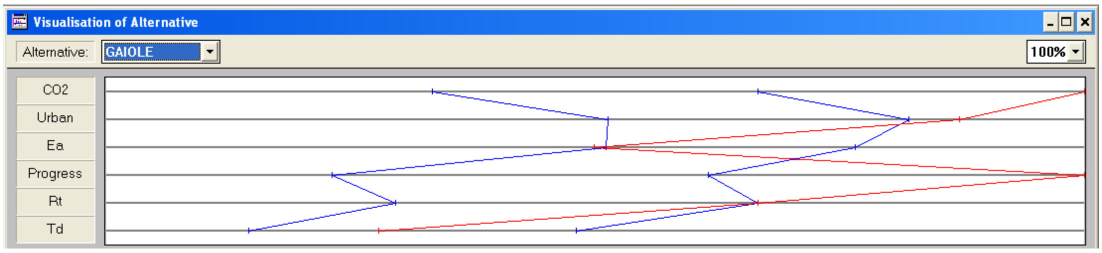


Figure 2.18: Visualization of Gaiole in Chianti

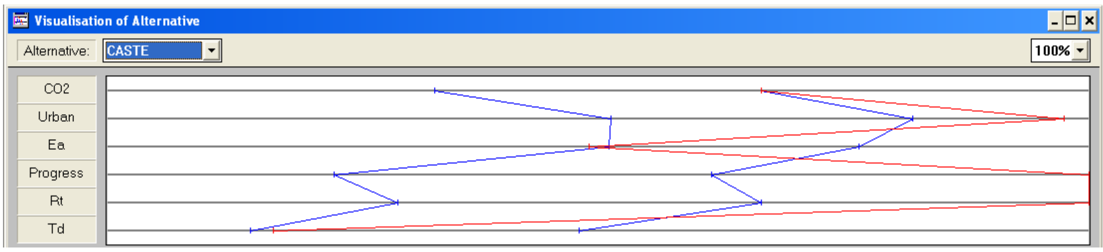


Figure 2.19: Visualization of Castenuovo Berardenga

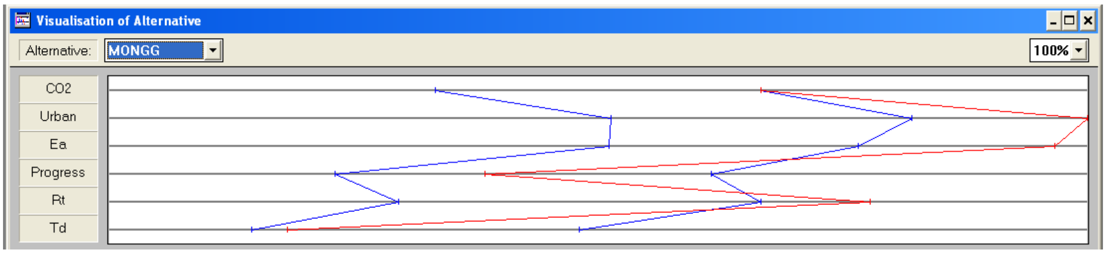


Figure 2.20: Visualization of Monteriggioni

Scenario 3: sensitivity analysis

The result by the software MCDA-Ulaval is the same, and then the software is used to know the stability interval of the result in relation to the parameter λ. The lower bound is not so low (λ = 0.63001096) and the upper bound is very high (λ = 0.7399963). Therefore the changes of the result for λ=0.63 are analyzed (see table 2.15b). The differences refer to λ = 0.65 are MONGG becomes another Good-Good action with RADDA; SOVIC and PIENZA are Intermediate- Intermediate actions. The stability interval is [0.62005126, 0.63006103]. The result with λ=0.62 is synthesized in table 2.15c. The differences refer to λ = 0.63 is that there are two more actions become Good-Good action. The interval of stability is [0.5000049, 0.62006104]. The lower bound is very close to 0.5.

Table 2.15 a: Scenario 3, synthesis of the assignments of 21 actions (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	<u>RADDA</u> (1/21)	SOVIC,CASTE, <u>RADDA</u>, MONGG, MONTE, CHIUS, SANQ, PIENZ (8/21)
Intermediate	(18/21)	(13/21)
Bad	SARTE, SANGI (2/21)	

Table 2.15 b: Scenario 3, synthesis of the assignments of 21 actions (cutting level λ=0.63)

Categories	Pessimistic	Optimistic
Good	<u>RADDA, MONGG</u> (2/21)	SANQ, MONTE,CASTE, <u>RADDA, MONGG</u>, CHIUS (6/21)
Intermediate	(15/21)	(15/21)
Bad	CASTI, SANGI (2/21)	

Table 2.15 c: Scenario 3, synthesis of the assignments of 21 actions (cutting level λ=0.62)

Categories	Pessimistic	Optimistic
Good	<u>CASTE, GAIOLE, RADDA, MONGG</u> (4/21)	SANQ, MONTE,<u>CASTE, GAIOLE, RADDA, MONGG</u>, CHIUS (7/21)
Intermediate	(15/21)	(14/21)
Bad	CASTI, SANGI (2/21)	

In Scenario 3, when cutting level decreases (see table 2.15c), there are 3 Good-Good actions which were Intermediate-Good actions. SARTE also becomes better, from Bad-Intermediate to

Intermediate-Intermediate. No matter which cutting level, RADDA is always a Good-Good action. Only CASTI and GAIOLE become worse, CASTI is from an Intermediate-Intermediate action to a Bad-Intermediate action while GAIOLE is from a Good-Good action to an Intermediate-Intermediate action.

2.2 Synthesis of the results and new activity proposal

A first synthesis of the results includes the number of times each action is assigned to two possible categories (the same or different), by means of the assignment procedures, in the several applications of ELECTRE Tri. This visualization of the previous results is proposed in table 2.16. For each action and each number of assignments, some symbols (for example * and °) could indicate a strong indication of a robust assignment (main model, scenarios from policies, limited variations of the main model parameters,…) and a weak indication of an assignment connected to big changes (changes of veto thresholds, extreme scenarios, …).
The table 2.16 facilitates the identification of some clusters of actions that could be used to generate some new categories or subcategories. In this table, which is only a temporary result, we can see actions that are Good (CASTE, RADDA, MONGG, and also GAIOLE and SOVIC) or Intermediate (RADI, ASCIA, RAPOL and RADIC), but also actions that are not Good but Interesting (PIENZ, MURLO, BUONC, TREQU, MONTE, CHIUS) or Very Interesting (MONTA and SANQ). SARTE is the only action nearly Bad.
Others may be considered "critical or risky actions". CASTI and SANGI in at least one test result Bad-Good actions and their performances were discussed and presented in figures 2.14 and 2.3. MONTI and CASTI change their assignments, in some cases oriented to the Good and in others to the Bad categories. SANGI is more oriented to the categories Bad-Intermediate. Some of these actions are really strange and any decision should be postponed to a deep analysis of these municipalities and their evaluations in the model. The analysis of these actions, visualized in the figure 2.1 as the few actions incomparable with some profile, anticipated the synthesis of table 2.16. Only one action, Monteroni d'Arbia (MONTE), was considered a strange action in section 2.1 and figures 2.1 and 2.5 because incomparable with one profile, but shows a clear tendency to be assigned to the category Good, in the developed tests. All these actions have the best performance in at least one criterion (not the same one), but they present bad or very bad performances in some others. MONTE is the lower bound of the performance scale in the criterion Territory Desirability, and the upper bound in the criterion Progress in Social Life, in addition to good performances in other two criteria. MONTI and CASTI are the upper bound of criterion CO_2 Emission and have a high performance in the criterion Urbanization. MONTI is the worst in the criterion Environmental Awareness and the CASTI performances in the other criteria are quite bad. So these strange actions result incomparable with one or another profile, or in some cases with both. CASTI presents different assignments (Good-Intermediate, Intermediate- Intermediate, Bad-Intermediate and Bad-Good). MONTI is Good-Intermediate, Intermediate- Intermediate and Bad-Intermeidate.
SANGI is the only action which is the lower bound of two criteria: Progress in Social Life and Reaction Time. At the same time, it is the upper bound of criterion CO_2 Emissions. And therefore it is assigned to the Bad-Intermediate categories in almost all the ELECTRE Tri applications, except in one in which it is Bad-Good.

Table 2.16 Synthesized of results

Classes Actions	Good - Good	Intermediate -Good	Intermediate – Intermediate	Bad - Good	Bad - Intermediate	Bad - Bad
RADICOFANI (RADI)			16			
SARTEANO (SARTE)			4		12	
PIENZA (PIENZ)		7	9			
SAN QUIRICO D'ORCIA (SANQ)		16				
CASTIGLION D'ORCIA (CASTI)		4	5	2	5	
MANTALCINO (MONTA)	2	9	5			
MURLO (MURLO)		6	10			
BUONCONVENTO (BUONC)		8	8			
SAN GIOVANNI D'ASSO (SANGI)			2	1	13	
TREQUANDA (TREQU)		6	10			
ASCIANO (ASCIA)			16			
MONTERONI D'ARBIA (MONTE)		14	2			
RAPOLANO TERME (RAPOL)			16			
CASTELNUOVO BER. (CASTE)	7	9				
GAIOLE IN CHIANTI (GAIOLE)	7	4	5			
RADDA IN CHIANTI (RADDA)	9	7				
MONTERIGGIONI (MONGG)	9	7				
SOVICILLE (SOVIC)	5	3	8			
RADICONDOLI (RADIC)			16			
CHIUSDINO (CHIUS)		15	1			
MONTICIANO (MONTI)		6	8		2	

Some actions, visualized in figure 2.1 as the few actions incomparable with some profile, cannot be considered strange and can suggest a better definition of some parameters, above all the veto thresholds

2.2.1 Proposals of change in the veto thresholds

A change in the veto thresholds is suggested when it can produce a result more consistent with the visualization of the action behavior. Each change can produce a generalized change in some elements of the result, which in this case is sensitive to this parameter, or only in the assignment of a specific action that has suggested the change.

If we change the veto of the criterion Urbanization from 1.2 to 1.4, action Sarteano changes from Bad-Intermediate to Intermediate-Intermediate. The other assignments do not change; therefore the result is not sensitive to this parameter. If we change the veto of the criterion Territory Desirability from 9 to 10, action Sovicille changes from Intermediate-Intermediate to Good-Good in the model with cutting level λ=0.65 and in Scenario 3 with cutting level λ=0.62. Without the change of veto this was its assignment only in Scenario 2. This change is significant, but all the other assignments do not change.

Therefore a proposal of veto threshold changes could include a change for the criterion Environmental Awareness in relation to B_1 (veto threshold equal to 30 and not 25); another change in the veto of CO_2 Emissions in relation to B_2 (6 and not 5); a change of the veto threshold for the profile B_2, in the criterion Urbanization, from 1.2 to 1.4; two possible changes for the criterion Territory Desirability, in relation to both the profiles, from 9 to 10 and from 9 to 8. They are synthesized in table 2.17.

Table 2.17 Scales, thresholds and new reference actions

Criteria [used scales], thresholds v, q and p	**Profiles that separate the three categories**			
CO2 Emission [7-1], v_{B1}=5, v_{B2}=6	7	5	3	1
Urbanization [2-0,1],v_{B1}=1.2, v_{B2}=1.4, q=0.1,p= 0.2	2	1	0.4	0.1
Environ.aw. [14.9-54.2], v_{B1}=30, v_{B2}=25, q=0.5, p=2	14.9	35	45	54.2
Progress social life [0.38-0.519], q=0.01, p=0.02	0.38	0.42	0.47	0.519
Reaction time lim.[0.76-0.49],v=0.19, q=0.02, p=0.04	0.76	0.68	0.58	0.49
Territori.des. [1.39-19.29],v=8 (or 10), q=0.4, p=1.5	1.39	4	10	19.29

2.2.2 Changes in the profiles

The SW tool of LAMSADE ELECTRE Tri proposes a clear visualization of the categories and the profiles that separate the categories. Figure 2.21 allows us to see that the categories are almost equilibrated, but the profiles B_1 and B_2, in relation to the criteria Urbanization and Environmental Awareness, and also in relation to Territory desirability, could be re-analyzed, in order to verify their reliability. Analyzing the action performances, in relation to the criterion Territory Desirability, it is evident that the performance of the action San Quirico d'Orcia is much higher than the others. Its evaluation is 19.29 and the second best to this criterion is action Pienza, whose performance is 13.68 and B_1 is 10. If we temporary eliminate this action, a new visualization of the profile is proposed in figure 2.21. Now the Good category is not so wide, on the contrary the Intermediate category seems too wide and could be re-analyzed.

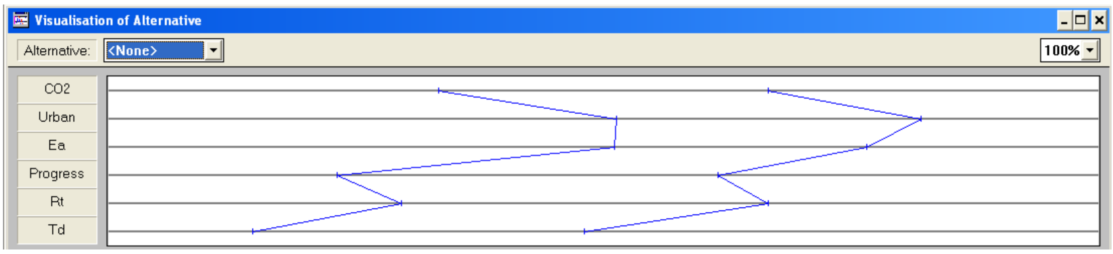


Figure 2.21: Visualization of the profile

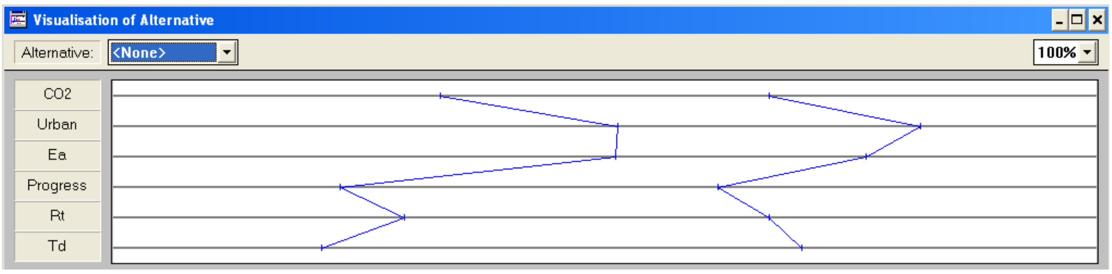


Figure 2.22: Visualization of the profile after eliminating action San Quirico d'Orica

In relation to the criterion Urbanization, two actions have very bad evaluations, Sarteano (2) and Pienza (1.8), when all the others are included in the interval 1-0.1. In relation to the criterion Environmental Awareness only two evaluations are less than 18 and all the others are between 23.5 and 54.2. Also in these cases a temporary elimination of the extreme evaluations allows a better visualization of the categories. The figure 2.23 proposes a visualization of the profiles after the temporary elimination of the extreme actions in the three criteria.

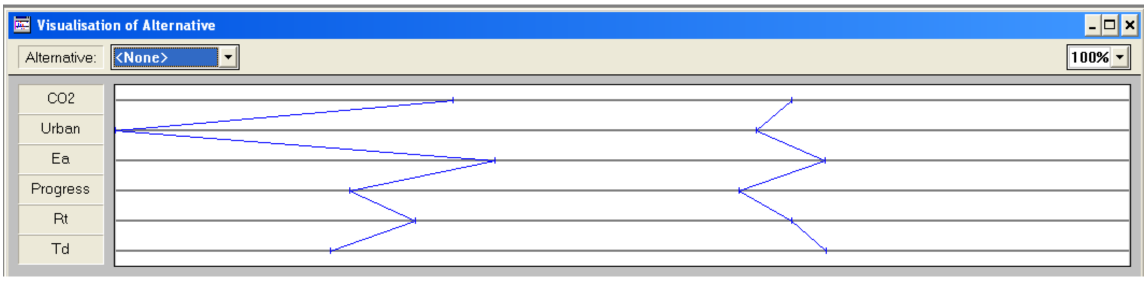


Figure 2.23: Visualization of the profile after eliminating extreme actions

Two are the proposals of change. The first is very limited and is only related to two criteria: for Urbanization, B_2 from 1 to 0.9; for Territorial Desirability, B_2 from 4 to 5 and B_1 from 10 to 9 (see table 2.18). The second is in relation to four criteria and it is proposed in table 2.19.
In the next chapter a new phase of ELECTRE Tri applications to the model, consistent with the suggested procedural sequence of activities, aims to produce definitive results and represent them in a clear and rich way.

Table 2.18: Scales, thresholds and new reference actions (the first change)

Criteria [used scales], thresholds v, q and p	**Profiles that separate the three categories**			
CO2 Emission [7-1], v=5	7	5	3	1
Urbanization [2-0,1],v=1.2, q=0.1,p= 0.2	2	0.9	0.4	0.1
Environment.aw. [14.9-54.2], v=25, q=0.5, p=2	14.9	35	45	54.2
Progress social life [0.38-0.519], q=0.01, p=0.02	0.38	0.42	0.47	0.519
Reaction lim.[0.76-0.49],v=0.19, q=0.02, p=0.04	0.76	0.68	0.58	0.49
Territorial des. [1.39 -19.29], v=9, q=0.4, p=1.5	1.39	5	9	19.29

Table 2.19: Scales, thresholds and new reference actions (the second change)

Criteria [used scales], thresholds v, q and p	**Profiles that separate the three categories**			
CO2 Emission [7-1], v= 5	7	5	3	1
Urbanization [2-0,1],v=1.2, q=0.1, p= 0.2	2	0.7	0.4	0.1
Environ.aw. [14.9-54.2], v=25, q=0.5, p=2	14.9	35	45	54.2
Progress social life [0.38-0.519], q=0.01, p=0.02	0.38	0.44	0.48	0.519
Reaction lim.[0.76-0.49],v=0.19, q=0.02, p=0.04	0.76	0.65	0.57	0.49
Territori.des. [1.39 -19.29], v=9, q=0.4, p=1.5	1.39	6	10	19.29

Chapter 3

Model improvement and result analysis

The several proposals of chapter 2 to modify the model have any effect in terms of model improving? Testing the nature of the changes by analyzing the result is the first aim of this chapter, which should be facilitated by means of a comparison of the model results with external judgements and the proposal of different scenarios in relation to possible decision policies.
Other important aim is a clear proposal on how can be presented a result in an understandable way, without the elimination of the uncertainties or strange elements that can make the result useful.

3.1 Changes in the veto thresholds

The proposal of few changes in the veto thresholds was formulated starting from the analysis of some "strange" results and it was evident that the results are not so sensitive to the changes. For this reason the proposal was calibrated in relation to the criteria CO2 emissions, Environmental Awareness, Urbanization and Territory Desirability. The results are synthesized for each change and then discussed.

New veto threshold in the criterion CO_2 Emission

A new veto threshold, 6, is proposed (see table 2.17) in relation to the profile B_2 in the criterion CO_2 Emission, while it remain the same, 5, in relation to B_1. The result is synthesized in table 3.1, without any difference with the result in table 2.2.

Table 3.1: Synthesis of the assignments (cutting level λ=0.65 and new veto threshold)

Categories	Pessimistic	Optimistic
Good	<u>CASTE, GAIOLE, RADDA, MONGG</u> (4/21)	<u>CASTE, GAIOLE, RADDA, MONGG</u>, SANQ, MONTE, CHIUS, (7/21)
Intermediate	(15/21)	(14/21)
Bad	SARTE, SANGI (2/21)	

New veto threshold in the criterion Urbanization

A new veto threshold, 1.4, is proposed (see table 2.17) in relation to the profile B_2 in the criterion Urbanization, while it remain the same, 1.2, in relation to B_1.The result is synthesized in table 3.2, where the result remains the same (compare with table 2.2), except for SARTE, which was a Bad action in the pessimistic procedure and now becomes an Intermediate action in the pessimistic procedure.

Table 3.2: Synthesis of the assignments (cutting level λ=0.65 and new veto threshold)

Categories	Pessimistic	Optimistic
Good	<u>CASTE, GAIOLE, RADDA, MONGG</u> (4/21)	<u>CASTE, GAIOLE, RADDA, MONGG</u>, SANQ, MONTE, CHIUS, (7/21)
Intermediate	(16/21)	(14/21)
Bad	SANGI (1/21)	

New veto threshold in the criterion Environmental Awareness

A new veto threshold, 30, is proposed (see table 2.17) in relation to the profile B_1 in the criterion Environmental Awareness, while it remain the same, 25, in relation to B_2.

The result is synthesized in table 3.3, without any difference with the result in table 2.2.

Table 3.3: Synthesis of the assignments (cutting level λ=0.65 and new veto threshold)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG (4/21)	CASTE, GAIOLE, RADDA, MONGG, SANQ, MONTE, CHIUS, (7/21)
Intermediate	(15/21)	(14/21)
Bad	SARTE, SANGI (2/21)	

New veto thresholds in the criterion Territory Desirability

Two veto thresholds are proposed (see table 2.17) and tested in the criterion Territory Desirability, one is 8 and another one is 10.

Result analysis with the new veto 8

The result is synthesized in table 3.4, without any difference with the result in table 2.2.

Table 3.4: Synthesis of the assignments (cutting level λ=0.65 and new veto threshold)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG (4/21)	CASTE, GAIOLE, RADDA, MONGG, SANQ, MONTE, CHIUS, (7/21)
Intermediate	(15/21)	(14/21)
Bad	SARTE, SANGI (2/21)	

Result analysis with the new veto 10

The result is synthesized in table 3.5, where SOVIC, which was an Intermediate-Intermediate action, becomes a Good-Good action (compare with table 2.2).

Table 3.5: Synthesis of the assignments (cutting level λ=0.65 and new veto threshold)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG, SOVIC (5/21)	CASTE, GAIOLE, RADDA, MONGG, SANQ, MONTE, SOVIC, CHIUS, (8/21)
Intermediate	(15/21)	(13/21)
Bad	SARTE, SANGI (2/21)	

There are only two changes in the results in relation to the original expression of veto thresholds. The only change that could improve the model is in relation to the criterion Territory Desirability and 10 as new value of the veto threshold, where SOVIC, which was an Intermediate-Intermediate action, becomes a Good-Good action. This could be an interesting improvement of the model. SOVIC resulted the only one Good-Good action in the scenario 2, with all the different cutting levels. In the other results it was always an Intermediate-Intermediate or Intermediate-Good action. The original penalization of the veto could be too heavy. The visualization of the action performance was proposed in figure 2.13.

3.2 Marginal changes in the profiles

There are two proposals of profile change in the last chapter. The first in relation to only two criteria is proposed in 2.18. The second, in relation to four criteria, is proposed in table 2.19. Here the results of the ELECTRE Tri application to the first profile change are synthesized in tables 3.6 and 3.7.

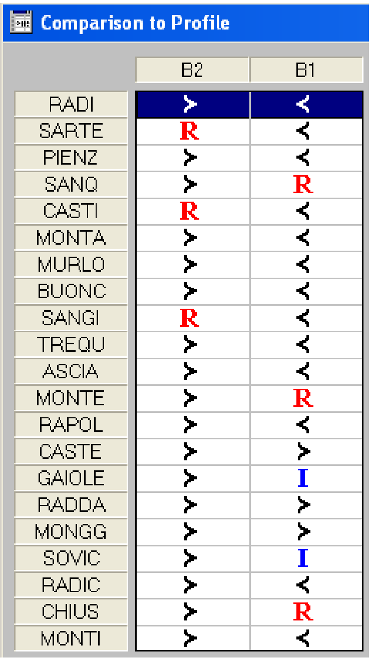
Table 3.6: Assignment by Alternative for λ=0.65 marginally new profile

Candidate action	Pessimistic	Optimistic
RADICOFANI (RADI)	Intermediate	Intermediate
SARTEANO (SARTE)	Bad	Intermediate
PIENZA (PIENZA)	Intermediate	Intermediate
SAN QUIRICO D'ORCIA (SANQ)	Intermediate	Good
CASTIGLION D'ORCIA (CASTI)	Bad	Intermediate
MONTALCINO (MONTA)	Intermediate	Intermediate
MURLO (MURLO)	Intermediate	Intermediate
BUONCONVENTO (BUONC)	Intermediate	Intermediate
SAN GIOVANNI D'ASSO (SANGI)	Bad	Intermediate
TREQUANDA (TREQU)	Intermediate	Intermediate
ASCIANO (ASCIA)	Intermediate	Intermediate
MONTERONI D'ARBIA (MONTE)	Intermediate	Good
RAPOLANO TERME (RAPOL)	Intermediate	Intermediate
CASTELNUOVO BERARDENGA (CASTE)	Good	Good
GAIOLE IN CHIANTI (GAIOLE)	Good	Good
RADDA IN CHIANTI (RADDA)	Good	Good
MONTERIGGIONI (MONGG)	Good	Good
SOVICILLE (SOVIC)	Good	Good
RADICONDOLI (RADIC)	Intermediate	Intermediate
CHIUSDINO (CHIUS)	Intermediate	Good
MONTICIANO (MONTI)	Intermediate	Intermediate

Table 3.7: Assignment by Alternative for cutting level λ=0.65 with marginally new profile

Categories	Pessimistic	Optimistic
Good	<u>CASTE, GAIOLE, RADDA, MONGG, SOVIC</u> (5/21)	SANQ, MONTE, <u>CASTE, GAIOLE, RADDA, MONGG, SOVIC</u>, CHIUS (8/21)
Intermediate	(13/21)	(13/21)
Bad	SARTE, CASTI, SANGI (3/21)	

With the new profiles the original 4 Good-Good actions become 5 (the new action is SOVIC) and the original 2 Bad-Intermediate actions now include also CASTI. If we look into the window Comparison to profile (Figure 3.1), we will find that there are 6 incomparable situations and 2 indifference situations. The two differences are CASTI, which was preferred to B_2 and now profile and action become incomparable, and SOVIC that was outranked by B_1 and now action and profile become indifferent. For these reasons CASTI is a Bad-Intermediate action and SOVIC becomes a Good-Good action. We can analysis these two actions by their visualizations in figures 3.2 and 3.3.



	B2	B1
RADI	>	<
SARTE	R	<
PIENZ	>	<
SANQ	>	R
CASTI	R	<
MONTA	>	<
MURLO	>	<
BUONC	>	<
SANGI	R	<
TREQU	>	<
ASCIA	>	<
MONTE	>	R
RAPOL	>	<
CASTE	>	>
GAIOLE	>	I
RADDA	>	>
MONGG	>	>
SOVIC	>	I
RADIC	>	<
CHIUS	>	R
MONTI	>	<

Figure 3.1: Comparison to Profile of new model with new profile

Castiglion d'Orcia and Soviclle

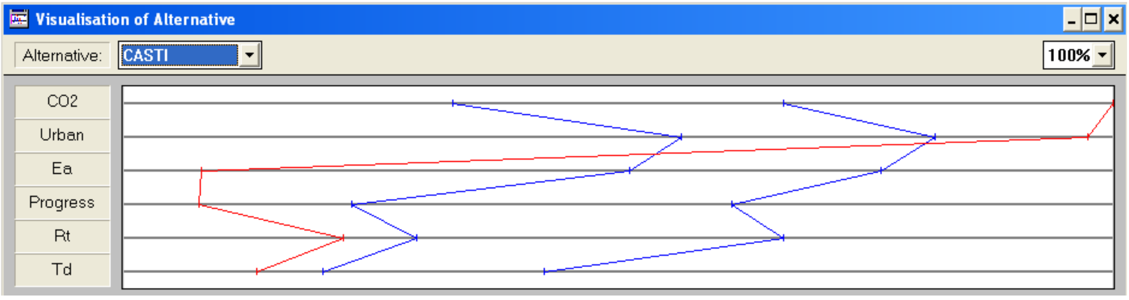


Figure 3.2: Visualization of Alternative – Castiglion d'Orcia (with the first new profile)

CASTI is better than B_1 in only two criteria and worse in the other four criteria. Therefore it does not outrank B_1 also if it has the highest performance in the criterion CO_2 Emission and a very high performance in the criterion Urbanization. Its performance in the criterion Territory Desirability is 3.8, which was indifferent to the B_2 profile, when it was 4 in the original profile. Not it becomes 5 in the new profile. So CASTI does not outrank B_2 and becomes Bad in the pessimistic procedure.

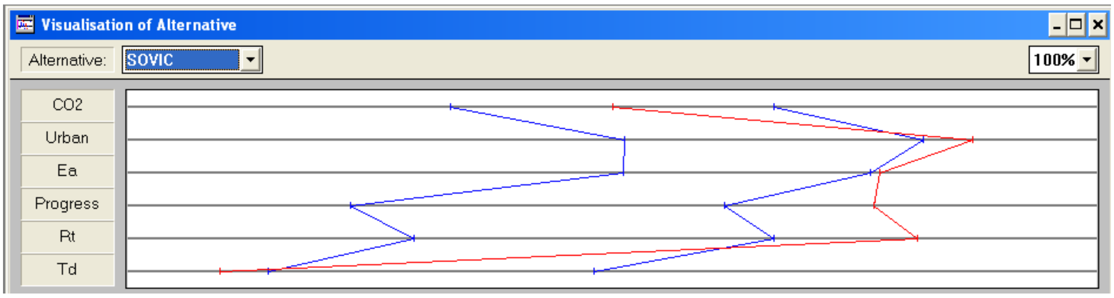


Figure 3.3: Visualization of Sovicille (with the first new profile)

SOVIC was Intermediate-Intermediate in the original model. Its performance in the criterion Territory Desirability is 3.11 and its distance from B_1, which was 10 in this criterion, activated a high discordance index. Now B_1 becomes 9, so the discordance index is reduced. Therefore, in the new profile, action SOVIC and B_1 result indifferent, and SOVIC is assigned to the Good-Good categories.

3.2.1 Changes to the profile and the veto thresholds

The result of ELECTRE Tri applied to the model with changes to profile and veto, using λ=0.65, does not change, in relation to the previous result of tables 3.6 and 3.7. It is synthesized in tables 3.8 and 3.9.

Table 3.8: Assignment by Alternative (λ=0.65 and new profile and veto)

Candidate action	Pessimistic	Optimistic
RADICOFANI (RADI)	Intermediate	Intermediate
SARTEANO (SARTE)	Bad	Intermediate
PIENZA (PIENZA)	Intermediate	Intermediate
SAN QUIRICO D'ORCIA (SANQ)	Intermediate	Good
CASTIGLION D'ORCIA (CASTI)	Bad	Intermediate
MONTALCINO (MONTA)	Intermediate	Intermediate
MURLO (MURLO)	Intermediate	Intermediate
BUONCONVENTO (BUONC)	Intermediate	Intermediate
SAN GIOVANNI D'ASSO (SANGI)	Bad	Intermediate
TREQUANDA (TREQU)	Intermediate	Intermediate
ASCIANO (ASCIA)	Intermediate	Intermediate
MONTERONI D'ARBIA (MONTE)	Intermediate	Good
RAPOLANO TERME (RAPOL)	Intermediate	Intermediate
CASTELNUOVO BERARDENGA (CASTE)	Good	Good
GAIOLE IN CHIANTI (GAIOLE)	Good	Good
RADDA IN CHIANTI (RADDA)	Good	Good
MONTERIGGIONI (MONGG)	Good	Good
SOVICILLE (SOVIC)	Good	Good
RADICONDOLI (RADIC)	Intermediate	Intermediate
CHIUSDINO (CHIUS)	Intermediate	Good
MONTICIANO (MONTI)	Intermediate	Intermediate

Table 3.9: Assignment by Alternative for λ=0.65 and new profile and veto

Categories	Pessimistic	Optimistic
Good	<u>CASTE, GAIOLE, RADDA, MONGG, SOVIC</u> (5/21)	SANQ, MONTE, <u>CASTE, GAIOLE, RADDA, MONGG, SOVIC</u>, CHIUS (8/21)
Intermediate	(13/21)	(13/21)
Bad	SARTE, CASTI, SANGI (3/21)	

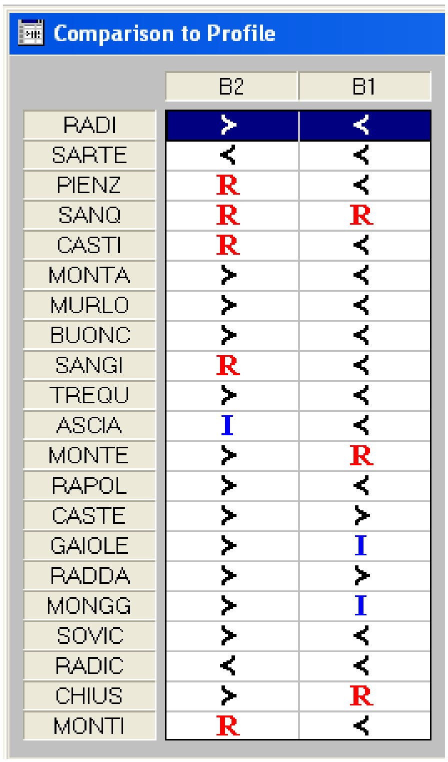
The new veto thresholds in the criteria CO_2 Emission, Environmental Awareness and Territory Desirability (8) do not cause any change in the result. The new veto threshold in the criterion Urbanization changes the assignment of SARTE, which becomes an Intermediate-Intermediate action. However, through the visualization of SARTE, it should be a Bad action, therefore this change is not a good proposal. The only interesting change is the new veto (10) in the criterion Territory Desirability because SOVIC, which was an Intermediate-Intermediate action, becomes a Good-Good action. If we apply the marginal changes of the profile, SOVIC becomes a Good-Good action and CASTI becomes a Bad-Intermediate action. And the result is the same if we introduce both the new veto and the new profile.

3.3 Second profile change

The results of the ELECTRE Tri application to the second and bigger profile change are synthesized in table 3.10 and figure 3.4.
There are four Good-Good actions (CASTE, GAIOLE, RADDA and MONGG, the same of the model with the original profiles), for the first time two Bad-Bad actions (SARTE and RADIC), four Bad-Intermediate actions (PIENZA, CASTI, SANGI and MONTI) and one Bad-Good action, SANQ. Eight incomparable situations and three indifferent situations are underlined in figure 3.4

Table 3.10: Assignment by Alternative (second change of the profiles and λ=0.65)

Candidate action	Pessimistic	Optimistic
RADICOFANI (RADI)	Intermediate	Intermediate
SARTEANO (SARTE)	Bad	Bad
PIENZA (PIENZA)	Bad	Intermediate
SAN QUIRICO D'ORCIA (SANQ)	Bad	Good
CASTIGLION D'ORCIA (CASTI)	Bad	Intermediate
MONTALCINO (MONTA)	Intermediate	Intermediate
MURLO (MURLO)	Intermediate	Intermediate
BUONCONVENTO (BUONC)	Intermediate	Intermediate
SAN GIOVANNI D'ASSO (SANGI)	Bad	Intermediate
TREQUANDA (TREQU)	Intermediate	Intermediate
ASCIANO (ASCIA)	Intermediate	Intermediate
MONTERONI D'ARBIA (MONTE)	Intermediate	Good
RAPOLANO TERME (RAPOL)	Intermediate	Intermediate
CASTELNUOVO BERARDENGA (CASTE)	Good	Good
GAIOLE IN CHIANTI (GAIOLE)	Good	Good
RADDA IN CHIANTI (RADDA)	Good	Good
MONTERIGGIONI (MONGG)	Good	Good
SOVICILLE (SOVIC)	Intermediate	Intermediate
RADICONDOLI (RADIC)	Bad	Bad
CHIUSDINO (CHIUS)	Intermediate	Good
MONTICIANO (MONTI)	Bad	Intermediate



Comparison to Profile

	B2	B1
RADI	>	<
SARTE	<	<
PIENZ	R	<
SANQ	R	R
CASTI	R	<
MONTA	>	<
MURLO	>	<
BUONC	>	<
SANGI	R	<
TREQU	>	<
ASCIA	I	<
MONTE	>	R
RAPOL	>	<
CASTE	>	>
GAIOLE	>	I
RADDA	>	>
MONGG	>	I
SOVIC	>	<
RADIC	<	<
CHIUS	>	R
MONTI	R	<

Figure 3.4: Comparison to Profile of new model with new profile

Sensitivity analysis (the cutting level)

The result is synthesized in table 3.11a. When λ=0.65, the stability interval is [0.5712036, 0.6599487]. When the cutting level is 0.66, U-laval shows the stability interval is [0.659939, 0.66006106], and the two SWs show different results (see table 3.11b and 3.11c) because they have different approximation rules. The result of U-laval includes only two Good-Good actions, RADDA and MONGG, and not 4; GAIOLE is assigned in Intermediate category in optimistic category while MONTA is assigned in Good category.

In order to homogenize the results of the two SWs we can use two different cutting levels, the first equal to 0.65995 and the second equal to 0.661. In relation to the first the result is identical to the result of table 3.11a, and the stability interval becomes [0.5712049, 0.66001105]. In relation to the second cutting level, equal to 0.661, the result presents two Good-Good actions (see table 3.11d) and a stability interval [0.6600513, 0.67006105].

The result of cutting level equal to 0.671 is synthesized in table 3.11e. The stability of this new interval, [0.6700513, 0.68006104], is small and a new application of the method with a cutting level equal to 0.681 produces result in table 3.11f. The stability interval of this last result is [0.68005127, 0.7719702].

When the cutting level becomes 0.661, MONTE becomes a Bad-Good action. When the cutting level becomes 0.671, there is not any action assigned to the Good category in pessimistic procedure. PIENZA, CASTI, BUONC, TREQU and MONTI become Bad-Good actions and then potentially risky actions. When the cutting level increases to 0.681, two more actions, MURLO and GAIOLE, become Intermediate-Good actions.

Table 3.11a: Synthesis of the assignments of 21 actions (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	<u>CASTE, GAIOLE, RADDA, MONGG</u> (4/21)	<u>CASTE, GAIOLE, RADDA, MONGG</u>, ***SANQ***, MONTE, CHIUS (7/21)
Intermediate	(10/21)	(12/21)
Bad	<u>SARTE</u>, PIENZA, ***SANQ***, CASTI, SANGI, <u>RADIC</u>, MONTI (7/21)	<u>SARTE, RADIC</u> (2/21)

Table 3.11b: Synthesis of the assignments of 21 actions (cutting level λ=0.66) LAMSADE

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG (4/21)	CASTE, GAIOLE, RADDA, MONGG, ***SANQ***, MONTE, CHIUS (7/21)
Intermediate	(10/21)	(12/21)
Bad	SARTE, PIENZA, ***SANQ***, CASTI, SANGI, RADIC, MONTI (7/21)	SARTE, RADIC (2/21)

Table 3.11c: Synthesis of the assignments of 21 actions (cutting level λ=0.66) U-laval

Categories	Pessimistic	Optimistic
Good	RADDA, MONGG (2/21)	CASTE, RADDA, MONGG, ***SANQ***, MONTA, MONTE, CHIUS (7/21)
Intermediate	(10/21)	(13/21)
Bad	SARTE, PIENZA, ***SANQ***, CASTI, BUONC, SANGI, MONTE, RADIC, MONTI (9/21)	SARTE (1/21)

Table 3.11d: Synthesis of the assignments of 21 actions (cutting level λ=0.661)

Categories	Pessimistic	Optimistic
Good	RADDA, MONGG (2/21)	***SANQ***, MONTA, ***MONTE***, CASTE, RADDA, MONGG, CHIUS (7/21)
Intermediate	(10/21)	(13/21)
Bad	SARTE, PIENZA, ***SANQ***, CASTI, BUONC, SANGI, ***MONTE***, RADIC, MONTI (9/21)	SARTE (1/21)

Table 3.11e: Synthesis of the assignments of 21 actions (cutting level λ=0.671)

Categories	Pessimistic	Optimistic
Good		***PIENZA, SANQ, CASTI***, MONTA, ***BUONC, TREQU, MONTE***, CASTE, RADDA, MONGG, CHIUS, ***MONTI*** (12/21)
Intermediate	(11/21)	(9/21)
Bad	SARTE, ***PIENZA, SANQ, CASTI, BUONC***, SANGI, ***TREQU, MONTE***, RADIC, ***MONTI*** (10/21)	

Table 3.11f: Synthesis of the assignments of 21 actions (cutting level λ=0.681)

Categories	Pessimistic	Optimistic
Good		***PIENZA, SANQ, CASTI***, MONTA, MURLO, ***BUONC, TREQU, MONTE***, CASTE, GAIOLE, RADDA, MONGG, CHIUS, ***MONTI*** (14/21)
Intermediate	(11/21)	(7/21)
Bad	SARTE, ***PIENZA, SANQ, CASTI, BUONC***, SANGI, ***TREQU, MONTE***, RADIC, ***MONTI*** (10/21)	

In table 3.12, we can see that with the cutting level increases, the number of the incomparability situations is increased and the number of the indifference situations is decreased.

Table 3.12: Number of situations in all cutting level

	0.65	0.661	0.671	0.681
Incomparable	8	13	22	24
Indifferent	2			

Sensitivity analysis (three extreme scenarios of weights)

The stability interval of the result (table 3.13a) in the first scenario is [0.63001096, 0.650061]. There are 6 Bad-Good actions, PIENZA, SANQ, CASTI, BUONC, MONTE and MONTI.

The stability interval of the result (table 3.13b) in the second scenario is [0.63001096, 0.66922605]. SOVIC is the only one Good-Good action. No risky action or Bad-Bad action.

The stability interval of the result (table 3.13c) in the third scenario is [0.63001096, 0.66922605]. RADDA is the only one Good-Good action. There are 2 Bad-Good actions, PIENZA and MONTE, and 2 Bad-Bad actions, SARTE and RADIC.

Table 3.13a: Scenario 1, synthesis of the assignments of 21 actions (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	<u>CASTE, GAIOLE, RADDA, MONGG</u> (4/21)	***PIENZA, SANQ, CASTI***, MONTA, MURLO, ***BUONC,*** TREQU, ***MONTE***, <u>CASTE, GAIOLE, RADDA, MONGG</u>, CHIUS, ***MONTI*** (14/21)
Intermediate	(8/21)	(7/21)
Bad	SARTE, ***SANQ, PIENZA, CASTI, BUONC***, SANGI, ***MONTE***, RADIC, ***MONTI*** (9/21)	

Table 3.13b: Scenario 2, synthesis of the assignments of 21 actions (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	<u>SOVIC</u> (1/21)	SANQ, MONTA, MURLO, BUONC, MONTE, CASTE, GAIOLE, RADDA, MONGG, <u>SOVIC</u>, CHIUS (11/21)
Intermediate	(13/21)	(10/21)
Bad	SARTE, PIENZA, CASTI, SANGI, TREQU, RADIC, MONTI (7/21)	

Table 3.13c: Scenario 3, synthesis of the assignments of 21 actions (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	<u>RADDA</u> (1/21)	***PIENZA***, SANQ, ***MONTE***, CASTE, <u>RADDA</u>, CHIUS (6/21)
Intermediate	(12/21)	(13/21)
Bad	<u>SARTE</u>, ***PIENZA***, CASTI, BUONC, SANGI, ***MONTE***, <u>RADIC</u>, MONTI (8/21)	<u>SARTE, RADIC</u> (2/21)

3.3.1 Results in relation to the policy scenarios

Since the case is without a decision maker, the model is analyzed in relation to two different scenarios that are defined in relation to possible policies of the decision system. The first policy, *Improving resilience by educating people***,** assumes that Awareness is the most important dimension because it could be improved by education (40% of the total weight) and each criterion of this dimension (Environmental Awareness and Progress in Social Life) has the same importance (0.20). Reaction Capability can be poorly improved by education (its importance is equal to 25%) and the relative importance of the criterion Reaction Time can be 0.12 and of the criterion Territory Desirability 0.13. Risky behavior may be only partially improved by education (its importance is equal to 35%), then the relative importance of the criterion CO_2 Emission becomes 0.17 and of Urbanization 0.18.
The second policy, *Improving resilience by training on how to react in case of disaster (Civil protection),* assumes that Reaction capability is the most important dimension (40% of the total weight) because training can improve Reaction Time (0.20) and the reaction capability when the Territory Desirability is high (0.20). Risky behavior (30% of the total weight) and Awareness (30% of the total weight) are less important in this scenario. Therefore, the relative importance of the criteria CO_2 Emission, Urbanization, Environmental Awareness and Progress in Social Life is always the same (0.15).

Result analysis in Policy 1
The ELECTRE Tri result in relation to the model with the second new profiles and the first policy and its weights is synthesized in table 3.14. There are 4 Good-Good actions, CASTE, GAIOLE, MONGG and SOVIC, and no one Bad-Bad action. There is only one risky action, SANQ, a Bad-Good action. The stability interval is [0.63001096, 0.650061].

Table 3.14: Policy 1, synthesis of the assignments of 21 actions (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, MONGG, SOVIC (4/21)	***SANQ***, MONTA, MURLO, BUONC, MONTE, CASTE, GAIOLE, RADDA, MONGG, SOVIC, CHIUS (11/21)
Intermediate	(9/21)	(10/21)
Bad	SARTE, PIENZA, ***SANQ***, CASTI, SANGI, TREQU, RADIC, MONTI (8/21)	

Sensitivity analysis in Policy 1
Since I have not done any sensitivity analysis in policy 1 and 2, therefore it is necessary to do it with the second new profile. The result of λ=0.65 is already synthesized in table 3.14, and the stability interval is [0.63001096, 0.650061]. When cutting level decreases to 0.629 (see table 3.15a). MURLO and BUONC become an Intermediate-Intermediate action. There occurs a Bad-Bad action, SARTE. The stability interval is [0.62002784, 0.6299766]. When cutting level decreases to 0.619 (see table 3.15b), the stability interval is [0.6000181, 0.6199766]. RADIC becomes a Bad-Bad action and MONTE becomes an Intermediate-Intermediate action. When cutting level increases to 0.651 (see table 3.15c), the stability interval is [0.65002346, 0.65643215]. Compare it with table 3.15a, there are 3 more Bad-Good actions, which are CASTI, TREQU and MONTI. When cutting level increases to 0.657 (see table 3.15d), the stability interval is [0.6564502, 0.67006105]. SOVIC becomes an Intermediate-Intermediate action from a Good-Good action. When cutting level increases to 0.671 (see table 3.15e), the stability interval is [0.670011, 0.69006103]. There is no action assigned in good category in pessimistic procedure. When cutting level increases to 0.691

(see table 3.15f), the stability interval is [0.69005126, 0.700061]. There are 6 Bad-Good actions, which are SANQ, CASTI, BUONC, TREQU, MONTE and MONTI.

Table 3.15a: Policy 1, synthesis of the assignments of 21 actions (cutting level λ=0.629)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, MONGG, SOVIC (4/21)	***SANQ***, MONTA, MONTE, CASTE, GAIOLE, RADDA, MONGG, SOVIC, CHIUS (9/21)
Intermediate	(9/21)	(11/21)
Bad	SARTE, PIENZA, ***SANQ***, CASTI, SANGI, TREQU, RADIC, MONTI (8/21)	SARTE (1/21)

Table 3.15b: Policy 1, synthesis of the assignments of 21 actions (cutting level λ=0.619)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, MONGG, SOVIC (4/21)	***SANQ***, MONTE, CASTE, GAIOLE, RADDA, MONGG, SOVIC, CHIUS (8/21)
Intermediate	(9/21)	(11/21)
Bad	SARTE, PIENZA, ***SANQ***, CASTI, SANGI, TREQU, RADIC, MONTI (8/21)	SARTE, RADIC (2/21)

Table 3.15c: Policy 1, synthesis of the assignments of 21 actions (cutting level λ=0.651)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, MONGG, SOVIC (4/21)	***SANQ, CASTI***, MONTA, MURLO, BUONC, ***TREQU***, MONTE, CASTE, GAIOLE, RADDA, MONGG, SOVIC, CHIUS, ***MONTI*** (14/21)
Intermediate	(9/21)	(7/21)
Bad	SARTE, PIENZA, ***SANQ, CASTI***, SANGI, ***TREQU***, RADIC, ***MONTI*** (8/21)	

Table 3.15d: Policy 1, synthesis of the assignments of 21 actions (cutting level λ=0.657)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, MONGG (3/21)	***SANQ, CASTI***, MONTA, MURLO, BUONC, ***TREQU***, MONTE, CASTE, GAIOLE, RADDA, MONGG, CHIUS, ***MONTI*** (13/21)
Intermediate	(10/21)	(8/21)
Bad	SARTE, PIENZA, ***SANQ, CASTI***, SANGI, ***TREQU***, RADIC, ***MONTI*** (8/21)	

Table 3.15e: Policy 1, synthesis of the assignments of 21 actions (cutting level λ=0.671)

Categories	Pessimistic	Optimistic
Good		***SANQ, CASTI***, MONTA, MURLO, BUONC, ***TREQU***, MONTE, CASTE, GAIOLE, RADDA, MONGG, CHIUS, ***MONTI*** (13/21)
Intermediate	(13/21)	(8/21)
Bad	SARTE, PIENZA, ***SANQ, CASTI***, SANGI, ***TREQU***, RADIC, ***MONTI*** (8/21)	

Table 3.15f: Policy 1, synthesis of the assignments of 21 actions (cutting level λ=0.691)

Categories	Pessimistic	Optimistic
Good		***SANQ, CASTI***, MONTA, MURLO, ***BUONC, TREQU, MONTE***, CASTE, GAIOLE, RADDA, MONGG, CHIUS, ***MONTI*** (13/21)
Intermediate	(11/21)	(8/21)
Bad	SARTE, PIENZA, ***SANQ, CASTI, BUONC***, SANGI, ***TREQU, MONTE***, RADIC, ***MONTI*** (10/21)	

Policy 1 is a very sensitive scenario. Above all the situations in Policy 1, SARTE and RADIC have been assigned in Bad-Bad category; CASTE, GAIOLE, MONGG and SOVIC have been assigned in Good-Good category. SOVIC is the only one action has a worse assignment with the cutting level increases in optimistic procedure. SANQ is always a Bad-Good action, except SANQ, action CASTI, TREQU and MONTI are the most frequent being assigned in Bad-Good category. MONTI becomes a Bad-Good action only when cutting level is larger than 0.69.

Result analysis in Policy 2

The ELECTRE Tri result in relation to the model with the second new profiles and the second policy and its weights is synthesized in table 3.16. There are 4 Good-Good actions, CASTE, GAIOLE, MONGG and SOVIC; and two Bad-Bad actions, SARTE and RADIC. There is only one risky action, SANQ, a Bad-Good action. The stability interval is [0.566687, 0.650061].

Table 3.16: Policy 2, synthesis of the assignments of 21 actions (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG (4/21)	***SANQ***, MONTE, CASTE, GAIOLE, RADDA, MONGG, CHIUS (7/21)
Intermediate	(10/21)	(12/21)
Bad	SARTE, PIENZA, ***SANQ***, CASTI, SANGI, RADIC, MONTI (7/21)	SARTE, RADIC (2/21)

Sensitivity analysis in Policy 2

The result of λ=0.65 is already synthesized in table 3.16, and the stability interval is [0.566687, 0.650061]. When cutting level increases to 0.651, the stability interval is [0.65002346, 0.700061] (see table 3.17). RADDA becomes the only one Good-Good action. There are 3 Bad-Good actions, which are PIENZA, SANQ, and MONTE.

Table 3.17: Policy 2, synthesis of the assignments of 21 actions (cutting level λ=0.651)

Categories	Pessimistic	Optimistic
Good	RADDA (1/21)	***PIENZA, SANQ, MONTE***, CASTE, RADDA, CHIUS (6/21)
Intermediate	(11/21)	(13/21)
Bad	SARTE, ***PIENZA, SANQ***, CASTI, BUONC, SANGI, ***MONTE***, RADIC, MONTI (9/21)	SARTE, RADIC (2/21)

In general, above all the situations with the second new profile and λ=0.65, SANQ is always a Bad-Good action except in scenario 2 and 3. SARTE and RADIC are Bad-Bad actions. CASTE, GAIOLE, RADDA and MONGG are the four actions that most frequently result Good-Good actions, while SOVIC is a Good-Good action only two times, but in one of these times it is the only Good-Good action. PIENZA is always evaluated as a Bad action in the pessimistic procedure.

TREQU, BUONC and MONTE are evaluated as a Bad action in pessimistic procedure frequently. These four actions were never been assigned in a Bad category in pessimistic procedure in the model with the original profiles and now they become risky actions, Bad-Good actions, several times. As a conclusion, the new profiles increase the number of actions oriented to the Bad category.

3.4 Analysis of the last results and their visualization

The second new profiles were analyzed by means of sensitivity and scenario analyses. Their results can be visualized in the table 3.18.

Table 3.18: Times of actions are assigned into classes

Classes Actions	Good - Good	Intermediate -Good	Intermediate - Intermediate	Bad - Good	Bad - Intermediate	Bad - Bad
RADICOFANI (RADI)			16			
SARTEANO (SARTE)					9♥ $\downarrow_2 \circ^{1,2} \wedge_4$	7♠♣♦ $\downarrow_2 \circ^{3} \wedge_2$
PIENZA (PIENZ)				5♦ $\downarrow_2 \circ^{1,3}$	11♠♥♣ $\downarrow_1 \circ^{2} \wedge_6$	
SAN QUIRICO D'ORCIA (SANQ)		2 $\circ^{2,3}$		14♠♥♣♦ $\downarrow_3 \circ^{1} \wedge_6$		
CASTIGLION D'ORCIA (CASTI)				7 $\downarrow_2 \circ^{1} \wedge_4$	9♠♥♣♦ $\downarrow_1 \circ^{2,3} \wedge_2$	
MANTALCINO (MONTA)		11♥ $\downarrow_3 \circ^{1,2} \wedge_5$	5♠♣♦ $\circ^{3} \wedge_1$			
MURLO (MURLO)		8♥ $\downarrow_1 \circ^{1,2} \wedge_4$	8♠♣♦ $\downarrow_2 \circ^{3} \wedge_2$			
BUONCONVENTO (BUONC)		5♥ $\circ^{2} \wedge_3$	4♠♣ $\wedge_2$	4 $\downarrow_2 \circ^{1} \wedge_1$	3♦ $\downarrow_1 \circ^{3}$	
SAN GIOVANNI D'ASSO (SANGI)					16	
TREQUANDA (TREQU)		1 $\circ^{1}$	5♠♣♦ $\downarrow_1 \circ^{3}$	6 $\downarrow_2 \wedge_4$	4♥ $\circ^{2} \wedge_2$	
ASCIANO (ASCIA)			16			
MONTERONI D'ARBIA (MONTE)		9♠♥♣ $\downarrow_1 \wedge_5$		7♦ $\downarrow_2 \circ^{1,2,3} \wedge_1$		
RAPOLANO TERME (RAPOL)			16			
CASTELNUOVO BERRARDENGA (CASTE)	8♠♥♣ $\circ^{1} \wedge_4$	8♦ $\downarrow_3 \circ^{2,3} \wedge_2$				
GAIOLE IN CHIANTI (GAIOLE)	8♠♥♣ $\circ^{1} \wedge_4$	4 $\downarrow_1 \circ^{2} \wedge_2$	4♦ $\downarrow_2 \circ^{3}$			
RADDA IN CHIANTI (RADDA)	6♠♣♦ $\downarrow_1 \circ^{1,3}$	10♥ $\downarrow_2 \circ^{2} \wedge_6$				
MONTERIGGIONI (MONGG)	9♠♥♣ $\downarrow_1 \circ^{1} \wedge_4$	5 $\downarrow_2 \circ^{2} \wedge_2$	2♦ $\circ^{3}$			
SOVICILLE (SOVIC)	5♥ $\circ^{2} \wedge_3$		11♠♣♦ $\downarrow_3 \circ^{1,3} \wedge_3$			
RADICONDOLI (RADIC)					11♥ $\downarrow_3 \circ^{1,2} \wedge_5$	5♠♣♦ $\circ^{3} \wedge_1$
CHIUSDINO (CHIUS)		16				
MONTICIANO (MONTI)				7 $\downarrow_2 \circ^{1} \wedge_4$	9♠♥♣♦ $\downarrow_1 \circ^{2,3} \wedge_2$	

The table synthesizes the results of the seventeen tests of sections 3.3.
The first three labels indicate specific situations, all with λ=0.65:
Stronger changes of profile (new profile) - ♠ (1 time);
Policy 1 (new profile) - ♥ (1 time);
Policy 2 (new profile) - ♣ (1 time).
Other four labels distinguish the other four cases:
New profile, Sensitive analysis of lambda, with the original weights - ↓ (3 times);
New profile, Sensitive analysis, in relation to 3 extreme scenarios of weight - ° (3 times);
Policy 1 (new profile), sensitive analysis (lambda) of policy 1: ^ (6 times),
Policy 2 (new profile), sensitive analysis (lambda) of policy 2: ♦ (1 time)
The number after symbol ° indicates in which scenario it is assigned in the category, for example: $^{\circ 1,2}$ means it is assigned in this category in scenario 1 and 2;
The number after symbol ↓ and ^ means it is assigned in this category how many times, for example: $\hat{}_4$ means it is assigned in this category 4 times in sensitive analysis (lambda) of policy 1.

In the table we can see five actions that are always assigned to the same categories (CHIUS as an Intermediate-Good action; RADI, ASCIA and RAPOL always as Intermediate-Intermediate actions; SANGI always as a Bad- Intermediate action).
For all the other actions the results change, in relation to the nature of the tests. Sometimes the actions are assigned to several and different categories (above all BUONC and TREQU that present extreme assignments) and these two actions plus other five (PIENZA, SANQ, CASTI, MONTE and MONTI) in some cases are Bad-Good actions.
Four actions (CASTE, GAIOLE, RADDA, and MONGG) are clearly oriented to the Good category. Other actions (SOVIC, MONTA and MURLO) are also oriented to the Good category, but almost only in relation to one of the policy scenarios. CHIUS is always an Intermediate-Good action.
Only three actions are clearly oriented to the Bad category. They are SARTE, RADIC and SANGI.
Three actions are evidently Intermediate (RADI, ASCIA and RAPOL). The seven “variable” situations (TREQU, SANQ, MONTE, BUONC, PIENZA, CASTI and MONTI), three of them are oriented to the Bad category: PIENZA, CASTI and MONTI. TREQU and BUONC are assigned to almost every category. TREQU is weakly oriented to the Bad category; SANQ and MONTE are weakly oriented to the Good category. BUONC is an Intermediate action that is oriented to the Good category, in relation to one policy scenario, and to the Bad in relation to the other policy scenario.

3.5 Comparisons with the ELECTRE III results

In the results of ELECTRE III, RADDA, GAIOLE, MONGG and CASTE are in the best positions, also in the different scenarios of weights, and this performance is consistent with the ELECTRE Tri indication that these actions are clearly oriented to the Good category.
In ELECTRE III other four actions, CHIUS, BUONC, PIENZA and SOVIC, are in the first positions, near or immediately after the firsts, in at least 3 of the 4 scenarios. This indication is consistent with the ELECTRE Tri results for SOVIC and CHIUS, while PIENZA seems a risky action, more oriented to the Bad than to the Good category, and BUONC is an Intermediate action that is oriented to the Good category, in relation to one policy scenario, and to the Bad in relation to the other policy scenario.

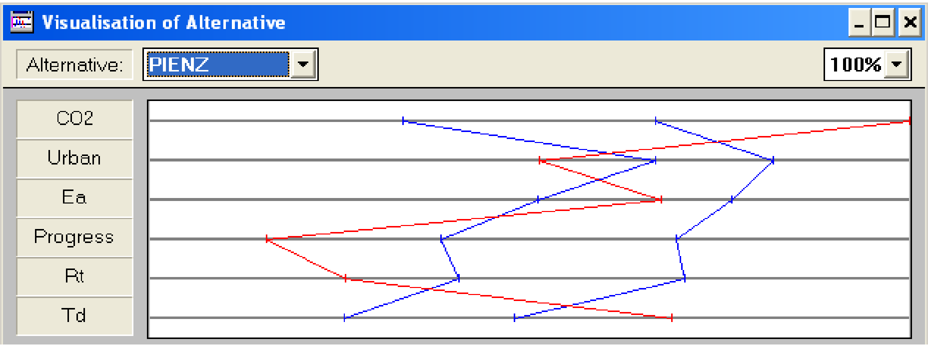


Figure 3.5: Visualization of Alternative – Pienza (with the second new profile)

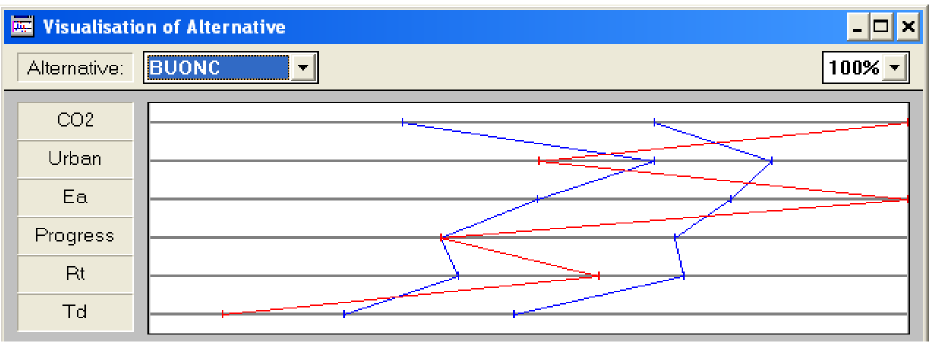


Figure 3.6: Visualization of Alternative – Buonconvento (with the second new profile)

In ELECTRE Tri also MONTA and MURLO are oriented to the Good category, but with a less evident attitude, because almost only in relation to one of the policy scenarios. In ELECTRE III they are immediately after the best positions in the main result and in some scenarios of weights. Therefore, there is a clear consistency of the results.

In ELECTRE III three actions are always in the worst positions, SARTE, RADIC and. CASTI. Other three actions are near to the lasts and they are SANGI, RADI and ASCIA. In ELECTRE Tri only three actions are clearly oriented to the Bad category. They are SARTE, RADIC and SANGI. Three risky actions are oriented to the Bad category: PIENZA, CASTI and MONTI.

Therefore, there is a consistent result for four actions SARTE, RADIC, SANGI and. CASTI. A different indication for RADI and ASCIA, which are evidently intermediate in ELECTRE Tri and near to the worst positions in ELECTRE III, and for PIENZA and MONTI, which seem risky actions in ELECTRE Tri, weakly oriented to the Bad category.

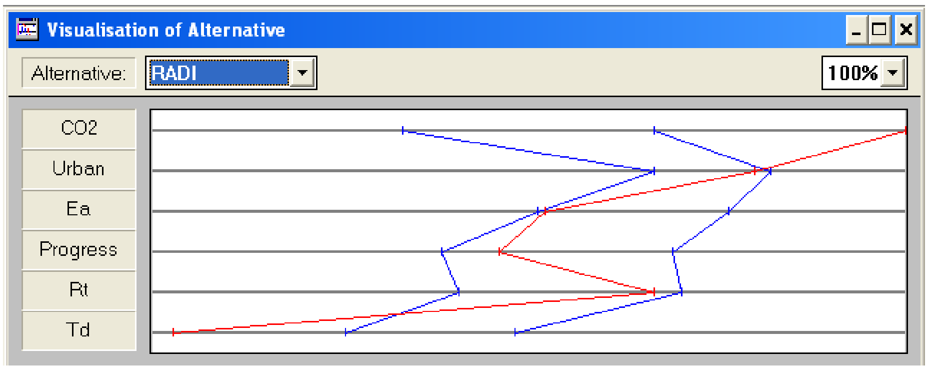


Figure 3.7: Visualization of Alternative – Radicofani (with the second new profile)

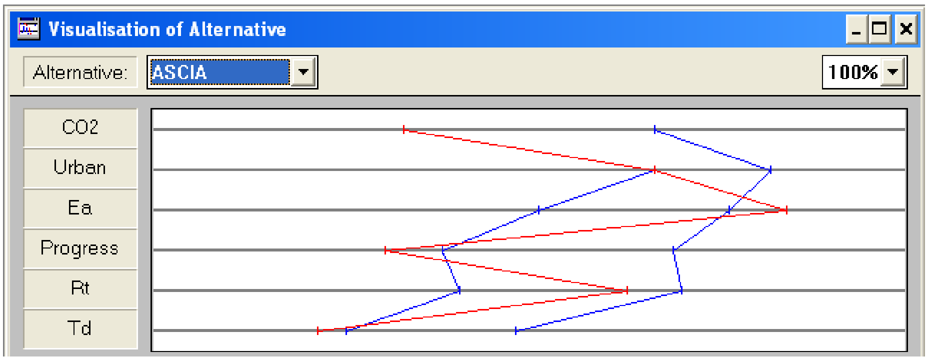


Figure 3.8: Visualization of Alternative – Asciano (with the second new profile)

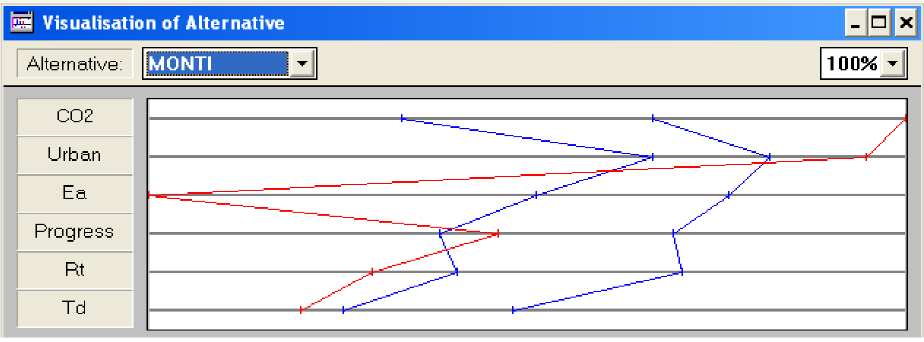


Figure 3.9: Visualization of Alternative – Monticiano (with the second new profile)

The other four actions are in the intermediate part of the rankings: RAPOL both in ELECTRE III and Tri, SANQ and MONTE, weakly oriented to the Good category in ELECTRE Tri and to the first positions in ELECTRE III, TREQU clearly variable in the results of both the methods.
In six cases the results of the two methods are not consistent. The actions are PIENZA, BUONC, RADI, ASCIA and MONTI. The action performances of figures 3.5, 3.6, 3.7, 3.8 and 3.9 underline that the comparative analysis of ELECTRE III in these cases produces results less convincing than in the sorting method.

3.6 Results and robustness analysis of the last model variant

In this chapter, the second new profile and the new veto threshold (10) in the criterion Territory Desirability are used to generate the last variant of the model (see table 3.19).

Table 3.19 Scales, thresholds and new reference actions (last variant)

Criteria [used scales], thresholds v, q and p		**Profiles that separate the three categories**		
CO2 Emission [7-1], w=0.16, v=5	7	5	3	1
Urbanization [2-0,1], w=0.17, v=1.2, q=0.1, p= 0.2	2	0.7	0.4	0.1
Environ.aw. [14.9-54.2], w=0.17, v=25, q=0.5, p=2	14.9	35	45	54.2
Progress social life [0.38-0.519], w=0.16, q=0.01, p=0.02	0.38	0.44	0.48	0.519
Reaction time lim.[0.76-0.49],w=0.17, v=0.19, q=0.02, p=0.04	0.76	0.65	0.57	0.49
Territorial des. [1.39-19.29], w=0.17, v= 10, q=0.4, p=1.5	1.39	6	10	19.29

The result of the ELECTRE Tri application to the model is synthesized in table 3.20, the result in relation to the Policy 1 and the Policy 2 scenarios are in tables 3.21 and 3.22.
If we compare these results with the others in the section 3.3, the only different action is SOVIC, which becomes Good-Good with the original weight and in the policy 2 scenario. The result is consistent with the aim of applying the new veto 10 in the criterion Territory Desirability.

Table 3.20: Assignments of the 21 actions in the last model (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG, SOVIC (5/21)	***SANQ***, MONTE, CASTE, GAIOLE, RADDA, MONGG, SOVIC, CHIUS (8/21)
Intermediate	(9/21)	(11/21)
Bad	SARTE, PIENZA, ***SANQ***, CASTI, SANGI, RADIC, MONTI (7/21)	SARTE, RADIC (2/21)

Table 3.21: Policy 1 scenario, synthesis of the assignments (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, MONGG, SOVIC (4/21)	***SANQ***, MONTA, MURLO, BUONC, MONTE, CASTE, GAIOLE, RADDA, MONGG, SOVIC, CHIUS (11/21)
Intermediate	(9/21)	(10/21)
Bad	SARTE, PIENZA, ***SANQ***, CASTI, SANGI, TREQU, RADIC, MONTI (8/21)	

Table 3.22: Policy 2 scenario, synthesis of the assignments (cutting level λ=0.65)

Categories	Pessimistic	Optimistic
Good	CASTE, GAIOLE, RADDA, MONGG, SOVIC (5/21)	***SANQ***, MONTE, CASTE, GAIOLE, RADDA, MONGG, SOVIC, CHIUS (8/21)
Intermediate	(9/21)	(11/21)
Bad	SARTE, PIENZA, ***SANQ***, CASTI, SANGI, RADIC, MONTI (7/21)	SARTE, RADIC (2/21)

3.6.1 Robustness analysis

A robustness analysis is developed in relation to the results of the ELECTRE Tri applications to the model that is showed in table 3.19, with the original weights and then in relation to the weights of the policy 1 and policy 2 scenarios. For every result the ULaval SW tool proposes an interval of robustness in relation to the weights, the veto thresholds and the cutting level (starting from the intermediate value λ=0.65).

Result with the original weights
The original weights are indicated in table 3.19. The stability intervals of the result in relation to the weight of each criterion are: CO_2 Emission [0.1314, 0.1908]; Urbanization [0.1414, 0.1854]; Environmental Awareness [0.1414, 0.1854]; Progress in Social Life [0.1314, 0.1908]; Reaction Time [0.1414, 0.4450]; Territory Desirability [0.1414, 0.1854].
The stability intervals of the result in relation to the veto threshold of each criterion are: CO_2 Emission [3, 6]; Urbanization [0.78, 1.24]; Environmental Awareness [15.98, +∞]; Reaction Time [0.04, +∞]; Territory Desirability [9.43, 10.98].
The stability interval of the result in relation to the cutting level is [0.51004636, 0.6599487].

Policy scenarios
The first policy is *Improving resilience by educating people***,** therefore the importance of Awareness, improved by education, is 0.4, higher than the other main aspects. *Reaction capability* can be poorly improved (0.25) and *Risky behavior* may be improved (0.35). Therefore the weights that are

associated to the criteria are: CO_2 Emissions (0.17), Urbanization (0.18), Environmental Awareness (0.20), Progress in Social Life (0.20), Reaction Time (0.12), and Territory Desirability (0.13).
The second policy is *Improving resilience by training on how to react in case of disaster* (one of the aims of Civil protection). Therefore the most important aspect is *Reaction capability* (0.40), while *Risky behavior* (0.30) and *Awareness* (0.30) are less important. The weights that are associated to the criteria are: CO_2 Emissions (0.15), Urbanization (0.15), Environmental Awareness (0.15), Progress in Social Life (0.15), Reaction Time (0. 2), Territory Desirability (0.2).

Policy 1
The stability intervals of the result in relation to the weight of each criterion are: CO_2 Emission: [0.1392, 0.1701]; Urbanization: [0.1339, 0.1800]; Environmental Awareness: [0.1999, 0.2308]; Progress in Social Life: [0.1999, 0.2308]; Reaction Time: [0.1199, 0.1771]; Territory Desirability: [0.1299, 0.1608].
The stability intervals of the result in relation to the veto threshold of each criterion are: CO_2 Emission: [4, 6]; Urbanization: [0.36, 1.25]; Environmental Awareness: [14.95, 28.81]; Reaction Time: [0.04, $+\infty$]; Territory Desirability: [8.98, 10.62].
The stability interval of the result in relation to the cutting level is [0.63001096, 0.650061].

Policy 2
The stability intervals of the result in relation to the weight of each criterion are: CO_2 Emission: [0.1499, 0.1501]; Urbanization: [0.1499, 0.1501]; Environmental Awareness: [0.1499, 0.1501]; Progress in Social Life: [0.1499, 0.1501]; Reaction Time: [0.1999, 0.3250]; Territory Desirability: [0.0577, 0.2000].
The stability intervals of the result in relation to the veto threshold of each criterion are: CO_2 Emission: [4, 6]; Urbanization: [0.73, 1.22]; Environmental Awareness: [15.54, $+\infty$]; Reaction Time: [0.04, $+\infty$]; Territory Desirability: [9.79, 11.30].
The stability interval of the result in relation to the cutting level is [0.566687, 0.650061].

Conclusions of the stability analysis and proposals of new activities
The model result, in relation to the original weights, is almost robust. The robustness is less evident in relation to the policy 1 scenario and absent in relation to the policy 2.
The model results, in relation to the veto thresholds, are always almost robust, with the exception of the criterion Urbanization (a new veto could underline the Bad nature of SARTE) and of Territory Desirability. In this case, the behavior of the result has been analyzed and the veto has been changed, specifically in relation to the impact of the veto in relation to SANQ. Therefore it is clear how the result can change in relation to the parameter.
In relation to the cutting level, the results are not robust and this behavior has been identified and analyzed in the sections 3.3. For this reason table 3.18 has been introduced and used to analyze how the results can change. Here we should activate a similar analysis, to synthesize the results of small changes of some parameters and to identify a robust solution, if it exists. In the table 3.23 a synthesis of the stability analysis and its results underlines the values that indicate a not so robust result.

Table 3.23: Results synthesis of robustness analysis

		Original weight	Policy 1	Policy 2
CO_2 Emissions	Weight	[0.1314, 0.1908]	[0.1392, **0.1701**]	[**0.1499, 0.1501**]
	v=5	[3, 6]	[4, 6]	[4, 6]
Urbanization	Weight	[0.1414, 0.1854]	[0.1339, **0.1800**]	[**0.1499, 0.1501**]
	v=1.2	[0.78, **1.24**]	[0.36, **1.25**]	[0.73, **1.22**]
Environmental Awareness	Weight	[0.1414, 0.1854]	[**0.1999**, 0.2308]	[**0.1499, 0.1501**]
	v=25	[15.98, +∞]	[14.95, 28.81]	[15.54, +∞]
Progress in Social Life	Weight	[0.1314, 0.1908]	[**0.1999**, 0.2308]	[**0.1499, 0.1501**]
	No veto			
Reaction Time	Weight	[0.1414, 0.4450]	[0.1199, 0.1771]	[**0.1999**, 0.3250]
	v=0.19	[0.04, +∞]	[0.04, +∞]	[0.04, +∞]
Territorial Desirability	Weight	[0.1414, 0.1854]	[**0.1299**, 0.1608]	[0.0577, **0.2000**]
	v=10	[**9.43, 10.98**]	[8.98, **10.62**]	[**9.79**, 11.30]
Cutting Level		[0.51004636, **0.6599487**]	[0.63001096, **0.650061**]	[0.566687, **0.650061**]

Twelve tests can be activated in relation to these parameters and the results are synthesized in table 3.24. This is the list of the twelve tests:

- Model with the original weights: $\spadesuit_1$ veto of Urbanization 1.25, $\spadesuit_2$ cutting level 0.66 and $\spadesuit_3$ veto of Urbanization 1.25 and cutting level 0.66;
- Model with the Policy 1 weights: $\heartsuit_1$ veto of Urbanization 1.26, $\heartsuit_2$ cutting level 0.66 and $\heartsuit_3$ veto of Urbanization 1.26 and cutting level 0.66;
- Model with the Policy 2 weights: $\clubsuit_1$ veto of Urbanization 1.23, $\clubsuit_2$ cutting level 0.66 and $\clubsuit_3$ veto of Urbanization 1.23 and cutting level 0.66;
- Model with the Policy 1 new weights: $\diamondsuit_1$ CO_2 Emissions (0.171), Urbanization (0.181), Environmental Awareness (0.198), Progress in Social Life (0.198), Reaction Time (0.122), Territory Desirability (0.128).
- Model with the Policy 2 new weights (1): $\diamondsuit_2$ CO_2 Emissions (0.151), Urbanization (0.151), Environmental Awareness (0.151), Progress in Social Life (0.151), Reaction Time (0. 195), Territory Desirability (0.201).
- Model with the Policy 2 new weights (2): $\diamondsuit_3$ CO_2 Emissions (0.148), Urbanization (0.148), Environmental Awareness (0.148), Progress in Social Life (0.148), Reaction Time (0. 203), Territory Desirability (0.201).

Table 3.24: Results of the robustness analysis

Classes Actions	Good – Good	Intermediate -Good	Intermediate - Intermediate	Bad - Good	Bad - Intermediate	Bad - Bad
RADICOFANI (RADI)			12			
SARTEANO (SARTE)					4 ♥♦$_{1}$	8 ♠♣♦$_{2,3}$
PIENZA (PIENZ)				4 ♣$_{2,3}$♦$_{2,3}$	8 ♠♥♣$_{1}$♦$_{1}$	
SAN QUIRICO D'ORCIA (SANQ)		6 ♠$_{1,3}$♥$_{1,3}$♣$_{1,3}$		6 ♠$_{2}$♥$_{2}$♣$_{2}$♦		
CASTIGLION D'ORCIA (CASTI)				3 ♥$_{2,3}$♦$_{1}$	9 ♠♥$_{1}$♣♦$_{2,3}$	
MANTALCINO (MONTA)		4 ♥♦$_{1}$	8 ♠♣♦$_{2,3}$			
MURLO (MURLO)		4 ♥♦$_{1}$	8 ♠♣♦$_{2,3}$			
BUONCONVENTO (BUONC)		4 ♥♦$_{1}$	2 ♠$_{1}$♣$_{1}$		6 ♠$_{2,3}$♣$_{2,3}$♦$_{2,3}$	
SAN GIOVANNI D'ASSO (SANGI)					12	
TREQUANDA (TREQU)			8 ♠♣♦$_{2,3}$	3 ♥$_{2,3}$♦$_{1}$	1 ♥$_{1}$	
ASCIANO (ASCIA)			12			
MONTERONI D'ARBIA (MONTE)		6 ♠$_{1}$♥♣$_{1}$♦$_{1}$		6♠$_{2,3}$ ♣$_{2,3}$♦$_{2,3}$		
RAPOLANO TERME (RAPOL)			12			
CASTELNUOVO BERRARDENGA (CASTE)	6 ♠$_{1}$♥♣$_{1}$♦$_{1}$	6 ♠$_{2,3}$♣$_{2,3}$♦$_{2,3}$				
GAIOLE IN CHIANTI (GAIOLE)	6 ♠$_{1}$♥♣$_{1}$♦$_{1}$		6 ♠$_{2,3}$♣$_{2,3}$♦$_{2,3}$			
RADDA IN CHIANTI (RADDA)	8 ♠♣♦$_{2,3}$	4 ♥♦$_{1}$				
MONTERIGGIONI (MONGG)	8 ♠♥♣$_{1}$♦$_{1}$		4 ♣$_{2,3}$♦$_{2,3}$			
SOVICILLE (SOVIC)	8 ♠♥♣$_{1}$♦$_{1}$		4 ♣$_{2,3}$♦$_{2,3}$			
RADICONDOLI (RADIC)					4 ♥♦$_{1}$	8 ♠♣♦$_{2,3}$
CHIUSDINO (CHIUS)		12				
MONTICIANO (MONTI)				3 ♥$_{2,3}$♦$_{1}$	9 ♠♥$_{1}$♣♦$_{2,3}$	

Results of the robustness analysis

The result is partially robust.

For twelve actions the robustness analysis produces a clear assignment. CASTE and RADDA are Good actions; SOVIC, GAIOLE, CHIUS and MONGG are clearly oriented to the Good category. SARTE, RADIC and SANGI are clearly oriented to the Bad category.

RADI, ASCIA and RAPOL are consistently intermediate.

The assignment is more difficult for other actions.

For two actions, MONTA and MURLO, the assignments are to the Intermediate category and, only in relation to one of the policy scenarios, to the Good category.

PIENZA, CASTI, MONTI and MONTE are oriented to the Bad category, the first three, and to the

Good category, the last, but they result critical (Bad-Good) for one of the policy scenarios.
A clear and robust assignment to a category is impossible for the actions TREQU, SANQ and BUONC.

Annex

1. ELECTRE TRI-B

The elements those are required as inputs to apply this method are:
a set of candidate actions A, A= $\{a_1, a_2, . . ., a_k, . . .,a_o\}$;
a family of criteria F, F= $\{g_1, g_2, . . .,g_j, . . .,g_n\}$;
a set of scales the evaluation of each elements on each criterion ……$g_j(a_i)$
a set of predefined ordered categories C (classes or groups), C= $\{C_1… C_h…C_p\}$;
a set of reference actions B, B= $\{b_1,b_2,…,b_h,b_{h+1},…,b_{p+1}\}$, which are real or imaginary actions used as profiles that are the (lower and upper) limits of the categories, where b_h is the upper bound of category C_h and the lower bound of category C_{h+1} .
The parameters of this model are:
the relative importance coefficients of the criteria W, W= $\{w_j, j=1,…,n\}$, whose sum is 1, without loose of generality;
the Veto threshold, v;
the Indifference and Preference thresholds, q and p, for each criterion and each reference action
the Cutting level λ.
The first phase of the method aims to model the outranking relation, the second to assigne actions to categories.

1.1 First phase

Preferences are modeled in ELECTRE TRI by a fuzzy outranking relations, *S,* whose meaning is *"at least as good as"*. It handles four preference situations ("Indifference", "Strict Preference", "Weak Preference" and "Incomparability") that can be the result of the comparison of two elements (Roy 1996). Outranking relation is based on the concordance and discordance principles. Concordance refers to the fact that a sufficient majority of criteria is favorable to the assertion a_i outranks b_h (a_iSb_h), while the discordance condition verifies if a distance between two performances, in relation to one or some criteria, is too strong to negate the previous assertion. Veto threshold shows the smallest difference between two elements which is discordant with the concordance principle and therefore precludes any outranking relation. The indifference and preference thresholds are defined to take into account the imperfect character of a specific evaluation $g_j(a_i)$ (Roy 1989). Preference threshold (p) is the smallest difference between the performances of two compared elements which is compatible with a strict preference in favor of one alternative. Indifference threshold (q) is the largest difference between performances of two alternatives that keeps indifference between them.
An outranking relation between a couple of elements (in this case an action a and a reference element b) is modelled in five steps:

1) Computation of concordance indices $c_j(a, b)$ and $c_j(b, a)$;
2) Computation of comprehensive concordance indices C(a,b) and C(b,a);
3) Computation of discordance indices $D_j(a, b)$ and $D_j(b, a)$;
4) Computation of (outranking) credibility degrees $\sigma_S(a, b)$ and $\sigma_S(b, a)$;
5) Passage from a fuzzy outranking relation to a crisp relation.

Computation of concordance indices $c_j(a, b)$ and $c_j(b, a)$

The index cj(a, b) expresses to which extend "a is at least as good as b", in relation to the criterion gj. If we assume that all criteria have to be maximized, the index cj (a,b), which is represented in figure x, is computed as follows:

- if $g_j(a) \le g_j(b) - p_j(b)$, then $c_j(a, b) = 0$
- if $g_j(a) > g_j(b) - q_j(b)$, then $c_j(a, b) = 1$;
- if $g_j(b) - p_j(b) < g_j(a) \le g_j(b) - q_j(b)$, then $0 < c_j(a, b) \le 1$, where the index value is computed by linear interpolation with the formula:

$$c_j(a, b) = \frac{p_j(b) - \left[g_j(b) - g_j(a)\right]}{p_j(b) - q_j(b)}$$

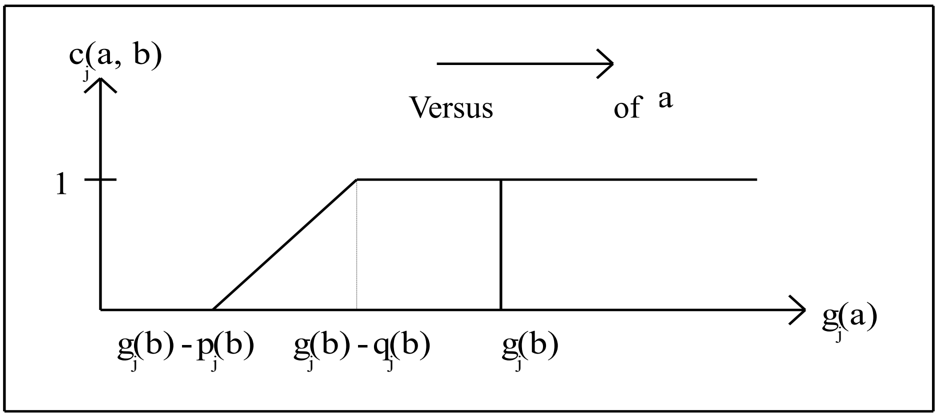


Figure 1: Concordance index cj(a, b)

The index $c_j(b, a)$ (see figure13) is computed as follows:

- if $g_j(a) \ge g_j(b) + p_j(b)$, then $c_j(b, a) = 0$
- if $g_j(b) + q_j(b) \le g_j(a) < g_j(b) + p_j(b)$, then $0 < c_j(b, a) \le 1$, computed by linear interpolation:

$$c_j(b, a) = \frac{p_j(b) - \left[g_j(a) - g_j(b)\right]}{p_j(b) - q_j(b)}$$

- if $g_j(a) < g_j(b) + q_j(b)$, then $c_j(b, a) = 1$.

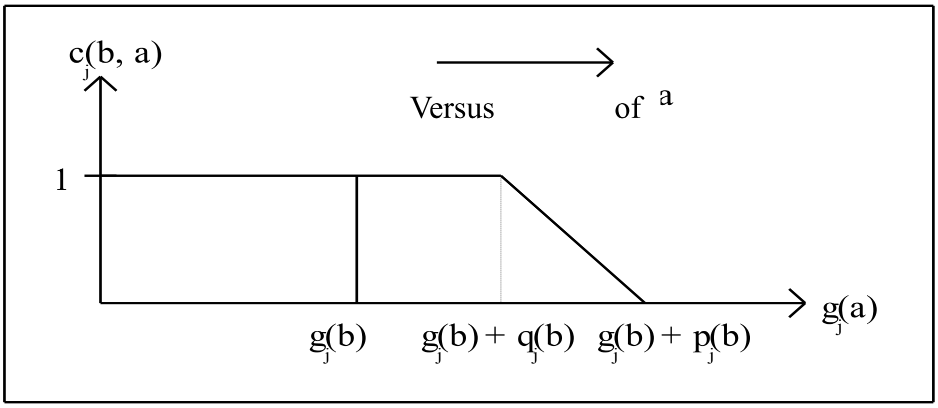


Figure 2: Concordance index cj(b, a)

Computation of comprehensive concordance indices C(a,b) and C(b,a);

The comprehensive concordance indices C(a,b) and C(b,a) are computed starting from the concordance indices c_j(a,b) and c_j(b,a), as the expression of the concordance principle:

$$C(a,b) = \frac{\sum_{j=1}^{n} k_j \cdot c_j(a,b)}{\sum_{j=1}^{n} k_j} \qquad C(b,a) = \frac{\sum_{j=1}^{n} k_j \cdot c_j(b,a)}{\sum_{j=1}^{n} k_j}$$

Computation of discordance indices D_j(a, b) and D_j(b, a)

D_j(a,b) expresses to which the criterion gj is against the assertion "a outranks b". A criterion gj is said to be discordant with the above assertion, if b is preferred to a, on this criterion, that is $c_h(a,b) = 0$ and $c_h(b,a) = 1$. The discordance principle is activated on this criterion, when the distance between gj(b) and gj(a) surpasses the threshold value v(gj(b)).

Also in this case we consider a growing preference. D_j(a, b), as represented in figure 14, is computed as follows:

- if $g_j(a) > g_j(b) - p_j(b)$, then D_j (a, b) = 0;
- if $g_j(b) - v_j(b) < g_j(a) \le g_j(b) - p_j(b)$, then $0 < D_j(a, b) \le 1$, where a formula is used to compute the index by linear interpolation:

$$D_j(a, b) = \frac{g_j(b) - g_j(a) - p_j(b)}{v_j(b) - p_j(b)}$$

- if $g_j(a) \le g_j(b) - v_j(b)$, then $D_j(a, b) = 1$.

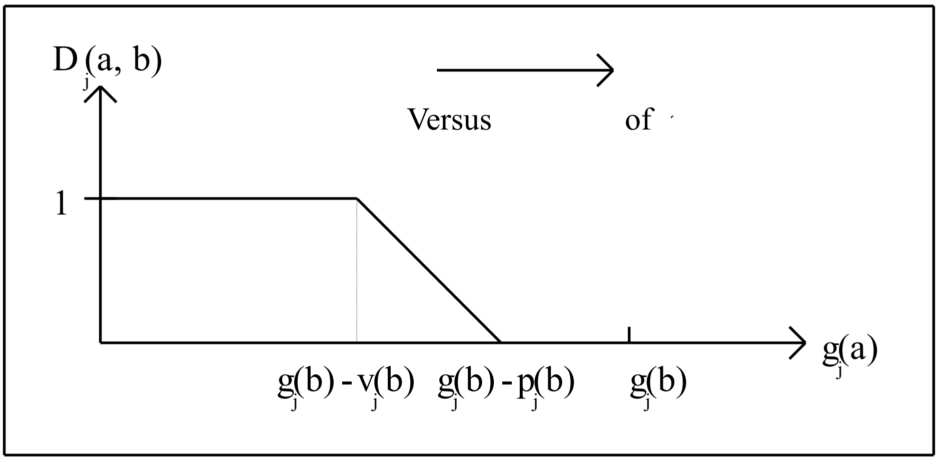


Figure 3: Discordance index D_j(a, b)

D_j(b, a), that is represented in figure 15, is computed as follows:

- if $g_j(a) \le g_j(b) + p_j(b)$, then $D_j(b, a) = 0$
- if $g_j(b) + p_j(b) < g_j(a) \le g_j(b) + v_j(b)$, then $0 < D_j(b, a) \le 1$, by means the formula:

$$D_j(b, a) = \frac{g_j(a) - g_j(b) - p_j(b)}{v_j(b) - p_j(b)}$$

- if $g_j(a) > g_j(b) + v_j(b)$, then $D_j(b, a) = 1$.

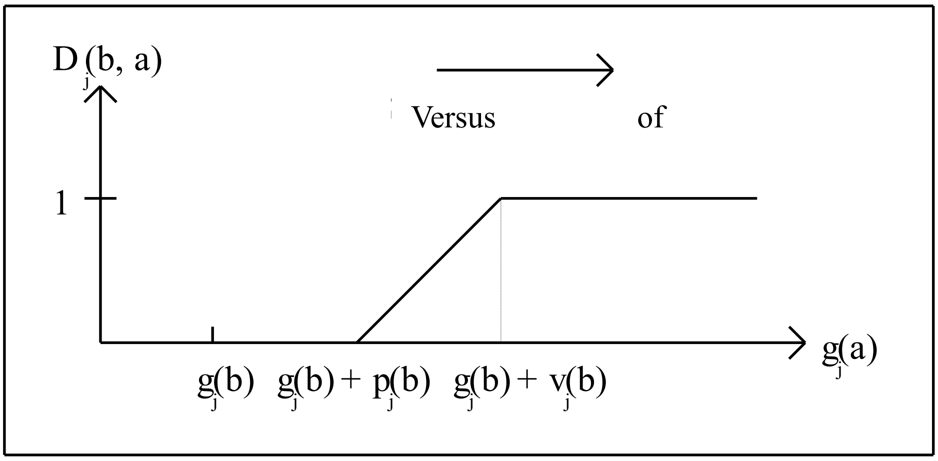


Figure 15: Discordance index $D_j(b, a)$

Computation of $\sigma_S(a, b)$ and $\sigma_S(b, a)$, degrees of outranking credibility

$\sigma_S(a,b)$ expresses to which extend "a outranks b" and is based on the concordance index C(a,b) and the discordance indices $D_j(a, b)$.

The definition of $\sigma_S(a,b)$ is based on the following main ideas.

a) When there is not any discordant criterion, or all the discordance indices are less than C(a,b), the credibility of the outranking relation is equal to the comprehensive concordance index, $\sigma_S(a,b)= C(a,b)$.

b) When at least one discordant criterion activates its veto power, ($D_h(a,b) = 1$), a does not outrank b, thus $\sigma_S(a, b) = 0$.

c) For the remaining situations, in which the comprehensive concordance index is strictly lower than at least one discordance index, the credibility index becomes lower than the comprehensive concordance index, because of the opposition effect on this criterion

The conclusions that $\sigma_S(a, b)$ is the comprehensive concordance index C(a, b) weakened by possible veto effects. It is computed as follows:

- if $F°(a, b) = \{j \in F / D_j(a, b) > C(a, b)\} = \varnothing$, then $\sigma_S(a, b) = C(a, b)$;
- if $F°(a, b) \neq \varnothing$, then:

$$\sigma_S(a, b) = C(a, b)\cdot \prod_{j\in F°} \frac{1-D_j(a,b)}{1-C(a,b)}$$

$\sigma_S(b, a)$ is computed in the same way:

- if $F°(b, a) = \{j \in F / D_j(b, a) > C(b, a) \} = \varnothing$, then $\sigma_S(b, a) = C(b, a)$;
- if $F°(b, a) \neq \varnothing$, then:

$$\sigma_S(b, a) = C(b, a)\cdot \prod_{j\in F°} \frac{1-D_j(b,a)}{1-C(b,a)}$$

Passage from a fuzzy outranking relation to a crisp relation

The introduction of a parameter λ ($1/2\leq\lambda\leq1$), called cutting level, transforms an outranking relation

in a crisp relation. λ is considered the smallest value of $\sigma_S(a, b)$ for which "a outranks b" (if $\sigma_S(a, b) \geq \lambda$, then aSb).
Let P denote the preference, I denote the indifference relation and R the incomparability binary relations. The action a and the profile b may be related to each other as follows:

- a I b (a is indifferent to b) is equivalent to: a S b and b S a;
- a $\succ$ b (a is preferred to b)is equivalent to: a S b and b/Sa (b does not outrank a);
- b $\succ$ a is equivalent to: a/S b and b S a;
- a R b (a is incomparable with b) is equivalent to: a/S b and b/S a.

1.2 Second phase

The second phase explores the above binary relations, in order to assign each action to a category. This can be done by two distinct forms, or rules, the pessimistic and the optimistic rules. Let b_h and b_{h+1} denote the lower and upper profiles of the category C^h.
The pessimistic rule i) successively compares a to b_i, starting from the "highest" b; ii) b_h is the first reference action for which a S b_h (stop of this procedure), therefore a is assigned to the category C^{h+1}.
The optimistic rule i) successively compares a to b_i, starting from the "lowest" b; ii) b_h is the first reference action for which $b_h \succ$ a (stop of this procedure), therefore a is assigned to the category C^h.
The above rules find minimum and maximum categories to assign an action. The minimum and maximum categories can be equal, adjacent or not adjacent or extreme categories.

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