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A Participatory Approach to Assess the Effectiveness of Responses to Cope With Flood Risk

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An Economic Assessment of the Impacts of the MOSE Barriers on Venice Port Activities

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Summary

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Keywords: Participatory Process, Climate Change, Flood Risk, Decision Support System, Multi Criteria Analysis, MCA, Eliciting Responses, Evaluating Responses, Integrated Water Resources Management, IWRM, Mulino Decision Support System, mDSS

JEL Classification: C61, Q01, Q54, Q56, Q58

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Abstract

This work illustrates the preliminary findings of a participatory research process aimed at identifying responses for sustainable water management in a climate change perspective, in two river basins in Europe and Asia. The paper describes the methodology implemented through local workshops, aimed at eliciting and evaluating possible responses to flood risk. Participatory workshops allowed for the identification of four categories of possible responses and a set of nine evaluation criteria, three for each of the three pillars of sustainable development. The main outcome of such activities consists in the ranking of broad response categories instrumental to the objective of the Brahmatwinn research project, i.e. the identification of Integrated Water Resource Management Strategies (IWRMS) based upon the issues and preferences elicited from local experts. The mDSS tool was used to facilitate transparent and robust management of the information collected through Multi-Criteria Decision Analysis (MCDA) and communication of the outputs.

Key words: participatory process; climate change; flood risk; decision support system; multi criteria analysis; MCA; eliciting responses; evaluating responses; integrated water resources management; IWRM; Mulino decision support system, mDSS.

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1. Introduction

According to the last assessment report released by IPCC in 2007, climate has been changing and will continue to change even if greenhouse gas (GHGs) emissions are reduced to meet the targets of the Kyoto protocol (IPCC, 2007; Mace, 2005). There is a call for policy measures both for emission abatement, i.e. *mitigation*, and for impact reduction, i.e. *adaptation*. Indeed, even if effective emission reduction policies were implemented, we would still need to adapt: as a consequence of lags in the response of the climate system to GHGs already emitted in the atmosphere, we will nonetheless experience an increase in temperature with respect to previously observed values (IPCC 2007). Poor and developing countries in particular, which are only marginally responsible for anthropogenic climate change, will be most affected by the expected impacts (Heltberg et al., 2009). Climate change is therefore also an equity issue and adaptation policies should continue to have a role in international negotiations (Mace, 2005).

Not giving the right importance to adaptation would imply burdening those sectors that will bear the biggest impacts of climate change, such as water provisioning in river basins fed by glacier melt (Mace, 2005). Places already facing unstable water regimes and resource availability are most likely to suffer from water shortages, but also flood risks may be exacerbated in different seasons (e.g. the post-monsoon season in the Himalayas) and therefore improving water management now would also mean investigating adaptation to future scenarios (EC, 2009). Management choices are becoming more and more urgent.

Adaptation has been on the agenda since the Earth Summit in Rio (1992) and reference to adaptation can also be found in the United Nations Framework Convention on Climate Change (UNFCCC, 1992) and the Kyoto Protocol (1997). According to the UNFCCC Annex II, countries that ratified the convention made a legally binding commitment to fund adaptation in developing countries (www.unfccc.int; Mace, 2005). However, it is not until the Marrakech Accords (2001) that adaptation policies and projects have gained importance (Schipper, 2006) and in the Fourth Assessment Report of the IPCC (2007), we find reference to a demand for research on adaptation, mitigation and development.

Projected climate changes for the 21st century in the mountains of the world is two to three times greater than the change observed in the 20th century (Nogues-Bravo et al., 2007). All mountains are expected to warm, but warming will vary with location. Depending on which IPCC-SRES scenario is considered, in 2055 mid-latitude mountains of Asia have a projected temperature increase between 2.7 and 3.8°C, while mid-latitude mountains of Europe have a projected temperature increase between 2.3 and 3.3 °C (Nogues-Bravo et al., 2007). However, assessing impacts of this temperature change is not so straightforward because of non-linear feedbacks between impacts and because of uncertainty in the downscaling of Global Circulation Models (Nogues-Bravo et al., 2007).

Glaciers have been retreating and decreasing in volume since the end of the 1980s, similarly mountain snowpack has been significantly decreasing. Thus their role as water reservoirs has been negatively affected, and this has in turn affected the hydrologic regimes (Nogues-Bravo et al., 2007) and in particular the water storage capacity of mountains (Stewart, 2009). Catchments that rely on either glacier or snowpack melt, or both, as a source of water will be significantly affected by climate change (Viviroli and Weingartner, 2004; Stewart, 2009). For example, earlier snowmelt might result in winter and spring floods, thus in longer summer droughts (Stewart, 2009). Climate change will also decrease water availability in lowlands that are influenced by discharge from contiguous mountain ranges (Messerli et al., 2004). Relatively high mountain run-off can be found in semi-arid and arid regions, such as the Himalayas, but also in some humid regions, such as the European Alps (Viviroli et al., 2007). Hence we can say that mountains are important for the hydrology of the lowlands, especially when lowlands are arid, as is the case of the Himalayas (Viviroli and Weingartner, 2004; Messerli et al., 2004). Though far from each other from a physical and social point of view, the populations of different parts of the world will be facing similar problems.

Moreover, large catchments are often trans-boundary. Hence research needs to span over borders encompassing the whole catchment and cooperation projects should be set up to enhance expertise and mutual learning (Renn, 2006). The latter can be very beneficial and needs to be horizontal, involving people who share background and knowledge on the same issue in different places. However, mutual learning should also be vertical, integrating knowledge coming from different sciences, including knowledge from stakeholders. Participatory processes can be of many kinds and defining what is the goal of the participatory process is necessary before identifying the most suitable approach for the given case (Irvin and Stansbury, 2004).

Stakeholders' involvement is at the basis of any participatory process of policy/decision making, such as the development of Integrated Water Resource Management (IWRM) plans and projects. Stakeholders hold necessary information that should be used in social and eco-system management, thus facilitating the exploitation of scientific knowledge with social relevance (De La Vega-Leinert et al., 2008). In the context of research projects, the participation of stakeholders can contribute significantly to the achievement of project outcomes that are better suited to fulfil society's needs (de La Vega-Leinert et al., 2008), thus increasing the impacts of research efforts. During participatory processes mutual learning occurs between scientists and stakeholders, new opinions can be expressed, problems can be addressed, technical expertise combined, agreements reached, and compromise solutions found if all vested interests are voiced (Renn, 2006).

In parallel to the increasing emphasis on public participation in IWRM, there is also an increasing attention to the need for efficient tools to support the management of those processes and to the role that could be played by information and communication technologies (ICT), mathematical simulation models and Decision Support System (DSS) tools, in particular. In the context of climate change research the first category of tools may provide scientifically-based scenarios and projections – prerequisites for any planning activity - while DSS tools may provide the ground for bridging the scientific contributions (i.e. by further elaborating model outcomes) and decision/policy making processes, including the management of the participation of different actors (e.g. policy makers, local experts, dwellers, etc.). Despite the theoretical potential, traditional modelling techniques have shown limited impacts on policy making, especially with respect to complex systems such as those involved in natural resource management, and one of the problems most often mentioned is the limited involvement of stakeholders and potential users (Geurts and Joldersma, 2001). Hence, the need emerges to develop new tools which combine the potentials of advanced ICT tools and robust participatory approaches (Mysiak et al., 2005). Such instruments could be identified as DSS methods and tools providing participatory modelling functionality, in which the formulation of a conceptual model and its formalisation is carried out by disciplinary experts with the direct involvement of stakeholders in a way that is coherent with the so-called "hard science" modelling approaches to be adopted (Sgobbi and Giupponi, 2007).

Having recognised the relevance of the issues briefly discussed above, the Brahmatwinn research project[1] has planned a participatory process to integrate scientific and stakeholders' knowledge to deal with water management, climate change and Alpine regions in Europe and Asia. For this purpose, a programme of local workshops in two twinned river basins, the Upper Brahmaputra and the Upper Danube (UBRB and UDRB, respectively), has been defined in parallel to the more common research activities in the various disciplinary fields (dynamic climatology, hydrology, sociology, economics, etc.) relevant for the integrated assessment of climate change impacts and the development of adaptation strategies. The integration of the two research streams allowed the project to facilitate the dissemination of results of scientific, data-driven analyses regarding the drivers of change on the river socio-ecosystems and related impacts on the one hand and, on the other, to orient and consolidate

[1] Project title: Twinning European and South Asian River Basins to enhance capacity and implement adaptive management approaches. (BRAHMATWINN). Project no: GOCE -036952. Research funded by the European Community, SUSTDEV-2005-3.II.3.6: Twinning European/third countries river basins.

those investigations according to the feedback collected through the involvement of local actors (LAs)[2].

In this article we present a methodological and operational proposal for the management of decision processes in a participatory context for the development of an IWRM plan, considering the climate change perspectives and adaptation needs too. In particular some of the methods and findings of the Brahmatwinn Project are illustrated, by referring to the participatory process carried out in the two river basins in Europe and Asia: UDRB and UBRB. In Section 2, the methodological framework adopted for the case studies, the information base and the DSS design is introduced. In Section 3 the results of the application of the proposed approach to the Brahmatwinn project are presented, and in Section 4 the outcomes obtained are discussed and some conclusive remarks are drawn.

2. Methods

2.1. The methodological framework

The approach adopted for the analysis of alternative adaptation responses is based on the NetSyMoD methodological framework (Giupponi et al., 2008) for the management of participatory modelling and decision processes (Figure 1).

The framework is organised in six main phases. The first three (*Actors' Analysis, Problem Analysis, Creative System Modelling*) provided the Brahmatwinn Project with (1) an in depth analysis of general problems related to water resources management in the two upper river basins, with the participation of the communities of interested parties in the case study areas, and (2) mental model representations of the problems, i.e. qualitative descriptions of the causal links between the various components of the local socio-ecosystems by means of cognitive maps clustered in order to be consistent with the DPSIR framework (Driving forces, Pressures, State, Impacts, and Responses; EEA, 1999), used as an upper – aggregated – level communication interface. The subsequent phases, *DSS Design* and *Analysis of Options*, were the object of the activities carried out at the two workshops discussed in this paper, and contributed to the design and evaluation of a set of alternative responses obtained with group elicitation techniques and with the application of the DSS tool. The last phase, *Actions and Monitoring*, is beyond the scope of the research project.

The *DSS Design* phase consists of system specification and development of software tools capable of managing the data required for informed and robust decisions. The *Analysis of Options* is performed with the mDSS software (Mulino DSS) through Multi Criteria Decision Analysis (MCDA), which provides a framework for decision analysis, and with a set of techniques aiming at the elicitation and aggregation of decision preferences (Figueira et al., 2005). In this case, MCDA demonstrates how to assist a decision maker, or a group of decision makers, in identifying the best alternative from a range of alternatives in an environment of conflicting and competing criteria and interests (Belton and Stewart, 2002).

2.2. The background information

The participation of local actors in the two case studies was achieved through a series of workshops (WSs) in which brainstorming techniques were initially used to elicit the most relevant local issues and the most promising responses - potential or in place - to cope with flood risk in a climate change perspective. In parallel, disciplinary experts of the project explored the problems, identified data sources and developed a system of representative indicators.

In order to combine and compare the information from both the researchers and the local actors belonging to the two case study sites, an extensive Integrated Indicator Table (IIT) was developed,

[2] We have preferred to use the term local actor (LA), to identify all the people involved in the case study activities instead of the more commonly used term stakeholder, to emphasise the fact that they were people who did not belong to the project consortium (typically local experts or policy makers), involved in project activities by partners responsible for the management of case studies to provide advice and steer project activities, without the ambition to assess their representativeness with robust procedures, such as Social Network Analysis.

which represented the knowledge base for the activities described herein. On the left side of the table a hierarchical classification of the information relevant to the whole research project is reported, starting with the level of greatest aggregation, i.e. the four “Themes” (Environmental, Economic, Social and Governance). The “Themes” are sub-divided into “Domains”, which are further segmented into “Sub-domains”. Such a categorisation of relevant information for the project was developed with a Delphi technique in a series of steps, in which all the project partners were involved. At the highest level of detail, “Indicators” were identified by partners (one or more per Sub-domain) as the means of providing quantitative assessment of the various typologies of information dealt with by the project. The left hand side of the IIT thus represents a comprehensive catalogue of the information provided in the project. On the right hand side of the IIT, the issues identified by local actors during the workshops dedicated to the NetSyMoD phases of *Problem Analysis* and *Creative System Modelling* were then assigned to ”Sub-domains”, thus providing an interface between the potential supply of information from project activities, and the demand for information from potential beneficiaries. Sub-domains were also assigned to the five nodes of the DPSIR framework, in view of the utilisation of the DSS adopted by the project, i.e. mDSS (Giupponi, 2007; www.netsymod.eu/mdss), which uses this framework for the analysis of the causal interactions between human activities and the environment (see Figure 2).

All the items relevant to the identification of possible IWRM strategies to cope with climate change adaptation needs in the two areas were categorised as Responses (according to the DPSIR definition) and classified in four broad typologies:

1. ENG-LAND: Engineering Solutions and Land Management (e.g. dam construction, river network maintenance, soil conservation practices, etc.);

2. GOV-INST: Investments in Governance and Institutional Strength (e.g. accountability and transparency in government actions, enforcement of existing regulations, flood insurance, etc.);

3. KNOW-CAP: Knowledge Improvement and Capacity Building (e.g. awareness raising activities, dissemination of scientific knowledge, training of public employees, etc.);

4. PLANNING: Solution based on planning instruments (e.g. design and implementation of relief and rehabilitation plans, hazard zoning, etc.).

A sixth category, Exogenous Drivers (ED), was introduced to classify indicators describing climate change projections.

2.3. The DSS Design and implementation

Building upon the information acquired in the participatory activities carried out in the first two years of the project and referred to in the first three NetSyMoD phases, two new workshops were organised, one in Salzburg, Austria (UDRB) and one in Kathmandu, Nepal (UBRB), with the aim of testing the proposed methodology and providing the project consortium with a preliminary assessment of the expected effectiveness of the four response categories to cope with flood risks under the pressure of climate change in the two river basins. In order to guarantee the comparability of the results of the two river basins, both workshops were structured using the same methodology and procedure, designed with the purpose of building a common language, knowledge and understanding of the problems within the groups of local actors, and between them and the research consortium.

Following the techniques developed in a series of previous applications of the NetSyMoD approach, the workshops started with the **presentation** of the goals and of the preliminary results of the downscaling of climate change (CC) scenarios, by means of storylines developed by the project climatologists (Institute for Atmospheric and Environmental Sciences of Johann-Wolfgang Goethe

University, JWG), focusing on the possible effects of CC on local water resources over the coming 40 years[3].

Having introduced the problem and the scenarios, a **brainstorming** session was conducted to elicit and consolidate the sets of possible responses within the four main categories that had been defined during the previous project meetings. This section created the basis for the correct implementation of the ensuing steps, and led to the identification of sub-categories and specific actions, within the proposed four major categories of responses, in order to:

- consolidate the range of possible adaptive responses to cope with flood risk and CC;
- develop a common understanding of the broad classes of adaptive responses;
- enhance the confrontation among LAs regarding the needs and the opportunities of intervention in the river basin;
- analyse and compare LAs' opinions from the twinned river basins in Europe and Asia.

Having consolidated the identification of responses, the participants were asked to move to the **selection of the criteria** for the evaluation of responses, from the Sub-domains listed in the IIT. Every participant was asked to rank them in terms of relevance for evaluating the responses, by identifying the first, second and third most important criterion (i.e. Sub-domain) within the three lists pertaining to the Economic, Social and Environmental Domains. The selection was carried out by every LA through a voting exercise, then the votes were summed up and the criteria with the highest scores selected. In the case of equal performance, the criterion voted by the highest number of LAs was chosen.

After having identified the evaluation criteria, participants were involved in the exercise of **attributing criteria weights**. Criteria weights provide information about the relative relevance to be given to the criteria, within the set of nine selected (three per sustainability Theme), in order to identify the most promising responses to cope with the issue of flooding under the pressure of CC. The criteria weighting procedure was based on a method proposed by Simos (1990) and revised by Figueira and Roy (2002). Following the method, two sets of cards are provided to each participant. In the coloured set, each card identifies one of the objects to be weighted (in this case the criterion) and the weighting is expressed by placing the cards according to their ranking. The set of white (blank) cards allows participants to emphasise differences between ranks by interposing one or more white cards between two successive coloured cards. The participants are also asked to express a measure of the overall multiplicative distance between the first and the last object[4]. Using the ranking and the overall difference, criteria weights are subsequently calculated, by means of a simple algorithm, which converts ranks into real numbers that sum up to 1, i.e. the vector of weights to be applied to the evaluation criteria in the subsequent MCDA. Experience shows that this method is very appropriate for these workshops, because it provides a simple and effective approach for weighting, without the need of a computer lab.

Criteria and responses were used to define the entries of the Analysis Matrix (AM) (9 rows and 4 columns for criteria and response categories respectively) and, together with the weight vectors, they were utilised for the subsequent evaluation exercise, by means of the MCDA methods provided by the mDSS software. Participants were asked to proceed to **fill in the matrix** by evaluating the potential effectiveness of each response (columns) in coping with the issues expressed by the criteria (rows) by means of a Likert scale (from 1 to 5 ranging from "very high effectiveness" to "very low effectiveness"). Forms were distributed to all the participants with the question: "What is the potential effectiveness of the responses (columns) in coping with the issues expressed by the criteria (rows)?" followed by the

[3] Climate Change scenarios provided climate simulations using three IPCC-SRES scenarios (A1B, A2 and B1) and the COMMIT scenario (i.e. the consequence of committing world economies to limit GHG concentrations at 2000 levels), five data sets (GPCC, UDEL, CRU, EAD, F&S) and four models (ERA40, CLM-ERA40, ECHAM5, ECHAM5-Γ).

[4] For practical reasons, the card sets were substituted by form sheets with graphical representations of the cards, to be compiled by colouring or coding blank cards, thus facilitating the recording and collection of data.

AM, where the Likert scale was reported in every cell and where participants were required to place one tick mark expressing their preference.

Moreover, in accordance with the “Guidance Notes for the lead authors of IPCC 4th Assessment Report on Addressing Uncertainties” (IPCC, 2005), a second scale was added in every cell to analyse the degree of confidence and uncertainty related to local actors’ opinion. Here, the concept of uncertainty was related to the unpredictability of the effectiveness of the responses, which can be due to various reasons: e.g. the unpredictable projections of human behaviour, the unpredictable evolution of political systems, the chaotic components of the eco-system, etc. Thus, a second question, “What is your degree of confidence in giving your answer, considering its predictability?” was added to the form sheets and a second Likert scale was added in every cell of the AM.

The compilation of the AM concluded the first part of the NetSyMoD workshop. All the data collected were coded with a spreadsheet software and then passed to the mDSS tool, for Multi-Criteria Analysis (MCA) and Group Decision Making (GDM). The mDSS software allowed for the comparison of the alternative options using MCA techniques, by operating parallel evaluation processes, representing the preferences of each participant. The alternative options (i.e. the four categories of responses), were assessed on the basis of their contributions to solve the expected impact due to flooding under a CC scenario, and expressed through the criteria values and their weights.

In practice, the qualitative evaluations contained in the Analysis Matrix were transformed into scores that expressed the performances of the responses by applying a normalisation procedure, which converted them into a continuous scale from zero to one, subsequently processed by means of MCA decision rules. For the purposes of the workshop the Electre III decision rule was utilised to rank the alternative responses. Electre III adopts a pairwise comparison of the alternatives, so it is computationally rather demanding, but very simple to be applied by practitioners. It imposes so-called outranking relation on a set of alternatives. An alternative ***a*** outranks an alternative ***b*** if ***a*** is at least as good as ***b*** and there is no strong argument against. Results of individual outranking procedures were subsequently combined in a Group Decision Making procedure by means of the Borda rule. The Borda rule is one of the most simple outranking procedures and it is provided by the mDSS software, in which a total Borda mark is calculated by summing up all the (reversed) rankings obtained by the LAs (i.e. the best option is given, in this case, a value of 3, while the worst the fourth, is given a value of 0). The best (consensus) option is obviously the one with highest total Borda mark.

All the results of the data processing were reported in a plenary session to the participants in the final part of the NetSyMoD workshop.

3. Results

According to the preliminary results of the downscaled CC scenarios, in both study areas, intensified weather events are expected to cause an increase in rainfall in the wet season and of droughts during the dry periods. Climate change could thus exacerbate the uncertainty related to water availability and its quality and the occurrence of extreme events, as Brahmatwinn climatologists have suggested. The procedure described above had as output the **selection of the criteria** from the Integrated Indicators Table (IIT). LAs in the two river basins converged on the same five criteria, out of nine, choosing from a set of 40 criteria listed in the IIT (15 social criteria, 17 environmental criteria, and 8 economic criteria). Such a relatively large number of common selected criteria reveals that the two river basins, even though characterised by different geographical locations, ecological, social and economic dimensions, present similar problems and issues, at least in the perception of LAs participating in the project meetings. This finding is very useful in addressing further research efforts more effectively, focusing not only on the analysis of the comparable relevant issues, but on specific indicators pertinent at the local level. These results have been circulated among the research consortium to direct the attention of modellers in the next phase of the project, where quantitative indicators will be produced in both case studies.

Besides the emergence of the above-listed important similarities in the opinions of LAs in the two river basins, further outcomes of the vote distribution analysis in each river basin are worth mentioning. As far as social criteria are concerned, the distribution of votes shows that, in both areas, the criteria relevant only in one or the other river basin were also the most voted. This demonstrates that even if we can pinpoint similarities in the two areas from a social point of view, strong attention has to be put on the peculiarities of each geographical area, trying to avoid a trite generalisation of problems. In the Upper Brahmaputra River Basin, to which mainly low income countries belong, "*Poverty*" is picked as the most relevant criterion by a broad majority of local actors, highlighting how the poverty level and low life styles strongly affect the significance of flooding damages. Indeed, any response to deal with poverty problems would not reduce flooding occurrence, but would lower flood risk vulnerability and increase the adaptive capacity of the socio-ecosystem. In the UDRB, instead, LAs concentrated their votes on "*Housing settlements*" and "*Population Dynamics*", showing the different perspective in the European area when considering flood risk. According to LAs, the flood risk in the UDRB seems to be affected mostly by housing concentration, high population density and the concentration of residential constructions in areas exposed to flood risk.

The preferences expressed on environmental criteria do not reveal a strong convergence of opinion to any specific criteria. In both river basins, a variety of different environmental indicators were considered as relevant. This is particularly marked in the UDRB, whereas in the UBRB, with the exception of "*Precipitation*", we can recognise a clear agreement on the importance of the three criteria "*Vulnerability*", "*Basin morphology*" and "*Forest management*"[5]. It is also interesting to notice that on average "*Forest management*" was considered relevant only in the UBRB. Forest management is, indeed, a historically important issue in this area, and probably as a result of this, LAs considered this criterion one of the most relevant also for evaluating the effectiveness of flood risk reduction policies.

With respect to the economic criteria, "*Agriculture production*" was considered as one of the most relevant in both river basins, but more so in the Upper Brahmaputra. This confirms that, according to the LAs' opinion, agricultural systems, irrigation infrastructures and land use in general are crucial and can contribute to either aggravate or reduce the risk of flooding. Among the criteria relevant only in one or the other specific area, in the UDRB LAs focused on the "*Construction sector*" and "*Energy consumption*", while in the UBRB "*Energy production*" and "*Employment*" appeared to be more significant.

Having identified the set of nine evaluation criteria, workshop participants defined their relative importance by **attributing criteria weights**. On average, in both river basins, the highest weight was given to the "*Vulnerability*" criterion, implying that it was considered the most important element for the ranking of flood responses (see Figure 3). In the UDRB, "*Ecosystem function*" obtained almost the same weight as "*Vulnerability*", revealing the European LAs' high regard for ecosystem health and the related services provided to human beings, closely followed by "*Housing Settlements*". In the Upper Brahmaputra river basin, the second most important criteria was "*Population dynamics*" and "*Poverty*" was the third, as reported in Figure 3.

Besides the difference in the relative importance of each criterion, it is interesting to observe that in both river basins LAs tend to hold environmental and social criteria in greater regard than economic ones. We can easily see this by summing up criteria weights for each dimension: the environmental dimension was considered the most important, accounting for 38% of the total weights, followed by the social (36-37%) and lastly by the economic one (25-26%).

The calculation of weights by means of average aggregation, however, can homogenise and flatten the values. Aggregate values can therefore hide important information, such as divergence and

[5] The "*Precipitation*" sub-domain was not included in the analysis matrix because it was not eligible as a decision criterion for the selection of adaptation strategies, while it would represent the object of mitigation measures.

convergence of participants' opinions. For this reason, we also analysed the distribution and the spread of individual preferences for each criteria weight using Box and Whisker plots (Figure 4) and the Variability Coefficient. In this way we were able to verify that in general, among the Salzburg participants, there was a fair concordance in weight attribution. The only exception was for "*Basin Morphology*", for which 50% of the LAs' opinions spread around a large range of weight values. On the contrary, in the Kathmandu workshop we observed quite a high discordance in weight evaluations around the average. Only the "*Employment*" criterion showed a good concordance in the weight distribution.

The discordance in the weight evaluations clearly reflects the different perceptions and objectives of LAs, and reveals the presence of possible conflicting interests among them. The elicitation of weights is therefore a very crucial phase, because weights can strongly influence the results. In fact, in theory, an equal representation and integration of all the issues at stake should be guaranteed in participative exercises.

Using all the information collected from the exercise of **fill in the matrix** and aggregating the individual LAs' evaluations, two average AMs were compiled (see Figure 5). Having taken into account the effect of averaging the different views of the LAs involved, we can observe that both the UDRB and UBRB results showed that none of the categories of responses clearly dominates the others. All the average criterion scores (row) or responses (columns) are in a range between "very high effectiveness" and "medium effectiveness", meaning that all the responses are considered to be potentially good for responding to flood risk. This stresses the potential validity of the four categories of responses, while, on the other hand, it also highlights the need for more detailed analyses within the categories, to be carried out in a subsequent phase of the project.

A supplementary confirmation of these results is given by the general confidence LAs attributed to their evaluations (see Figure 6). All the answers were given with a confidence above the normalised value of 0.5 and very close to the highest one (i.e. 1.0). Local actors thus seem to consider that all the four categories of responses positively match their expectations in terms of their effectiveness. A detailed analysis of Figure 5 and 6 allows further investigation into the relative variations of performances of the combination of criteria and responses, also in terms of uncertainty of the judgements provided. We will not go into such detail here given the demonstrative character of the application.

The last part of the analysis consists in the calculation of the ranking of alternatives by applying the MCDM capabilities of the mDSS software. The partial scores describing the performance of each alternative with respect to each single criterion are thus aggregated, considering the elicited weights and following a selected decision rule (i.e SAW, OWA, TOPSIS, ELECTRE). Decision rules aggregate partial preferences describing individual criteria into a global preference and rank the alternatives. In our case, ELECTRE III method was adopted in order to be coherent with the revised Simos methodology used for weights elicitation. The latter consents to give an intrinsic weight to each criterion, which does not depend either on the range of the scale or on the encoding and unit selected, as it is also in any aggregation procedure of ELECTRE type methods (Figueira and Roy 2002).

The preference (P) and indifference thresholds (Q) were parameters defined by the research team as an input, while no veto threshold (T) was introduced in the analysis, because not pertinent to the selected indicators. The Normalised Average Matrix was used as input for the analysis.

As it can be seen from Figure 7, LAs of both river basins evaluated the PLANNING solution as the most effective one. The remaining categories show different preferences and ranking in the two basins: all of them are equally preferred in the UBRB, while in the UDRB we don't see a clear preference between investments in GOV-INST (e.g. accountability and transparency in government actions, enforcement of existing regulations, flood insurance, etc.) and KNOW-CAP (e.g. awareness raising activities, dissemination of scientific knowledge, training of public employees, etc.); at the same time, in the UDRB ENG-LAND (e.g. dam construction, river network maintenance, soil conservation practices, etc.) is strictly dominated (not preferred) by all the other alternatives.

Considering the latter outcome and the average AM, we record that all the categories of responses performed very similarly, meaning that no solution was clearly preferred, with the only exception for PLANNING. This was quite predictable due to the effect of two factors: the very broad categories of responses analysed, and the effect of averaging highly dispersed preferences of different LAs. Regarding the first factor, a new application of the same conceptual decision model is planned for the final phases of the project with a focus on a much better defined set of concrete responses to be identified within the category of PLANNING. Regarding the last factor, it can be dealt with by means of the capabilities of the mDSS software in terms of application of non compensatory decision rules, exploration of conflicts and group decision making procedures.

The LAs preferences show that there is No strictly Condorcet winner, however, considering the Borda mark, we can see much clearly that the PLANNING category is the dominating solution (most preferred one) in both basins (see Figure 8). This result is coherent also with the outputs of Electre and with the AMs, confirming that PLANNING instruments (e.g. design and implementation of relief and rehabilitation plans, hazard zoning, etc.) are the most promising response in terms of effectiveness to cope with problems related to flood risk under the pressure of climate change.

We recognise, therefore, that very similar results were recorded in the two river basins, including those concerning the most preferred solution in the final ranking, confirming that, notwithstanding the differences in their environmental and socio-economic conditions, the areas present certain similarities not only regarding the problems to address but also regarding the expectations of possible solutions.

4. Discussion and conclusions

The methodological framework applied in the Brahmatwinn project and reported above facilitated exchanges of experiences between the twinned river basins and between scientists of different disciplines and local actors (in particular local experts and representatives of local institutions). The two parallel participatory processes allowed the understanding of the visions and preferences of local actors regarding the sustainable management of water resources. Moreover, they contributed significantly to ensuring that the scientific knowledge and approaches provided by the research consortium could meet the perceptions and needs of local people and decision makers, who would ultimately be the end-users of the project's outputs.

The participatory activities integrated with scientific research led to structured and very effective discussions concerning adaptation responses for flooding in those areas, and allowed for the collection of a significant amount of insights and lessons, drawn from the involvement of local actors.

This result validates the motivations which triggered the Brahmatwinn project design and led to develop a twinning river basin research approach, characterised by a strictly coordinated and combined series of participatory activities in the two geographical areas.

The participatory process carried out in this project, like many similar efforts implemented within research project activities, should not be intended as public participation in a strict sense, because the activities were, at least to some extent, academic simulations of social processes; this implies that the results must be considered only for their role of methodological demonstration. For this reason, crucial aspects of real world applications were not dealt with by the project, such as the statistically sound identification of representative local actors.

Having clarified this from the beginning also with the participants involved, these activities can still provide two very important opportunities: (1) testing and refining methods and tools to be applied in real world decision processes, and (2) disseminating information about scientific developments and the availability of methods and tools to potential users of the project results.

Indeed, as previously stated, there was no ambition to provide any kind of internal decision process for the project and neither to provide outcomes with any statistical significance for the two areas; various reasons explain this, such as the fact that the processes of selection of actors were not carried out with the intention to identify “representative” stakeholders, the multi-criteria analyses were conducted with very simple decision rules, the potential conflicts between participants were not investigated in depth. Having made this clear, the case remains interesting for the development and testing of innovative participatory approaches within research activities and for the exploitation of these activities, for establishing communications outside the research consortium, for collecting information, for having very valuable feedbacks, and for disseminating ongoing efforts, innovative methods, and results.

The experimental application of the NetSyMoD approach to the twinned river basins provided the Brahmatwinn project with an effective interface between the research activities and potential beneficiaries, in the case studies located in Asia and Europe.

In this case, the participative activities presented in this paper and those that were carried out before, in the earlier phases of the project, made it possible to maintain an open communication interface with communities of experts, policy makers, and bureaucrats, allowing the project consortium to learn from local knowledge and orient research activities. They also provided a means of concretely carrying out the twinning of the two river basins, shedding light on commonalities and distinct features.

As far as the results of the two workshops reported above are concerned, the phases of climate change scenarios **presentation** and **brainstorming** proved to be very important, because they set the foundations for the *DSS Design* and enabled the setting up of the activities on a common and shared framework of understanding of the features of each local river basin. These phases also contributed to raise awareness about climate change dynamics, and the state-of-the-art of the available modelling approaches downscaled to the level of the two case studies.

The phase of *DSS design* carried out by means of the mDSS software raised great interest among the participants, who were thus involved in the project activities, exposed to preliminary results and contributed to orient the final phases of the project. Several participants appreciated the use of public domain software in particular, which provided a perspective of possible reutilisation of the approach proposed in local decision problems.

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FIGURES

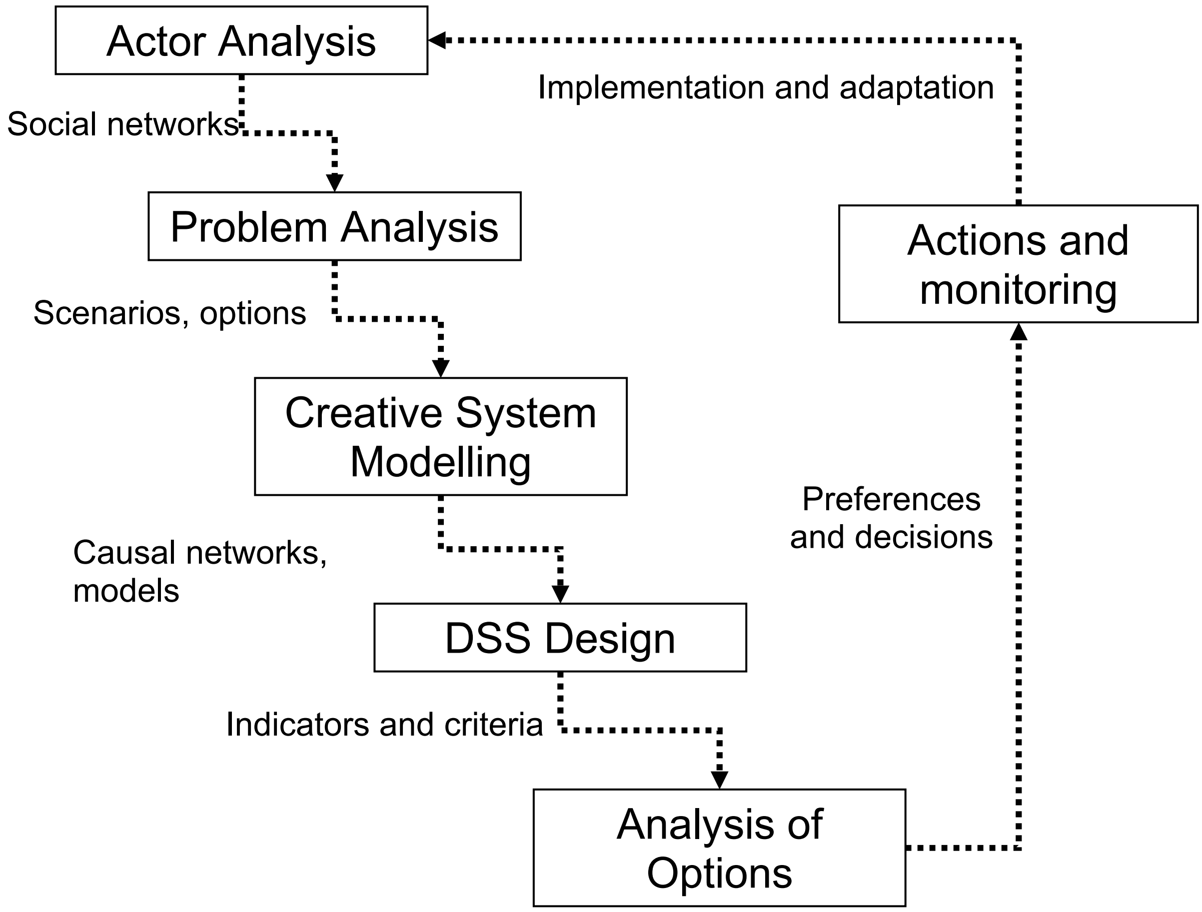


Figure 1: The NetSyMoD approach for participatory modelling and decision making (source: Giupponi et al., 2008).

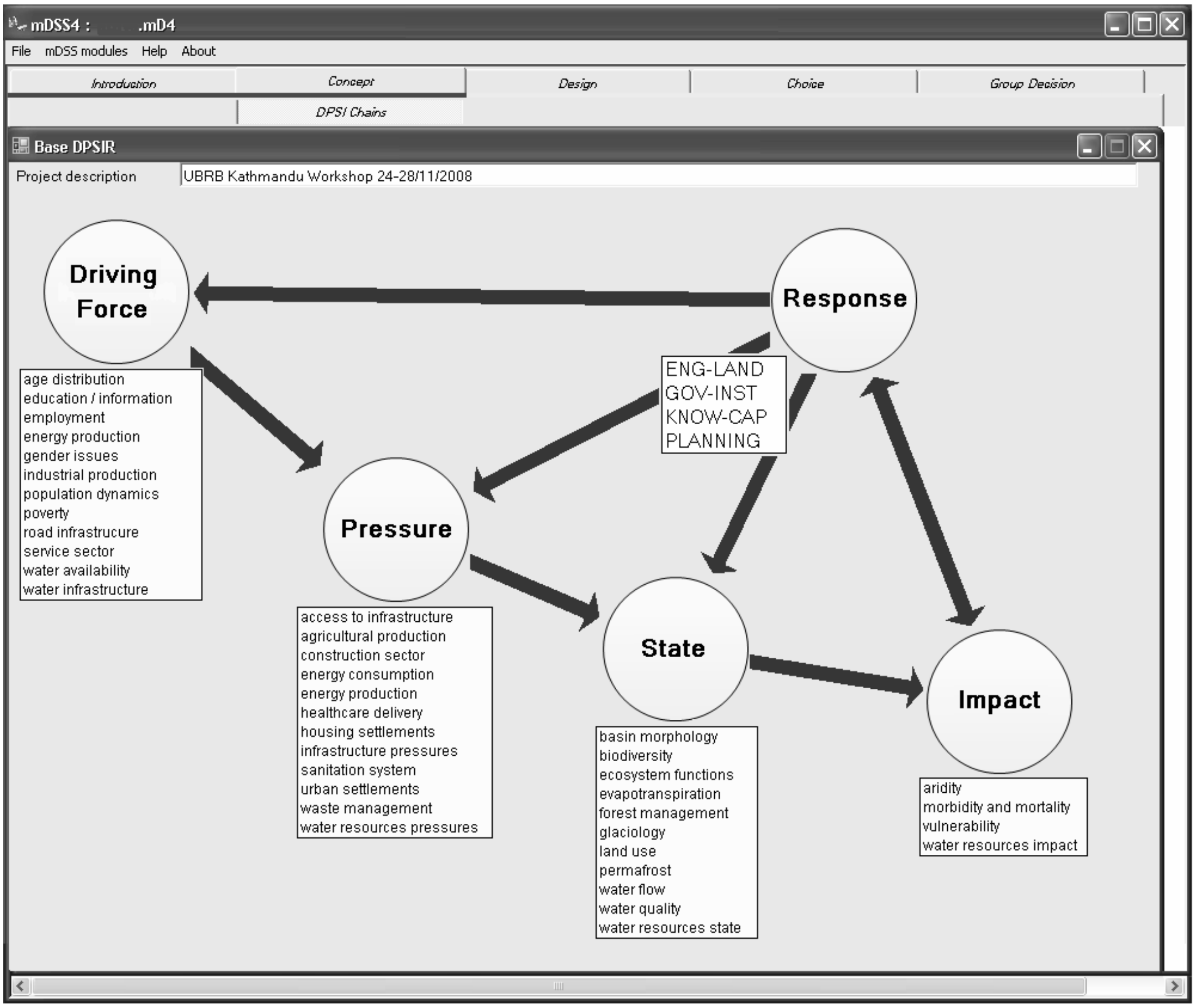
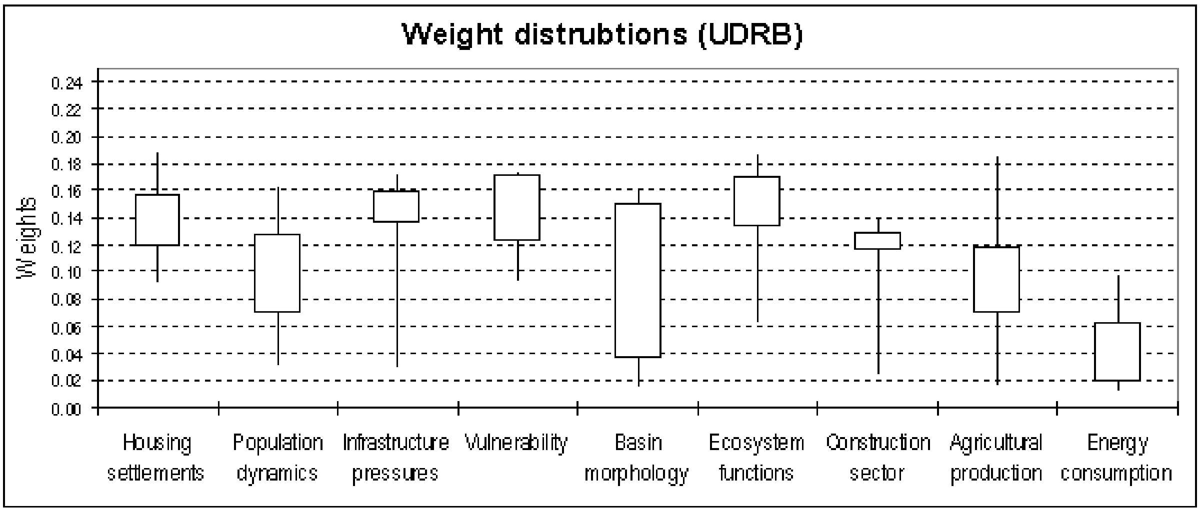


Figure 2: The conceptualisation of the information base stored in the IIT within the DPSIR framework (screenshot of the mDSS software).

	Criteria selected at the UDRB WS	Weight	Criteria selected at the UBRB WS	Weight
SOC.1	Housing settlements	0.138	Poverty	0.125
SOC.2	Population dynamics	0.097	Population dynamics	0.132
SOC.3	Infrastructure pressures	0.133	Infrastructure pressures	0.100
ENV.1	Vulnerability	0.144	Vulnerability	0.145
ENV.2	Basin morphology	0.091	Basin morphology	0.125
ENV.3	Ecosystem functions	0.143	Forest management	0.113
ECO.1	Agricultural production	0.111	Agricultural production	0.103
ECO.2	Construction sector	0.099	Energy production	0.101
ECO.3	Energy consumption	0.043	Employment	0.056

Figure 3: Criteria selected by LAs from the Integrated Indicators Table



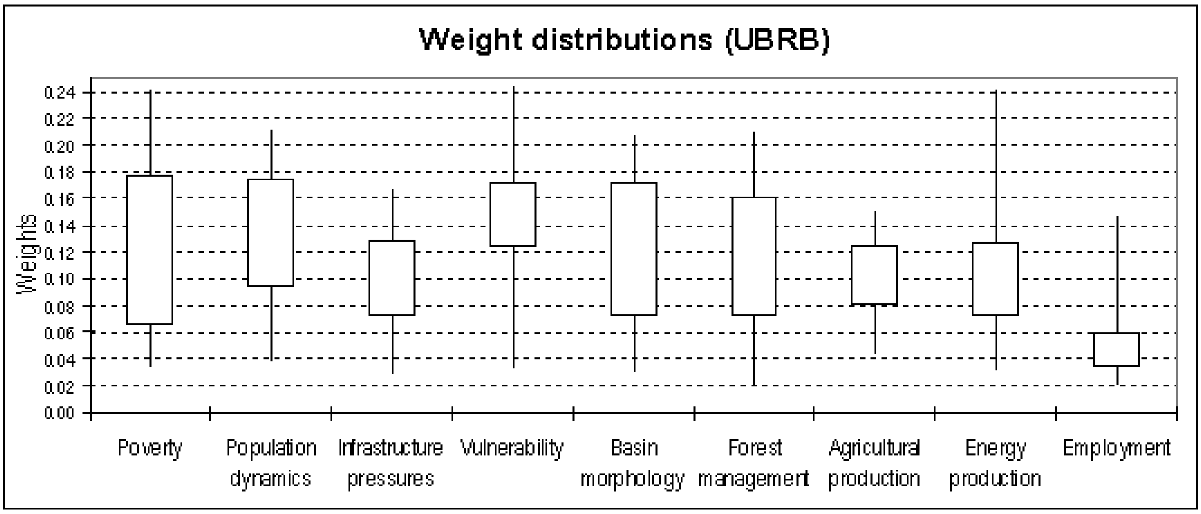


Figure 4: Spreads of weights as expressed by workshop participants in the two river basins.

Analysis Matrix (Average values) **Upper Danube RB**		PLANNING	KNOW-CAP	GOV-INST	ENG-LAND	**Average**
SOC.1	Housing settlements	2,00	2,43	2,57	2,71	2,43
SOC.2	Population dynamics	2,86	3,00	2,29	3,29	2,86
SOC.3	Infrastructure pressures	2,43	2,14	2,57	2,00	2,29
ENV.1	Vulnerability	2,33	2,67	2,50	2,67	2,54
ENV.2	Basin morphology	2,71	2,57	3,43	3,29	3,00
ENV.3	Ecosystem functions	2,86	2,43	2,29	3,43	2,75
ECO.1	Construction sector	2,14	3,29	2,57	2,43	2,61
ECO.2	Agricultural production	2,86	3,14	2,71	2,57	2,82
ECO.3	Energy consumption	2,86	2,43	2,57	2,86	2,68
	Average	2,56	2,68	2,61	2,80	

Analysis Matrix (Average values) **Upper Brahmaputra RB**		PLANNING	KNOW-CAP	GOV-INST	ENG-LAND	**Average**
SOC.1	Poverty	2,43	2,62	2,00	3,33	2,60
SOC.2	Population dynamics	1,76	2,52	2,33	3,19	2,45
SOC.3	Infrastructure pressures	2,00	2,86	2,67	2,19	2,43
ENV.1	Vulnerability	1,71	2,43	2,24	1,95	2,08
ENV.2	Basin morphology	2,38	2,67	3,10	2,43	2,64
ENV.3	Forest management	1,86	2,10	2,10	1,95	2,00
ECO.1	Agricultural production	2,15	2,50	2,48	2,29	2,35
ECO.2	Energy production	2,19	3,00	2,43	2,10	2,43
ECO.3	Employment	2,43	2,57	2,43	3,52	2,74
	Average	2,10	2,58	2,42	2,55	

Figure 5: Analysis Matrix - average values of LAs' evaluations on the potential effectiveness of each response in coping with the issues expressed by the criteria (rows) by means of a Likert scale ranging from 1 "Very high effectiveness" to 5 "Very low effectiveness".

Uncertainty Matrix (Normalized Average values) **Upper Danube RB**		PLANNING	KNOW-CAP	GOV-INST	ENG-LAND	**Average**
SOC.1	Housing settlements	0,86	0,64	0,64	0,79	0,73
SOC.2	Population dynamics	0,79	0,64	0,79	0,71	0,73
SOC.3	Infrastructure pressures	0,71	0,71	0,64	0,71	0,70
ENV.1	Vulnerability	0,75	0,67	0,67	0,67	0,69
ENV.2	Basin morphology	0,64	0,79	0,64	0,71	0,70
ENV.3	Ecosystem functions	0,86	0,57	0,71	0,71	0,71
ECO.1	Construction sector	0,71	0,50	0,57	0,50	0,57
ECO.2	Agricultural production	0,64	0,57	0,57	0,57	0,59
ECO.3	Energy consumption	0,79	0,71	0,64	0,57	0,68
	Average	0,75	0,65	0,65	0,66	

Uncertainty Matrix (Normalized Average values) **Upper Brahmaputra RB**		PLANNING	KNOW-CAP	GOV-INST	ENG-LAND	**Average**
SOC.1	Poverty	0,57	0,62	0,70	0,67	0,64
SOC.2	Population dynamics	0,65	0,65	0,67	0,64	0,65
SOC.3	Infrastructure pressures	0,69	0,60	0,52	0,69	0,63
ENV.1	Vulnerability	0,77	0,73	0,68	0,74	0,73
ENV.2	Basin morphology	0,62	0,62	0,55	0,70	0,62
ENV.3	Forest management	0,75	0,64	0,65	0,74	0,70
ECO.1	Agricultural production	0,70	0,75	0,65	0,70	0,70
ECO.2	Energy production	0,74	0,61	0,63	0,77	0,69
ECO.3	Employment	0,63	0,60	0,62	0,55	0,60
	Average	0,68	0,65	0,63	0,69	

Figure 6: Uncertainty Matrix- average values of LAs evaluations expressing the degree of confidence related to their answer (Scale of confidence: 1 “Very high confidence” to 0 “Very low confidence”).

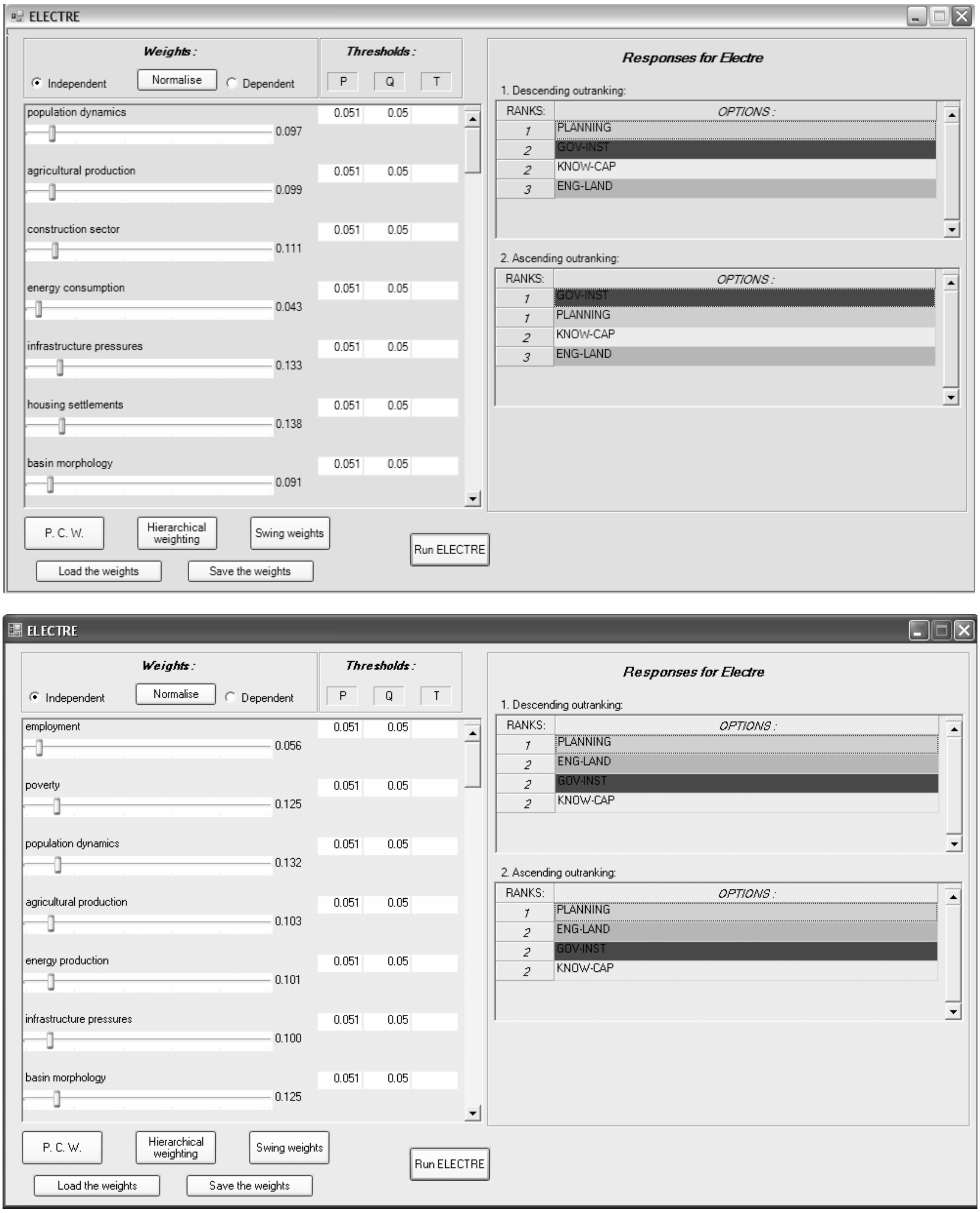


Figure 7: UDRB (top) and UBRB (bottom): ELECTRE Analysis of Alternatives. On the left side we can see the applied criteria weights and thresholds, while on the right side the ELECTRE window appears with the final ranking (screenshot of the mDSS software).

UDRB	PLANNING	ENG-LAND	KNOW-CAP	GOV-INST	**sum of votes in favor**	**BORDA Mark**
PLANNING	---------	3 (I=0)	4 (I=0)	3 (I=2)	**10**	**1°**
ENG-LAND	4 (I=0)	---------	1 (I=0)	2 (I=0)	**7**	**3°**
KNOW-CAP	3 (I=0)	5 (I=1)	---------	1 (I=3)	**9**	**2°**
GOV-INST	2 (I=2)	5 (I=0)	3 (I=3)	---------	**10**	**1°**
UBRB						
PLANNING	---------	10 (I=6)	16 (I=3)	12 (I=5)	**38**	**1°**
ENG-LAND	5 (I=6)	---------	9 (I=4)	8 (I=6)	**22**	**2°**
KNOW-CAP	2 (I=3)	8 (I=4)	---------	8 (I=6)	**18**	**3°**
GOV-INST	4 (I=5)	7 (I=6)	7 (I=6)	---------	**18**	**3°**

Figure 8: Group Decision Making marks. The first number refers to the N. of votes in Favour, while "I" refers to the votes of Indifference.

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