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Decision aiding in public policy generation and implementation: a multicriteria approach to evaluate territorial resilience

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Abstract A decision aid process should be the result of an interaction between analysts, decision makers and stakeholders. Decision aiding is sometimes required when the problem situation is new and a formal decision system does not exist. Its role becomes that of facilitating the Intelligence phase of a decision process. In other situations, a criticism of certain policy making processes and their use of data, which may be available in institutional databases or are required as indicators for the decision process, motivates an intervention oriented towards structure knowledge and improvements of these processes. A preliminary study, which includes modelling and application of multi-criteria methods, can clarify a complex and new situation, propose a consistent approach for the later phases of a decision process or propose a different and more effective use of the data. A case study is proposed here to describe this methodological approach in relation to the disaster resilience of municipalities near the Ombrone River, in Tuscany (Italy).

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INTRODUCTION

An analyst develops a Decision Aid (DA) process together with decision makers and stakeholders, in relation to a problem situation that involves all the actors in a decision process. When a problem situation is new or not well structured, a DA process can facilitate the phase of a decision process that Herbert Simon (1960) called Intelligence, even when interaction with the actors of the decision process is from necessity very limited. However, some precautions and focused and full attention to all the modelling and validation activities are required. In some situations, a decision problem is perceived, recognized and/or proposed by people (or organisations) that are only marginally connected to the problem, when a decision process has not yet been activated and a formal decision system, with well-defined rules, clear constraints, roles and relations, does not exist. In these situations, formal and informal documents may be present, and they could be used to understand the organizational context and define the decision problem. In these situations, huge lists of indicators, proposed by experts or in the literature and which are easily identifiable in official databases, are often the only possible answers to the need for a focused action that facilitates decision.

In other situations, when structured data are not available, the need for some actions, in relation to the new and not sufficiently defined problem, generates a request for investigation, data acquisition and elaboration. These activities are often not clearly defined and not aimed at a specific goal, because of a total lack of knowledge and specific competences, and their developments and results cannot be oriented and controlled because decision authority and accountability have not yet been foreseen.

When data and possible indicators are easily accessible in institutional databases, and are therefore not expensive, their use in active policy making processes is often characterized by a very high multiplicity of items/indicators, as a result of the general belief that only a large amount of data can produce information. An integration of these data becomes difficult for at least two reasons: because a logical structure of the problem and its information needs had not been generated before, and a synthesis of so different and "incomparable" elements, from different sources, is not so easy.

The same belief ("only a large amount of data produces information") generates project selection or personnel management procedures that can be used to evaluate numerous items/elements in relation to a large number of aspects. These long and heavy procedures are very expensive for an organization, and a final synthetic evaluation score that "could have the same meaning as a random number" is often associated to each examined item. An analysis of the 57 evaluation processes that were developed in 2003 in a public project selection context (Norese and Torta, 2014) underlined that the number of aspects/criteria/indicators was in general high (often more than 35), and in some examined cases was very high (the number of indicators in an evaluation model was found to be above 100).

The *evaluation* terminology assumes different forms (key performance indicators, outcomes, outputs, project performance metrics, key international indicators, monitoring data and so on) and proposes different uses, such as the benchmarking of alternatives, project selection or ranking of organizational or territorial units. The first section in this paper is dedicated to analysing some aspects in relation to the nature and the use of data as indicators, and a methodological approach is proposed to improve the use of data in DA procedures.

The second section describes *MultiCriteria Decision Aiding,* and how this methodology can be developed in relation to complex problem situations that have to be structured in order to propose models and DA procedures for the later phases of a decision process. A frequent problem situation is presented in the second part of the paper, in relation to the problem of a territorial agency that should allocate resources on the basis of the performances of some territorial units. Their behaviour, in terms of intangible assets of the local context and aspects of its identity, can easily be evaluated by means of a multicriteria (MC) model that includes technological, economic, environmental, political and social facets. Moreover, an MC method can be used to synthesize all these aspects.

A case study, related to the disaster resilience of the municipalities near the Ombrone River in Tuscany (Italy), is proposed to describe this methodological approach and its role in order to propose a collaboration, which is currently underway, in relation to a similar problem in the Piedmont Region.

FROM HUNDREDS OF INDICATORS TO STRUCTURED MODELS AND DA APPLICATIONS

Indicators are usually presented as an efficient way to synthesize information. However, several methodological problems are present when indicators are thought of as decision support models (Bouyssou *et al.*, 2000). The difficulty that is associated with the measurement of intangible assets, or with the identification of social metrics, is often underlined in studies that have to analyse social or organisational aspects. Some remarks are proposed in literature (and should be underlined and diffused) in relation to the nature and use of indicators that deal with these aspects.

Data-indicators are currently easily accessible in organizational and/or institutional data banks (such as balance sheets, vital statistics, reports of observatories, official reports or plans of local institutions or authorities, specialized web sites, …). Therefore, they are often used even though they may not be so pertinent to the examined aspects, or may be proposed as a useful element that facilitates decision, above all when formal decision processes and systems have not yet been made active. As a natural consequence, many not so reliable data are often used to generate a single indicator by means of an aggregation procedure that can be methodologically wrong, such as a weighted sum computed using ordinal data (Meilly *et al.*, 2014).

A frequent situation that arises is the request, from an authority or, in general, a public organization, for a long list of data that are not oriented towards a specific problem solving action, but are used to create a database for future and not yet defined possible decisions. If the decision problem is not structured enough or made explicit, each request for data, from a higher level to an organizational unit, creates communication problems, because the request is perceived as not being sufficiently motivated and as being expensive in terms of time, costs and wastefulness of resources. Communication becomes worse and worse when the acquired data are used badly, or are not used at all, in the decision processes.

In other situations, data/indicators are used to monitor and measure the progress that has been made towards specific goals. A decision system exists in these situations, an operational context is at least partially structured, and data acquisition should therefore be more easily oriented towards the context aims, with the clear perception that "*evaluation operations* are complex and should not be confused with *measurement operations* in Physics" (Bouyssou *et al.*, 2000). The quality of the data/indicators that are required, and their actual usability in the decision process, have to be generated and guaranteed, or analysed and improved, if data/indicators are available, above all when the procedure is new and there is not enough knowledge in the organization about the new decisional problem.

A **preliminary study** that orients the attention of stakeholders, or potentially involved actors, towards the specific nature of the decision problem may facilitate these situations. This kind of study (with the aid of formal but flexible and user-friendly models and methods) anticipates some possible uses of data, indicators and criteria in order to activate a learning process that orients the data and knowledge acquisition process (see, for instance, Norese, 2009). This preliminary study may be described as a *simulated* decision aid approach, because the decision process and the system are in a pre-decision phase, and may also be described as a *stimulating* approach, because the study is developed together with the few actors that perceive the need to understand and propose structured elements for later phases of a still not activated decision process.

This *SImulated and STImulating* (SISTI) approach integrates modelling and validation of each modelling result as the study is developed. The main results are: a **conceptual model**, which includes all the main aspects, requirements and uncertainties associated with the problem situation in a structured form; a **formal model**, specifically oriented towards the method that has to be adopted; the **result of the application of the method** to a formal model, and the **application** of this result to a real or virtual component of a specific problem situation. All the used data and each of these results have to be validated (Landry *et al.*, 1983) in order to demonstrate the consistency of each step in SISTI, and the quality of each answer to the problem difficulties, or to underline the need to re-act and improve the modelling process results.

MC models are used in SISTI above all because:

- they are able to transparently include all the relevant aspects of a decision problem using the language and procedural terminology of each specific analysis field that has to be involved;
- they are structured with the aim of eliminating redundancies, including the minimal set of essential and consistent elements, and distinguishing between data and reliable evaluations.

MC models and methods have to be integrated in SISTI with the aid of visualization tools (see Norese *et al.*, 2016), to facilitate individual and collective analyses, and revision, in all the modelling-validation activities of the learning process. This approach was applied, for the first time, to two problem situations in which several data were available and which suffered from an innovative and difficult modeling process (Balestra *et al.*, 2001; Cavallo and Norese, 2001). SISTI was found to be useful in this context, and for this reason it was introduced into some academic courses as a modeling tool to facilitate students' learning about modeling (Norese, 2006). SISTI has been applied to aid some decision makers in Public Administrations (Norese, 2009 and 2010; Norese and Carbone, 2014), and a systematic analysis of this approach has been proposed (Norese, 2016 and 2016a).

The roles that MC models and methods play in this decision aid process are synthetically described in the next section.

MULTICRITERIA DECISION AIDING AND THE INTELLIGENCE PHASE OF A DECISION PROCESS

Decision aiding is the activity of the person who, through the use of explicit but not necessarily completely formalized models, helps obtain elements of responses to the questions posed by a stakeholder of a decision process. These elements work towards clarifying the decision and usually towards recommending, or simply favouring, behaviour that will increase the consistency between the evolution of the process and this stakeholder's objectives and value system (Definition 2.2, Roy, 1996). The Multi Criteria Decision Aiding (MCDA) methodology makes use of formal MC methods that reduce ambiguity, which is typical of human communication (see the EURO Working Group MCDA web site: "http://www.cs.put.poznan.pl/ewgmcda/"). In this perspective, the output of the decision aiding process is not the result of a method, applied to a model, but instead is the advice given to a client and the use made of such advice by the client.

A clearly defined problem often does not exist in real life applications, and the way a problem is formulated cannot be totally objective, but it is expected to evolve throughout the decision-making process and above all the decision aiding process. MCDA adopts a *constructivist approach* in which problem formulation and investigation should progress simultaneously, by means of a "discussion" between the analyst and client, to construct the representations of the client's problem (Tsoukias, 2007). In the constructivist approach, the model, the concepts and the procedures are not envisaged to reflect a well-defined reality, existing independently of the actors. *First and foremost,* *they constitute a communication and reflection tool: these models and concepts should allow the participant in the decision process to carry forward a process of thinking and to talk of the problem* (Genard and Pirlot, 2002).

A constructivist approach cannot be applied easily in situations in which only some actors perceive the nature and importance of the decision problem, and in which there are not sufficient conditions to activate a process and decision system. An MCDA process can also be developed in these situations, and oriented towards facilitating a pre-decisional analysis and understanding phase. Effective interaction with the few involved actors and a preliminary study, which should include MC modelling, application of MC methods and result analysis and validation, become useful to clarify the situation, reduce uncertainty and structure the relevant complexity elements in a "good" model of the problem situation.

The points of view of the potential actors have to be gathered when SISTI (a simulated and stimulating approach to decision aid) is adopted. A set of possible decisions has to be identified, or elaborated, and an MC model has to be structured and formalized in analytical terms, to evaluate each alternative decision in relation to the actors' points of view. The different level of importance of each criterion can be set, without decision makers, in relation to specific action implementation scenarios, which may be associated with different control capacities in the decision implementation process, or alternative territorial development or policy activation processes, and so on.

An MC method can synthesize all these elements (the main aspects of a problem, possible courses of actions and criteria to evaluate alternative actions) in order to answer one of the following decision aid requests: description of the problem situation, choice of the best compromise solution, ranking of the analysed actions, or sorting and assignment to predefined categories of problem management. If there is time to carry out SISTI, the study needs great and full attention to the specific incremental nature of the associated learning process. A cyclic application of a method and an analysis of its results, at each iteration, can facilitate and control the development of this process. Each temporary result, in the various steps of the process, produces new knowledge and may include elements that stimulate a marginal or structural change to the model, or a problem formulation improvement or reformulation. Each method application implies a clear definition of all the inputs, and a critical analysis of each result, in order to use this knowledge to converge towards a final model, or to formulate new treatment hypotheses for the problem situation.

SISTI may also be motivated by the aim of improving the quality of indicators (often called indices), which are used in several organizational processes, to obtain evidence that can be used to set specific goals (the intelligence phase of some decision processes) and to establish the progress that has been made towards these goals (the choice phase in which a re-action may be required in relation to the monitoring results). An MC model and the application of an MC method may be developed to show how an indicator can be generated, and why this indicator is essential in policymaking (see the description of *policy analytics* in Tsoukias *et al.*, 2013). A SISTI application to model development is presented in the next sections, in relation to the limits of adopted resilience indices, and to the general problem of a territorial agency that has to allocate resources to resilience increasing processes.

A MULTICRITERIA APPROACH TO 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 new resilience model, that MC models and methods "exist" and can be very useful in resilience increasing processes (Scarelli and Benanchi, 2014). Starting from the results of this study, a SISTI application was carried out to test and 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.

The SISTI approach includes a recurring cycle of different steps. The first starts by analysing the problem and a first model, which may be taken from literature or set up directly on the basis of the examined context, in order to identify possible improvements, which may be very limited (only a single parameter of the model needs to be changed), more complex (when a combination of parameters need to be changed), or even still more complex (when the overall structure of the model needs to be improved). After this rather simple and fast first step, each improvement proposal is tested by means of the application of an MC method to the model variant and the result of this application is analysed and compared with other results of the original model and of the previously tested model variants. A result analysis is used to verify whether each proposed improvement would be possible and useful. The passage from one model revision to another more viable one may be linear, but a cycle of iterative tests is often required in this learning process, because a certain sequence of improvements may not produce interesting results, and a new analysis of the problem and model is needed to activate a new path.

In the analysed case, some criticisms emerged and improvement proposals were suggested in relation to the original Scarelli and Benanchi model (2014), 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 (Roy,1978; 1990), the same method that had been adopted in the original study. The result of some iterations and revisions of the original model was a new and rather interesting model.

The steps of this approach were then used to describe a modeling process to a team of officials from the Piedmont Region, who would like to face a problem of resource allocation that presents some innovative characteristics for the Italian territory. Both a definition of resilience and an MC approach to modelling and decision aid, in relation to resilience problems, are proposed in the next section.

Resilience

The term 'resilience' stems from the Latin verb *resilire* (rebound), and *resiliens* 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), 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 (Duijnhovena 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.

MC modelling

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 to synthesize the evaluations and rank the analysed territorial units from the most to the least resilient.

An MC model was structured in relation to a pilot case: the resilience of some territorial units, that is, twenty-one municipalities belonging to the Ombrone River hydrographic basin in the Tuscany region in Italy, where several floods events had occurred. Siena, the only city in the area, was excluded from the analysis, because its characteristics are too different from the others. An MC method, ELECTRE III, was applied to the model, to rank the municipalities in relation to their resilience capacity. 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 study were analysed, in SISTI, starting from the model structure (main aspects, or model dimensions, and criteria that analytically make each dimension operational) and the data used for the evaluations, and then a parameter analysis was conducted. 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 that 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 are used to reduce the uncertainty that may be associated to the data and the expressions of decision preference (see Roy, 1996).

All the parameters of the Scarelli and Benanchi model (2014) were taken from the literature (because of the absence of decision makers in this pilot case) or elaborated in relation to the quality of the used data.

The model structure and its components

The structure of the model that Scarelli and Benanchi (2014) had been taken from literature (above all from United Nations-ISDR, 2005; Cutter *et al.*, 2010; Kamani-Fard *et al.*, 2012; Ali and Jones, 2013; Hutter *et al.*, 2013) is shown in Table 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).

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 (in the first SISTI step) 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.

More than six criteria represented environmental aspects and/or data to evaluate the 21 municipalities, and they showed a net prevailing importance (78%). At least two reasons may have been responsible for the inconsistent structure of the model. One could have been the difficulty the researchers had found in acquiring data from public institutions, and above all from the municipalities. Accessibility had been limited by the nature of the study, which had been more oriented towards experts in resilience than towards possible decision makers. It had also been limited by a restricted interoperability between data at different institutional levels (national, regional or local level). Another reason could have been the prevailing presence of environmental data and possible indicators in the institutional databases.

However, the several indicators that the literature suggests to deal with socio-economic resilience are not frequently included in open data, or had been inconsistent with the socio-economic context of the analysed pilot case. For this reason, some evaluations of the socio-economic aspects (in the second part of Table 2) did not seem so consistent with the aspects they should have dealt with in analytical terms.

Criteria and indicators	Aspects (*aspects that seem more environmental than socio-economic)
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	Active population/young + old population ratio
Employees /residents *	Resource consumption and waste creation *
Spendable income	Economic resources from citizens to prevent disasters

Table 1 Model - the environmental criteria and aspects are in the first part of the table and the socio-economic ones in the second

The model parameters had been elaborated in the original model to show how resilience could be evaluated by means of an MC approach, and not to answer a precise decisional question. Therefore, a different importance of the criteria had been associated to the indications proposed

in literature, and not to a specific decision problem or expression of a policy. The thresholds of indifference and preference, which reduce the negative impact of a limited quality of data and uncertain preferences, had been proposed with very high values, because of the absence of decision makers who could have expressed their preference system and could have activated a data acquisition procedure or the transfer of data from “closed” data banks to the model.
These conclusions about the quality of some parameters were the result of the analysis of the model at the end of the first SISTI step, and above all of some ELECTRE III applications to the original model (second SISTI step) that were activated, in sequence at a later stage, in order to test the presence of some drawbacks of the model evaluations and parameters. The analysis of each new result and the comparative visualization of the different results are essential in SISTI, and can orient the sequence of changes and the proposal of some variants to the original model.
ELECTRE III compares the analysed elements and produces their classification, from “best to worst”, which is represented by a final partial graph, i.e. a pre-order that is developed as the intersection of 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, from the best to the worst element, the longest of which can be visualized as the vertical axis, and can be considered the main path, while each lateral path indicates a situation of incomparability between elements and underlines a distance between positions in the two distillation results (of one or more positions and sometimes even of several). The presence of different paths is more frequent when several elements are compared, and the lateral paths should be visualized above all in the middle part of the graph. The number of lateral paths grows if the comparability of the analyzed elements is not so high, but a high number of paths can sometimes be the sign of a difficult and not so clear definition of some model parameters (and above all of the veto thresholds). When the reasons for these “erroneous” definitions are analyzed and eliminated one by one, the number of incomparable elements is always reduced (Balestra *et al*., 2001; Cavallo and Norese, 2001; Norese, 2006).
In this case, the final partial graph that resulted from the ELECTRE III application to the original model is presented in Figure 1, with fifteen municipalities in the vertical path and six, which are only present in the middle part of the graph, in the lateral paths.

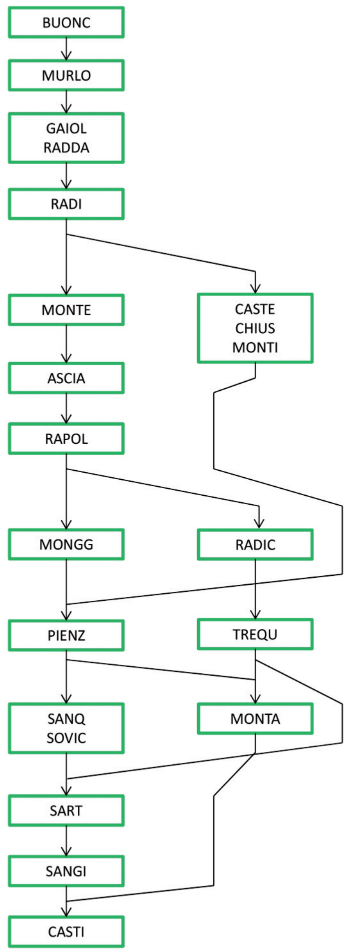

Figure 1 The result of the original model

The result is rather interesting, but the analysis of the model, in the first SISTI step, pointed out some weak elements, with the consequent need for an at least marginal revision of the model. Some different results were obtained from the ELECTRE III applications to some variants of the original model, which were proposed in the first SISTI step or were generated as a consequence of a previous result analysis.

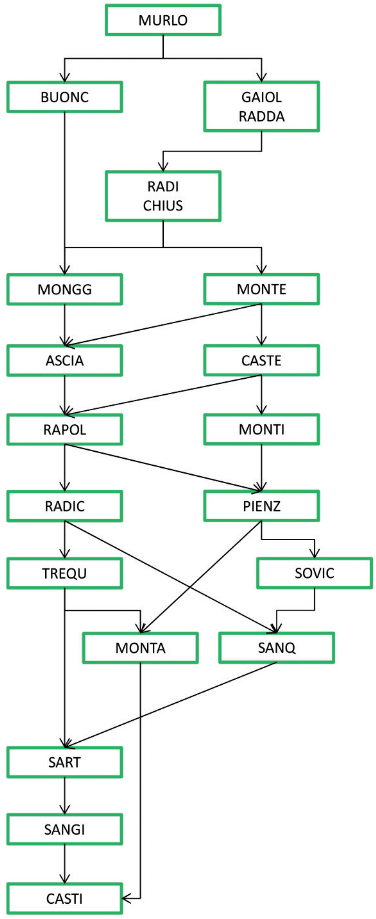

Figure 2 The result after some changes

The variants presented changes, in terms of evaluation uncertainty levels (and therefore of thresholds of indifference and preference) and activation of the discordance principle (veto thresholds). Two of the ELECTRE results are proposed in Figures 2 and 3, where the final partial graphs include different paths and several incomparability situations.

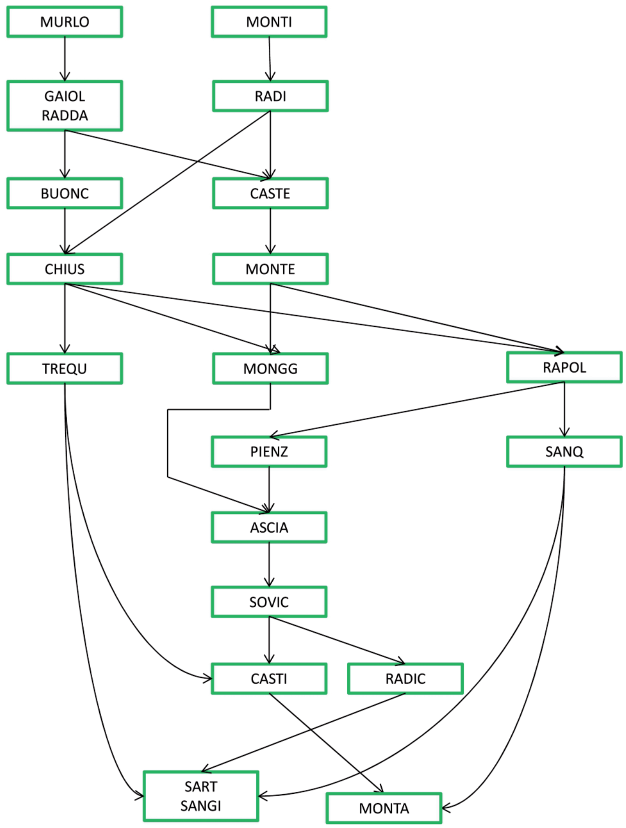

Figure 3 The latest result

Each model variant was considered an improvement of some of the model parameters, but each variation produced less interesting results. The last result (Figure 3) was unable to identify the first municipality in the ranking, because two of the municipalities (coded as MURLO and MONTI) were in the first position, but incomparable because they were in two different paths.
At this point, the authors realized that no single marginal change could improve the result, because the original choice of parameters had been conditioned by the very difficult modelling context: the original model had been proposed only as a logical and analytical synthesis of the several inputs from the literature, without a specific decision problem having been defined, and there had been few and not so reliable or consistent data. A structural change to the model was considered the only possible course of action in SISTI.

New MC model structuring for decision aid

A new modelling logic was adopted to deal with a specific decision problem, in relation to the disaster resilience topic, and to propose the results to policy makers and stakeholders involved in territorial processes. The model, which was analysed in terms of parameters (thresholds and modelling of the discordance principle) in the first step of the study, was then studied in terms of structure (the main conceptual aspects and a *consistent family of criteria* that analytically deal with these aspects (Roy, 1996)) and in terms of an evaluation process (choice of data-indicators to be used in the evaluations). A specific decision problem was formulated, and three main aspects were identified to deal with the decision problem of a territorial agency that should allocate resources to improve the disaster resilience of the Ombrone River basin, in relation to the different *Reaction capabilities* of some territorial units. Some *Social aspects* and the *Ethical behaviour* of the involved actors *can* increase the reaction capability of each territorial unit; instead, *Risky behaviour* aspects can reduce the reaction capability. These three main aspects became the dimensions of the model, which is shown in Table 2. Specific aspects, in relation to each dimension, can be translated into criteria that require data or judgements from experts to evaluate the territorial units.

MODEL DIMENSIONS	ASPECTS, POSSIBLE CRITERIA AND REQUIRED DATA
Risky behaviour, limited safety and risk awareness	**Anthropic impact on the environment** (uncontrolled urbanization and limited rainfall absorption, cemented riverbanks, uncontrolled use of aquifer layers, high values of CO2 emissions ....)
Social aspects	**Reaction time** (active population /young +old population ratio) **Progress in social life** (% of working women, scholastic attendance)
Ethical behaviour	**Awareness and interest in safeguarding the environment** (% of differentiated waste, alternative energy use, high territorial desirability) **Previous disaster prevention activities** (naturalised river banks, education programmes)

Table 2 Logical structure of the Reaction capability model

Some of the data that were required to evaluate the twenty-one municipalities, in relation to the Reaction capability model, could not have been acquired if a decision process had not been activated. For this reason, the new model (set up at the end of the first SISTI iteration cycle) included six of the fourteen criteria of the Scarelli and Benanchi model (2014) and the related original evaluations. The criteria that were chosen, because they allowed the three main Reaction capability dimensions to be dealt with analytically and were associated with the “clearest and most reliable” indicators, were:

- Risk of uncontrolled **Urbanization**, which could limit rainfall absorption (rate of urbanized area, elaborated by means of GIS)
- **CO2 emissions**, which could induce a high level of atmospheric contamination and alteration, as a sign of limited safety and risk awareness (source: Siena Province, Civil protection sector);
- **Reaction time**, which is evaluated in terms of the ratio between the active population and the young plus old population (from the Demographic Dependency index, source: ISTAT, the National Institute of Statistics);
- **Progress in social life,** a social aspect that can be expressed in terms of percentage of working women, but these data were not available and the rate of unemployed women with respect to the total population was used (source: Siena Province, Report on the labour market);
- **Environmental awareness**, which could be expressed by the percentage of differentiated waste (source: Siena Province, Civil protection sector);

- **Safeguarding the considered area**, which could be expressed by the touristic attractiveness that motivates citizens and administrators to preserve the territorial qualities and to prevent any kind of negative impact (ratio between the touristic flows and resident population, source: Siena Province Tourist Office).

Another criterion, which had also been included in the original model, was considered for inclusion in the new model: the Spendable income (source: Siena Province, Dossier on social politics). This criterion can indicate the wellbeing level of the citizens and therefore the possible economic effort of an administration to face a disaster, or the need for public intervention, unless the wellbeing level is so low that any individual effort is impossible. This dual interpretation was considered interesting, in terms of reaction capability, but it was decided that its inclusion could be a risk, because of the limited reliability of the data and the possible multiple interpretation of its meaning. Therefore, it was only used in the model sensitivity analysis.

ELECTRE III applications to the new model

The definition of the model parameters was facilitated by the knowledge that had been created in the previous SISTI step (pertaining to the veto, indifference and preference thresholds) and thanks to the clear structure of the new model that was now able to facilitate a consistent definition of the coefficients of the importance of the criteria and of the formulation of some scenarios. Three scenarios were introduced in relation to some possible policies: educating people to limit risky behavior, funding civil protection and training on how to react in case of a disaster activities , and funding landscape preservation and environmental protection activities. Each possible policy was associated to a different scenario, and was given a different weight vector (the coefficients of the relative importance of the criteria), because of the absence of actual decision makers.

The ELECTRE III application to the new model (with three dimensions and six criteria) produced a somewhat interesting result. The main path in Figure 4 contains twelve of the twenty-one municipalities, and some lateral paths (signs of incomparability situations) are present, above all in the middle part of the graph.

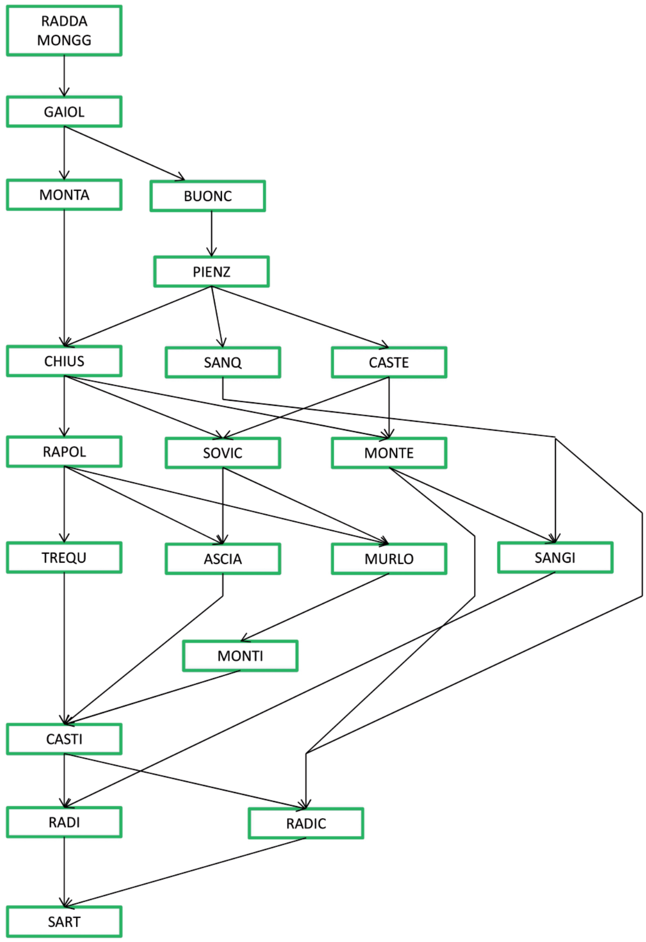

Figure 4 Result of the ELECTRE III application to the new model

When the ELECTRE III application to the model was repeated, with different importance of the criteria, in relation to the three different policies/scenarios, the result changed, but the first six municipalities and the last five always remained in their original positions in the ranking (see Figure 5). The other ten municipalities remained in the middle part, although there were some changes in their relative positions and they always suffered from incomparability.

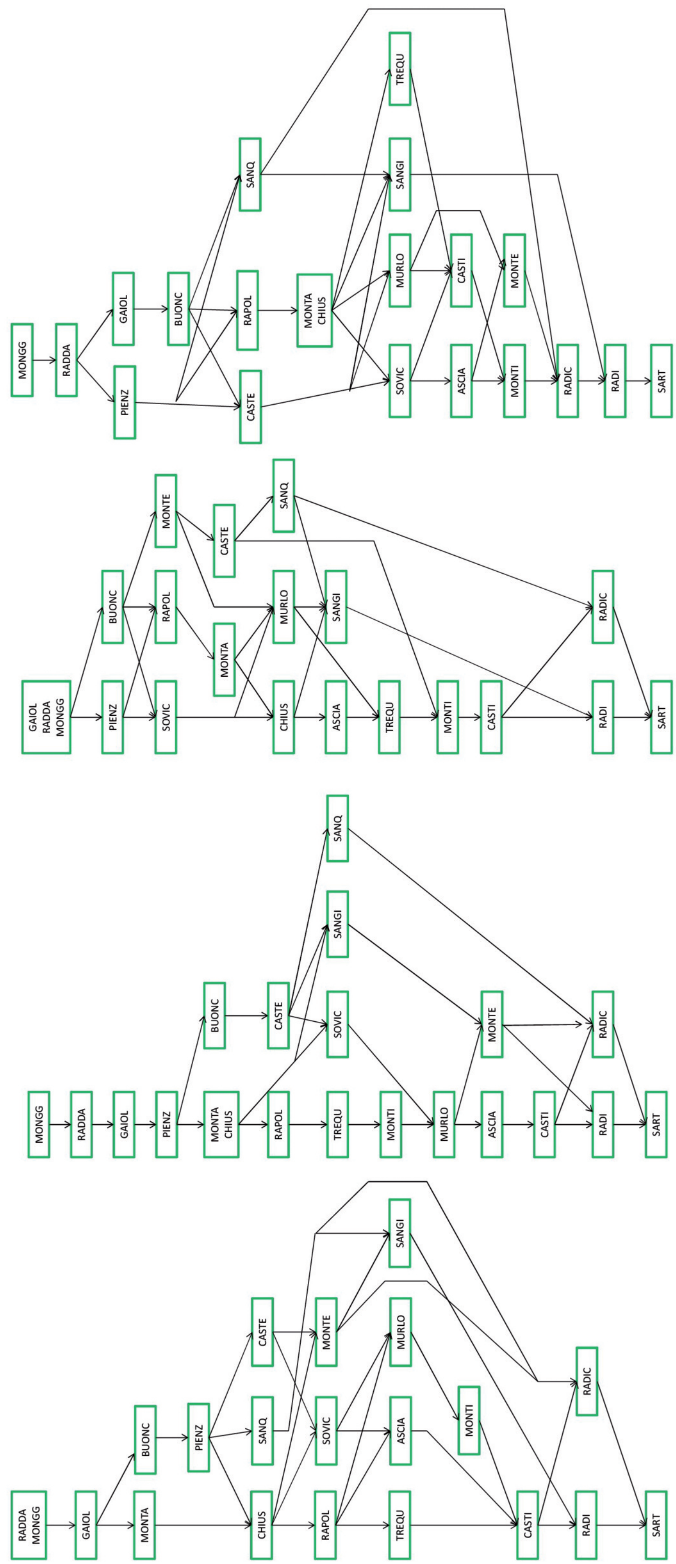

Figure 5 The results in relation to different scenarios-policies

An analysis that was conducted to test the sensitivity of the model and result, to veto changes (with the elimination of only one veto threshold each time) and to the introduction of a seventh criterion, produced the same result for the first six and last five municipalities, and only small changes in the middle part. The new model produced a robust result. However, although it was not able to produce a clear ranking of all of the twenty-one municipalities, it confirmed their differentiation into three classes, as well as the sequence of the elements in the first and last classes.

CODE	MUNICIPALITY	POPULATION
RADI	RADICOFANI	1,148
SART	SARTEANO	4,679
PIENZ	PIENZA	2,231
SANQ	SAN QUIRICO D'ORICA	2,526
CASTI	CASTIGLION D'ORICA	2,530
MONTA	MONTALCINO	5,272
MURLO	MURLO	2,116
BUONC	BUONCONVENTO	3,197
SANGI	SAN GIOVANNI D'ASSO	920
TRQU	TREQUANDA	1,388
ASCIA	ASCIANO	7,299
MONTE	MONTERONI D'ARBIA	7,548
RAPOL	RAPOLANO TERME	4,932
CASTE	CASTEL NUOVO BERARDENGA	8,081
GAIOL	GAIOLE IN CHIANTI	2,333
RADDA	RADDA IN CHIANTI	1,715
MONGG	MONTERIGGIONI	9,165
SOVIC	SOVICILLE	8,882
RADIC	RADICONDOLI	1,019
CHIUS	CHIUSDINO	1,944
MONTI	MONTICIANO	1,412

Table 3 List of the municipalities

The several incomparability situations between the intermediate class elements were unexplainable, and not so consistent with the high quality of the model parameters.

Some aspects pertaining to the intermediate class components, which could be useful to improve the model, arose from this analysis. Most of these components are municipalities with just a few people (see Table 3 with the population of each municipality and the code used in the ELECTRE III applications), and the economic activities are predominantly of an agricultural and cattle breeding nature. As a result, there is very low level of industrialization (and low CO_2 emissions) and limited urbanization. Their very poor "waste differentiation" performance may be the consequence of the natural attitude of the inhabitants to reuse the waste that they produce on the farms to improve the fertility of the land or to heat their farms. Therefore, the municipalities may be characterized by good environmental awareness and territorial safeguarding, even though they do not

differentiate their waste (the choice of a less ambiguous criterion is suggested in relation to this remark). Other municipalities are small, intact and picturesque Middle-Age villages, or small cities that are very famous throughout the world for their wine or touristic attractiveness. These municipalities showed the most unexpected results (high number of lateral paths and changes in their position in relation to different scenarios). This "natural" incomparability between the municipalities of this river basin has to be accepted and, as a consequence, their ranking in the form of a *complete order* has to be considered almost impossible.
Another point is that specific attention should be paid to some criteria that could have a specific meaning for some elements of the analyzed set and not for others, above all when the elements are so different.
A different and more effective approach would be to assign the units to categories of different reaction capability and resilience, by means of few general criteria and an ELECTRE method of sorting, and only in a second step to generate rankings of the homogenous units of each category, with different criteria, in consideration of the nature of these units.

CONCLUSIONS

The SISTI approach is very useful in innovative decisional contexts, which in general present a limited structure and knowledge. It may be used above all when the decisional system and process are still not activated, but there already is the perception of a decision problem. It should be analysed with whoever has perceived this problem, while paying attention to the specificity of the context and its social, environmental and economic identity, with the aim of obtaining an inter-institutional collaboration with the appropriate territorial actors.
The main limit of this approach is related to time: a reliable prevision of how many iterations and how much time is required to arrive at a good model, which would be able to express useful knowledge of the problem, is very difficult or even impossible. An essential prerequisite is the presence of at least some knowledge, which should be used to test the model that evolves in SISTI, or the existence of a great deal of data, from which to extract knowledge and use it for the problem analysis.
The Environment Department of the Piedmont Region has activated a new kind of participatory process, the *River contract,* which involves the citizens of a river basin in the formulation of an Action plan with a list of specific activities, starting from environmental, economic and technological points of view. The Department can activate projects, in order to improve safety and the quality of life in a specific river basin, in relation to an Action plan that identifies twelve lines of action and forty-nine activities or elementary actions.
The authors have proposed a collaboration, in relation to their decision problem, and the description of the SISTI application to the problem of disaster resilience, and its steps and results have been used to explain the possible role of this methodological approach. This collaboration, which is currently underway, may show these Piedmont Region actors what MC modelling is and how MC methods work in practice, and an actual decision aid intervention may then be activated together with them.
A team of analysts with different expertise is currently structuring an MC *Intervention priority* model, in which the forty-nine activities were aggregated into possible (and not alternative) actions; this number is now between sixteen and nineteen. A logical analysis is being developed to define each single action more appropriately.
How does one evaluate these actions? There could be three main aspects, or dimensions of the model: *Quality* of an activity that is targeted towards safeguarding, rehabilitating and revitalizing these territorial areas; *Feasibility* (limited by the cost, possible conflicts and associated uncertainties) and

Internal consistency (when an action, in a specific line of action, is consistent with other lines of actions; if there is compatibility or synergy of an action with others; the consistency is limited if the result of an action is dependent on the results of others; ...). It is necessary to identify the criteria that could be associated to these dimensions and the data that are required to evaluate each possible action.
The main message for the Piedmont Region Department is that no specific MC model already exists; it has to be *constructed* each time with the actors of the decision process or with whoever wants to activate a decision process.
An MC model has to be transparent and easily accessible (i.e., understandable). The quality of the used data is important, but the model itself, in its first draft, is used to orient data acquisition, and the results of an MC method application can be used to revise both the model structure and its components.

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