SISTI: a multicriteria approach to structure complex decision problems

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Abstract
A decision aid process should be the result of interactions between analysts, decision makers, knowledge sources and stakeholders. However, decision aiding is sometimes required when the problem situation is so complex and new that a decision process is not yet activated and a formal decision system does not exist. Any type of interaction with the participants in the decision process becomes very difficult or even impossible. SISTI is a methodological approach that can be used to deal with these situations; it involves cyclic applications of a multicriteria method and the analyses of the results of these applications. Draft models and unprocessed data are used in the first applications, and sensitivity analysis is used to orient and control the model evolution. Several possible paths and modelling hypotheses can be iteratively proposed and tested in this knowledge structuring context, until the conceptual structure of the problem and its model are considered consistent with the situation. SISTI is a SImulated decision aid approach, because the decision process and system are not yet activated and a decision aid process is not oriented towards an immediate decision. However, it may also be described as a STImulating approach, because the study is developed together with a few actors that perceived the need to understand and propose structured elements for later phases of a still not activated decision process. SISTI is not a new multicriteria method, but rather a methodological modelling approach that uses a multicriteria method to structure a new and complex problem and to elaborate and validate a new model, when decision makers do not exist or cannot participate, or do not want to be involved in the decision aid process. This approach has been applied several times to clarify and structure complex situations and has been made more and more general so that it can be proposed to young practitioners to help them understand what a "good" model is and how the robustness of their conclusions can be improved.

Key words: decision aid, multicriteria models and methods, ELECTRE methods, model robustness

1 Introduction

A multicriteria decision aid (MCDA) process should be the result of interactions between analysts, decision makers and stakeholders, but decision aiding is sometimes required when a problem situation is new and a formal decision system, with well-defined rules, clear constraints, roles and relations of the actors, does not exist. This situation arises frequently when the need for the activation of innovative situations is perceived, recognised and proposed by actors (people or organisations) in connected decision processes, who need to study the specific nature of the problem situation before the activation of a new decision process, or by experts in a specific domain, in relation to a new and badly structured research theme.

Formal or informal documents may be available, and they may be used to understand the organisational context and define the decision problem. When structured knowledge and data are not available, the need for a course of action, in relation to the new and not sufficiently defined problem, generates a request for investigation, data acquisition and elaboration. However, these activities are often not clearly defined and not aimed at a specific goal, because of a lack of knowledge and specific competences. Moreover, their development 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, their use in new and ill-structured situations is often characterised by a very high multiplicity of items/indicators, because of the general belief that only a large amount of data can produce information. An integration of these data becomes difficult, and therefore risky, for at least two reasons: first because a logical structure of the problem and its information needs had not been generated before, and also because a synthesis of such different and "incomparable" elements, from different and often inaccessible sources, is not easy.

Adopting Simon's three-phase framework of Intelligence, Design and Choice (Simon, 1960; 1991), an MCDA process can also be developed in these situations, and oriented towards facilitating the Intelligence phase of a not yet institutional decision process, which requires understanding and problem structuring. However, some precautions as well as focused and full attention to the structuring, modelling and control activities are required.

MCDA adopts a *constructivist approach* in which a model, concepts and procedures are not envisaged to reflect a well-defined reality that exists independently of the actors, but as a communication tool (Tsoukias, 2007) that allows the participants in the decision process to carry forward a process of thinking and to talk about the problem (Genard and Pirlot, 2002). A constructivist approach cannot be applied 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 decision process and a decision system. However, an effective interaction with the few potentially involved actors and a preliminary study, which should include problem structuring, multicriteria (MC) modelling, application of MC methods and result analysis and validation, become useful to clarify a complex and new situation, reduce uncertainty and structure the relevant complexity elements in a "good" model of the problem situation.

For this reason, a new methodological approach has been proposed, and is here called SISTI, to operate in relation to new, unstructured and complex decision problems, in which the decision makers' involvement is very limited or even absent. This kind of intervention is a *SImulated* decision aiding intervention, because the decision process and the system are not yet activated and a decision aid process is not oriented towards an immediate decision. Moreover, it may 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 and consistent (and then stimulating) elements for later phases of a still not activated decision process.

Understanding the problem situation and structuring its different aspects is essential in the presence of limited knowledge of the problem and informative uncertainty. Literature proposes the activation of problem structuring methods (see Rosenhead, 1996, for the definition and Rosenhead and Mingers, 2001, for the theory and practice), to orient an analysis, to create a common interpretation and understanding space, to structure the analysed system and to elaborate a clear problem formulation. The aims are similar in the *description problem statement,* an approach that was introduced in (Roy, 1981) and described in (Roy, 1985; 1996) as *a rudimentary type of aid that poses rather than solves the problem*. This approach aims to clarify a decision situation by identifying and describing the elements of an MC model without making any recommendation. When the decision maker's active part in the decision aid process is limited or impossible, this approach can be facilitated by introducing an *open model*, as described in (Vanderpoten, 2002), that is, a framework that supports reflection, investigation and/or negotiation.

SISTI makes this framework operational in a descriptive problem statement, without the proposal of a new MC method. SISTI has been proposed to improve understanding, reduce uncertainty and then facilitate problem structuring and modelling using a multicriteria approach (which connects the possibility of using MC methods with a specific way of acting on representations of a different nature and formalisation level, as described in de Montgolfier and Bertier, 1978) and to propose the logic and terminology of MC methods, from the beginning of an intervention. This methodological approach has been stimulated by the requests of decision aiding in these difficult decision situations, but also by the purpose of improving the modelling ability of students, young researchers and practitioners.

The main factors that characterise SISTI are described in the second section, with details of the activities that are required to implement the approach and the description of the SISTI evolution from an unusual intervention to a methodology. In the third section, SISTI is analysed in relation to a specific application in which visualization and comparison of different results are essential elements. The potentialities and drawbacks of SISTI and the need to make SISTI less demanding in practice are synthesised in the conclusions.

2 The SISTI approach to structure a decision problem

A new problem situation, in a given organisational context, requires a perspective and a specifically orientated decision aid process to identify the main complexity and uncertainty factors, and then to use this knowledge in order to control uncertainty and make complexity explicit and "manageable" by means of structured concepts, models and consistent methods.

Sometimes an unstructured problem and complex decision context make it necessary to combine a problem structuring method and an MC method, as described in (Belton et al, 1997; Bana e Costa, 1999; Rosenhead and Mingers, 2001) and more recently in (Petkov et al, 2007; Montibeller et al, 2008; Norese et al, 2008; Stewart et al, 2010; Belton and Stewart, 2010). A drawback of this interesting multi-methodology approach could be the need to introduce two different methodological approaches in a real and "messy" decision context. SISTI can instead be used to face these situations by means of the introduction of only one methodological approach and its formal language, both to structure the problem and to use MC methods to recommend possible solutions or conclusions.

In general, an MCDA process is developed in interaction with decision makers and stakeholders. However, when the problem is new and not sufficiently structured, their roles are often not yet clearly defined. If the problem does not require an immediate decision, the main aim of a decision aid intervention may be the understanding of the situation, and SISTI is a methodological approach that can be proposed for this kind of MCDA intervention. When an intervention starts, a realistic representation of the problem at hand is ill structured or unstructured. The original problem formulation gradually evolves in the course of the process and some aspects may change importance level or have to be determined and consolidated. The advantage of using the MCDA framework as a structuring template, to guide the representation of the "mess" as a problem defined in terms of criteria, alternatives, uncertainties, stakeholders and environment, "is that the transition from divergent structuring to convergent analysis is essentially seamless" (Belton and Stewart, 2010).

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 descriptive and procedural terminology of each specific analysis field;
- 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.

SISTI is a model-based process that is activated to develop a sequence of temporary MC models oriented towards clarifying the situation, reducing uncertainty, converging towards a robust model that is consistent with the problem situation and proposing an effective approach for the later phases of a decision process.

SISTI includes a recurring cycle of different activities. At the beginning, a draft MC model, which may be taken from literature, such as the expression of the experts in the involved fields, or may be set up directly on the basis of the examined context, is employed only as a basis of reasoning, to represent some first conceptual hypotheses in formal terms and to activate the first SISTI cycle. An MC method and a critical analysis of the result of its application to a model are used here, and at each iteration, to identify any weakness elements of the result and therefore of the model and/or of the modelling hypothesis that has led to the generation of the model. A sensitivity analysis (which concentrates attention on how the result changes in relation to the values of each single parameter) is developed in relation to the identified characteristics of the result. A structured synthesis of these results is used to verify whether a marginal or structural change in the (formal or conceptual) model would be possible and could generate a useful improvement.

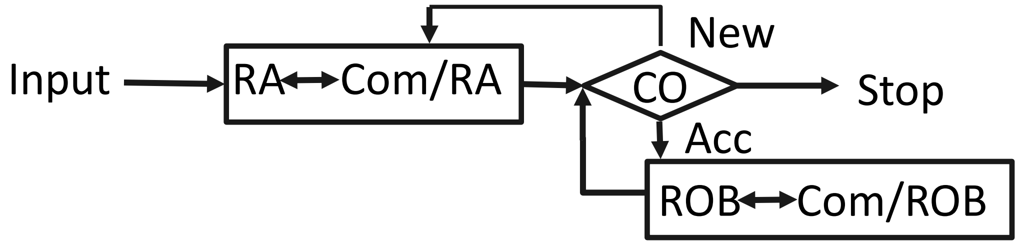

Figure 1 – Logical sequence of the SISTI activities

This sequence of activities (identification of the main characteristics of the result, development of a sensitivity analysis and translation of its result into an easily understandable framework that can be used in a communication context) can be defined a result analysis (RA) procedure (see Figure 1). RA is developed at a technical level, but its temporary results have to be analysed with the few actors involved in the various steps of the SISTI process (Com/RA). A collective visualisation of some scenarios, which concentrates attention on how the result changes in relation to the values of some parameters, and the examination of possible weakness elements of a result produce new knowledge and may include elements that stimulate a marginal or structural change of the model. A collective analysis of these change proposals is required to control the evolution of the process (CO), and it should first suggest a very limited model evolution (only a single parameter of the model needs to be changed), or less marginal changes (when a combination of parameters needs to be changed). At this point, "New" after CO implies new method applications to each model variant and then new cycles (RA plus Com/RA). The conceptual validity of each modelling hypothesis and the logical validity of each new version of the formal model (using the terminology of Landry et al, 1983 and Oral and Kettani, 1993) are tested and evaluated at each iteration in relation to internal consistency and external validity criteria (Genard and Pirlot, 2002), and compared with other results of the original model and of the previously tested model variants (CO).

A certain sequence of improvements may not produce interesting results. If some validity criteria are not satisfied, CO can require a more complex change of some structural elements of the model, whereby one criterion is added at a time or modified and, if these changes are not sufficient, the logical structure of the model is analysed and improved, or the problem formulation is changed and the model is connected to the new problem. Each modelling activity is completed with the application of an MC method to the new model version.

The passage from one model revision to another more viable one may be perceived as normal, logic or essential, but a cycle of iterative tests is often required in this learning process. If the structure and parameters of a model evolve too quickly, they can be exposed to the risk of accepting badly formulated and not fully validated hypotheses or of losing the actual meaning of each modification, because of, for example, the contemporary evolving of different elements.

Only when the modelling hypotheses and the last formal model have been considered acceptable ("Acc", after CO), can a robustness analysis be developed at a technical and collective level (ROB plus Com/ROB) in a new SISTI cycle, with the aim of testing the robustness of the collectively verified model (CO), rather than the robustness of the results, in order to stop the process or to activate a new SISTI cycle (Roy, 1998).

2.1 From some unusual interventions to SISTI

SISTI should be applied in relation to problem situations in which a constructive approach is made impossible because a decision process is not yet activated and the MCDA intervention is required to facilitate its future activation. MC models, concepts and procedures cannot be used as a communication tool for the participants in the decision process, but their potentiality, in terms of transparency and possible inclusion of different knowledge elements, can facilitate the structuring of a *conceptual model* (as it is defined in Landry et al, 1983), which includes all the main aspects, requirements and uncertainties associated with the problem situation. The conceptual model structure is the same as that of an MC model (action and criteria), but the passage from a conceptual model to the development of a formal representation of the problem situation *(the formal model)*, specifically oriented towards the application of an MC method, is the result of cycles of method applications, result analysis, proposals of model improvement and control of the process.

The documentation of the adopted logical paths and the main steps of the learning process facilitates a collective analysis of the process and above all of the evolution of the original problem formulation and importance of some aspects of the problem in the model. The often nonlinear path of a SISTI intervention stimulates new visions of the situation, orients the attention of stakeholders, or potentially involved actors, towards the specific nature of the decision problem, and sometimes anticipates some possible uses of data, indicators and experts' judgements that can lead to the data and knowledge acquisition process.

The idea that produced SISTI originated from the analysis of two old applications of MC methods in "unusual" MCDA interventions in research contexts, in relation to a pharmacological trial (Balestra et al, 2001) and to a heavy rain, flooding and landslide event (Cavallo and Norese, 2001). When the clients are researchers involved in a new research topic, they may have data that need to be interpreted and translated into an organic and operational framework. The ELECTRE III method (Roy, 1978; 1990) was used in both of these interventions to structure and calibrate a "robust" MC model. The network of the involved actors included only domain experts and researchers, in both of the cases, and there was the possibility of using knowledge (from the clinical and biomedical research group in the first case and from the consequences of a specific event, in terms of erosion and slope instability, in the second) to create external criteria to evaluate the quality of the result. An application of ELECTRE III to the starting model produced completely unreliable results in both of the interventions. The analysis of these critical results was useful to recognise specific signs of weakness in the final pre-orders of the ELECTRE III applications. At the same time, the external validity criteria confirmed the poor quality of the results. The process of arriving at a robust model was particularly long and difficult in the first case (Balestra et al, 2001). However, the acquired experience made the intervention described in (Cavallo and Norese, 2001) quicker and easier.

The factors that positively affected the two model-based interventions (above all the use of external criteria to evaluate the quality of the results and the identification of internal consistency/inconsistency signs) were proposed to students of degree and master courses and tested in laboratories (Norese, 2006).

At that point, the logic of the procedure that is here called SISTI was generalised and tested in a new intervention for a consultancy company that supplies different services to the Italian Aviation Authority and to several Italian airport concessionaire companies, in order to introduce an innovation in the airport services and to facilitate the decision process of the company's clients (Norese and Carbone, 2014). This time, the ELECTRE Tri method (Roy and Bouyssou, 1993) was used to generate a robust MC model that could be used by the consultancy company with its clients. Specific procedures of sensitivity analysis were introduced and tested.

Another SISTI application was developed in relation to the quality and shortcomings of the adopted resilience indices, and this application is presented in the next section.

3 MC modelling of resilience problems

Over the last few decades, the concept of 'resilience' has gained much ground in a wide variety of academic disciplines. The definitions are different and each of them includes different concepts, such as flexibility, adaptation or reaction. Resilience would seem to be the answer to a wide range of problems and threats.

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 . The definition of resilience that was proposed in the ANDROID Programme was rich and detailed: resilience is something that can grow in ourselves, in our family and in our communities, as the result of an educational activity addressed to the prevention and minimisation of negative effects of adversities, natural events, disasters and so on; 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 result of interactions between the environmental, socio-political and economic 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.

An MC model was elaborated in 2014 in the ambit of the ANDROID Programme and in relation to a pilot case, 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.

A first SISTI iteration cycle (RA plus Com/RA plus CO and New) was activated to analyse the results of the ELECTRE III application to the model and to propose model improvements, new applications of the method and new analyses of the results. When marginal changes to the model were considered insufficient to improve the model, a structural change of the model was implemented and a second iteration cycle of SISTI was activated.

3.1 Original model and first SISTI iteration cycle

A large number 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 were transparent, and they applied a multicriteria method, ELECTRE III, to synthesise the evaluations and rank the analysed territorial units (21 municipalities of the Ombrone river basin in the Tuscany region in Italy, see Table 1 for the code used in the ELECTRE III applications and the population of each municipality) 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.

Table 1 - List of the municipalities

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

The structure of an MC model (main aspects, or model dimensions, and criteria that analytically make each dimension operational) and the model parameters directly express the decision makers' points of view. In a model oriented towards the use of an outranking method, the relative importance of the criteria (which only the decision makers can express, in order to verify whether a concordance of "important" criteria exists and may facilitate a decision) and the veto thresholds, which model the need to control the risk of a high discordance between evaluations (complementary principle to the concordance principle in the ELECTRE methods and all the outranking methods), are the parameters that mainly require the expression of the decision makers' points of view and preference systems. Other parameters (the indifference and preference thresholds) are often proposed to the decision makers as a technical proposal to reduce the uncertainty that may be associated with the data and the expressions of decision preference (see Roy, 1996).

The structure of the model in (Scarelli and Benanchi, 2014) consisted of two strategic aspects, or dimensions, and fourteen criteria, the first six in relation to the environmental dimension, with almost the same importance as the other eight criteria, in relation to the socio-economic dimension (as indicated in the literature). The criteria were taken from literature, as was their relative importance (the "weights"), because of the absence of decision makers in this pilot case. The indifference and preference thresholds were instead elaborated in relation to the low quality of the data (taken from official data bases, but not so consistent with the nature of the required evaluations) that were used to evaluate the territorial units. No veto thresholds were introduced into the model.

A careful analysis of the ELECTRE III application results, and of their possible limits, was considered essential to verify whether this resilience model was sufficiently accurate, could give suitable explanations for the different situations in the Ombrone basin and could be used to facilitate improvement actions (Norese et al, 2016; Norese and Scarelli, 2016).

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 (see an example in Figure 2) can include different paths between the best and the worst actions, the longest of which can be visualised as the vertical and can be considered the main path, while each lateral path indicates a situation of incomparability for at least one couple of actions 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 when the lateral paths appear in the intermediate part of the graph they do not compromise a clear definition of a ranking of the best actions (or of the worst, if the decision activity is oriented towards the elimination of the worst actions).

The number of lateral paths grows if the comparability of some actions is not so high, but a high number of lateral paths can sometimes be the sign of a difficult definition of some model parameters and above all of the veto thresholds. When MC modelling is particularly difficult (because the problem is new and complex, or because modelling is requested in a laboratory for students who can be considered inexpert practitioners), the final partial graph often presents several incomparable actions that may be the consequence of incomplete or unstructured models, or of non-consistent or wrong definitions of some parameters (Norese, 2006).

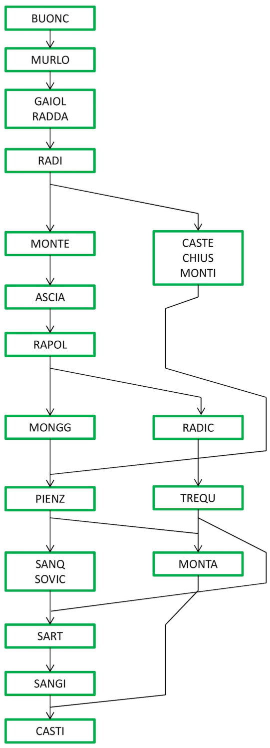

Figure 2 – Final partial graph of the original model

In this case, the original model included a high (but not very high) number of actions (21 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 synthesised logical inputs from literature and analytical inputs from the few available but not so reliable or consistent data.

The comparative visualisation of some final partial graphs that result from ELECTRE III applications to model variants could be facilitated by indices that characterise the quality of the different results. Some indices were proposed in this SISTI application (always referring to the total number of actions):

- the number of actions in the longest path (VP), whose order is clear,
- the number of the actions in the lateral path (LP = 1 –VP), which can be considered an index of incomparability (presence of incomparable actions),
- an index of indifference, and therefore of low/high discriminant power of the model, that represents the maximum number of actions that are assigned to the same class (II),
- another index of incomparability (RI) that is expressed in relation to the action that is incomparable with the maximum number of other actions (RI is the number of actions that are incomparable with this action and can indicate a situation of substantial, also if local, incomparability).

The final partial graph in Figure 2, which resulted from the ELECTRE III application to the original model, was quite interesting, with a long main path (VP = 15/21), few actions in the same class (II = 3/21), a not so high presence of incomparable actions (LP = 6/21), only in the intermediate part of the graph, but a rather high index of incomparability (RI = 7/21) in relation to two municipalities (Radicondoli - RADIC and Trequanda -TREQU).

At that point, some small changes were introduced to improve certain indifference and preference thresholds that were too large, and the result changed considerably in relation to each small change. When some veto thresholds were introduced, because the original model had not included any veto threshold, the final partial graph became disastrous (see Figure 3). The result of the ELECTRE III application to this model variant indicated the presence of several lateral paths and another critical and not so frequent element was present in the graph: just one best action was not included in this graph and a similar unusual situation emerged at the end of the ranking, with the consequence that the main path could not be identified.

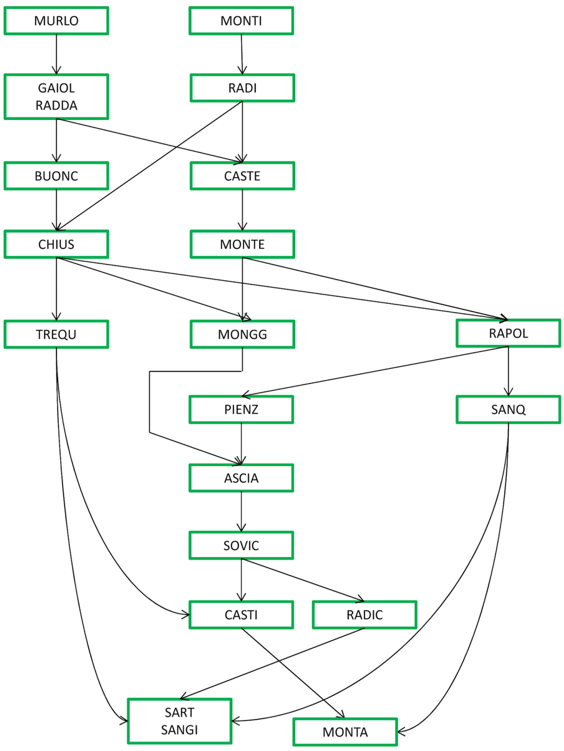

Figure 3 – Result after the inclusion of the veto thresholds in the original model

All the parameter changes that were introduced, step by step, to improve the model produced different results, and when some changes were introduced together it was evident how sensitive the result of the ELECTRE III application was to some parameter changes.

Each model variant was considered an improvement of some of the model parameters, but each variation produced less interesting results. At this point, the research team (which included the authors of the original model and the author of this paper together with a master thesis student) realised 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 and a new iteration cycle was activated.

3.2 The second SISTI iteration cycle and a new model

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 original model, which was analysed in terms of parameters (thresholds and modelling of the discordance principle) in the first iteration cycle, was then studied in terms of structure (the main conceptual aspects, or model dimensions, and a consistent family of criteria that analytically deal with these aspects (Roy, 1996)) and in relation to a possible evaluation process (choice of data-indicators-scales to be used in the evaluations).

A new and more specific decision problem was formulated by the research team, and three main aspects were identified to deal with the decision problem of a territorial agency that could allocate resources to improve the disaster resilience of the Ombrone river basin, in relation to the different *reaction capabilities* of the territorial units. In the Reaction capability model (see Table 2) some *Social aspects* and the *Ethical behaviour* of the involved actors are included as main aspects, because they can increase the reaction capability of each territorial unit; instead, *Risky behaviour* can reduce the reaction capability. These three main aspects were considered the dimensions of the new model (set up to activate a new SISTI iteration cycle), which included six of the fourteen criteria of the original model (Scarelli and Benanchi, 2014) and the related original evaluations.

Table 2 – Logical structure of the Reaction capability model

Model dimensions (aspects and possible data)	***Criteria***
Risky behaviour (anthropic impact on the environment, such as uncontrolled urbanisation, cemented riverbanks, uncontrolled use of aquifer layers, high values of CO2 emissions ….)	Uncontrolled ***Urbanisation,*** which could limit rainfall absorption (rate of urbanised 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)
Social aspects (% of working women, scholastic attendance, population characteristics, ….)	***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: INSTAT, the National Institute of Statistics) ***Progress in social life*** **(**rate of unemployed women with respect to the total population, source: Siena Province, Report on the labour market)
Ethical behaviour (Disaster prevention activities, such as naturalised river banks or education programmes, and awareness and interest in safeguarding the	***Environmental awareness*** (percentage of differentiated waste, source: Siena Province, Civil protection sector) ***Safeguarding the considered area****,* which could be expressed by the touristic attractiveness that motivates

environment, such as differentiated waste, alternative energy use, high territorial desirability, …)	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)

The definition of the model parameters was facilitated by the knowledge that had been created in the previous parameter improvement iteration cycle (pertaining to the veto, indifference and preference thresholds) and thanks to the clear structure of the new model that was able to facilitate a consistent definition of the criteria relative importance (in a logic of balancing the importance of the main aspects and of the criteria in relation to each aspect) and of the formulation of some policy scenarios. Three scenarios were introduced in relation to some possible policies: educating people to limit risky behaviour, funding civil protection and training on how to react in the case of disaster activities, and funding landscape preservation and environmental protection activities. Each possible policy was associated with 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 (in relation to the balanced scenario) produced a somewhat interesting result (see the first graph in Figure 4). Both the first actions and the others at the end of the ranking again appeared clear: there were two municipalities (RADDA, MONGG) together in the first position and only one in the last (SART). There was a main path that contained twelve of the twenty-one municipalities, but some lateral paths (signs of incomparability situations) were present, above all in the middle part of the graph.

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 and a comparative visualisation of the results (see the other three graphs in Figure 4) facilitated the analysis of weakness and strong points of the model for future decisions in relation to unpredictable policies.

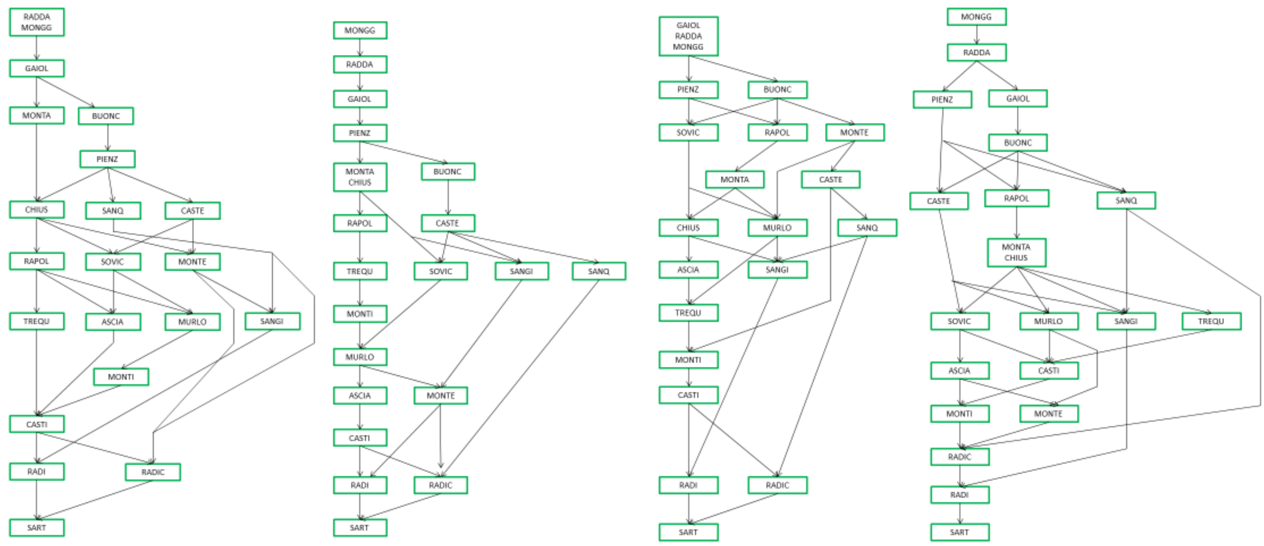

Figure 4 – Final partial graphs of the new model in four policy scenarios

Five municipalities (RADDA, MONGG, GAIOL, BUONC, PIENZ) always remained in the first positions and four (SART, RADI, RADIC, CASTI) in the last positions in the ranking. The other twelve municipalities remained in the middle part, although there were some changes in their relative positions and they always suffered from incomparability.

An analysis that was conducted to test the sensitivity of the new model result (in relation to the balanced scenario), 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 and the last municipalities, and only small changes in the middle part.

The new model seemed quite interesting, because the results were not so sensitive to the model parameters and allowed the study to came to some stable conclusions about the most and the least resilient municipalities. However, although the application of ELECTRE III to the model was not able to produce a clear ranking of all of the twenty-one municipalities (the maximum number of actions in the main path is fourteen in the four graphs in Figure 4), it confirmed their differentiation in three classes, as well as the sequence of the elements in the first and last classes. The several incomparability situations between the intermediate class elements limited the ranking capability and were unexplainable, because they were not consistent with the high quality of the model parameters and the apparent comparability of the municipalities of the Ombrone basin.

At that point, an investigation was activated to obtain external criteria and to analyse new aspects pertaining to the intermediate class components and to the few of them that clearly changed their position in the analysis of the policies/scenarios. Most of the analysed actions (see Table 1) are municipalities with just a few people, and the economic activities are predominantly of an agricultural and cattle breeding nature. Other municipalities are small, intact and picturesque Middle-Age villages, or small cities that are very famous throughout the world for their wine and/or touristic attractiveness. The latter municipalities showed the most unexpected results (incomparable with a high number of other actions and important changes in their position in relation to different scenarios). A “natural” incomparability between these municipalities and several others in this river basin had to be accepted and, as a consequence, their ranking in the form of a complete order had to be considered almost impossible.

A different and more effective approach would have been to assign the units to different reaction capability and resilience categories, by means of a sorting method, for example ELECTRE Tri (Roy and Bouyssou, 1993), 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. Specific attention should be paid in a future model to some criteria that could have a specific meaning for some elements of the analysed set and not for others, above all when the elements are very different. In most of the municipalities of Table 1 there is a very low level of industrialisation (and low $CO2$ emissions) and limited urbanisation. Their very poor "waste differentiation" performance may be the consequence of the natural attitude of the inhabitants (whose economic activities are predominantly of an agricultural and cattle breeding nature) 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 characterised 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).

3.3 From this result to future steps

This study started with an analysis of the results of an ELECTRE III application to a draft model, and continued with an examination of the model elements that could negatively influence the result. Some hypotheses of parameter change 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.

When each hypothesis of parameter change was analysed and implemented, without any clear improvements in the results and with an evident worsening of the result at the end, possible limits in the model structure were analysed and the structure was changed. A new model structure and a sequence of ELECTRE III applications to the new model, in relation to some policy/weight scenarios and parameter variants, produced more interesting results and the proposal of a new step of this SISTI application, which is currently underway (some first results are described in Norese, 2018).

Other SISTI applications have focussed on the central role of modelling in decision aiding, in terms of both adopting a certain perspective in which uncertainty is accepted and flexibility is favoured (as proposed in

Vanderpoten, 2002), and the key role of the model in communication is underlined (see Landry et al, 1996; Genard and Pirlot, 2002).

The previously presented SISTI application was more oriented towards improving the practitioners' knowledge of how a result should be interpreted, critically analysed and used to improve a model. Modelling is a very hard task, but analysis is an important activity, but a clear and detailed procedure does not exist in literature (at least in the MC field) and formulas "similar" to those proposed in the sensitivity other tasks are not easy either. Sensitivity analysis of an optimal solution are not present in the multicriteria analysis field.

The incomparability relation is a basic component of the outranking relation, but the interesting visualisation of incomparability in a partial final graph is often too difficult to be understood, at least for inexpert practitioners and young researchers. For this reason, some description of the graphs' meaning and a proposal of indices of result quality were proposed in this presentation of a SISTI application, in order to improve and generalize visualization and critical analysis of this kind of result. An SW tool could include and visualise parameters that describe the main elements of a final partial graph and its evolution during the modelling process, and could also propose other visualisation tools, such as the Surmesure diagram that is described in (Rogers et al, 2000). Some difficulties that the end users encounter when they use ELECTRE III are linked to the not so easy interpretation of its results, above all when the problem is new and several actions are compared.

The SISTI application to the resilience problems is not concluded, but the last step, which is currently underway, has the aim to arrive at a complete and well documented application that can be proposed as a way to improve model and problem formulation by means of an informed use of multicriteria methods and as a stimulus to improve the effectiveness of some MC SW tools in the modelling and result analysis activities.

4 Conclusions

Decision aiding and interaction with the participants in a decision process become difficult when a problem situations is so new that a decision process is not yet activated and a formal decision system does not exist, but there is already the perception of an unstructured decision problem.

SISTI is a methodological approach that can be used to deal with these situations by means of cyclic applications of a multicriteria method to a model, which has been developed without decision makers, and analyses of the results of these applications, to study how the uncertainty of an output can be connected to different sources of uncertainty in the model structure and parameters, which are the inputs of the method application. Some alternative assumptions on the choice of the parameters (or on the model structure), which could generate uncertainty or criticalities in the results, can be tested to determine their impact on the results, and then used. An identification of the inputs that cause significant uncertainty in the output should orient attention towards improving a model that cannot be validated by means of a natural interaction between decision makers and analysts. A comparison of the results, and above all of their unusual elements, with a different type of information about these elements (the external criteria) is essential to orient each cycle of modelling.

SISTI is a decision aid approach that *poses rather solves the problem* (Roy, 1996) during a study that simulates an interaction with decision makers and is instead developed together with a few actors who perceive the need to understand and propose structured elements for later phases of a still not activated decision process. SISTI is not a new multicriteria method, it is instead a proposal of using a multicriteria method with the same aim of a problem structuring method, to structure a new and complex problem and to elaborate and validate an open model (Vanderpoten, 2002) when decision makers do not exist, or cannot participate in, or do not want to be involved in the decision aid process. The study is not directly oriented towards a forthcoming and hard decision, but it has the aim of stimulating new points of view and perceptions of the problem situation and of increasing the actors' knowledge of the situation by means of the understanding of the expected and unexpected relationships between a model and the always clearer results of an MC method application.

The main drawback of SISTI 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.

Another shortcoming is that this approach, which has been applied several times to clarify and structure complex situations, is not general enough to be proposed to young researchers and inexpert practitioners, to help them understand what a "good" model is and how the robustness of their conclusions can be improved. The students' reactions to this message underlined this problem in the past and the need for an SW tool that could play an important role in this modelling process, by facilitating the comparison of the different results and the visualisation of the impact on the results that is generated by each parameter assumption or modelling scenario.

The integration of some "modelling assistants" that can be essential for MC decision aid, to improve the important role that an SW tool could play (but currently does not play) in the modelling process, was proposed during the 15th Decision Deck Workshop in Lisbon (Norese et al, 2018). This possible improvement, together with the description of a complete and not so complex case as a guideline for practitioners and young researchers, should make SISTI more and more general and easier to apply.

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