# Water Management, Public Participation and Decision Support Systems: the MULINO Approach

J. Feás

Carlo Giupponi

P. Rosato

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J. Feás [a], C. Giupponi [a,b], P. Rosato [a,c]
*a Fondazione Eni Enrico Mattei, Venice, Italy*
*b Università degli Studi di Milano, Italy*
*c Università di Trieste, Italy*

**Abstract:** One of the main issues in the environmental decision making field is the necessity, sometimes obligation imposed by the legislation, to communicate the decision process and make it more comprehensible. In other words, the objective is to increase the transparency of the decision making available all the relevant information related to the decision process for all interested actors. For this reason, many tools have been developed over the last decades: indicators, conceptual frameworks, and impact assessment studies are examples. However, many of these tools try to represent the environmental situation or hypothetical future states without any explicit reference to how decisions are taken or should be taken. Some environmental decision support systems are developed for that specific purpose. One critical point in the development of such a DSS is the connection between the representation of reality and the elicitation of preferences of the decision makers. Moreover, environmental decision making requires that preferences and value judgments refer to technical and scientific information that is not easy to communicate to people in general. The European project, MULINO (contract no. EVK1-2000-22089), completed at the end of 2003, has focused on connecting environmental tools and decision support methods, by combining the DPSIR approach with multicriteria analysis methods in a decision support system called mDSS. The DPSIR is a conceptual framework developed by the EEA through which environmental problems can be structured and explored in a heuristic way. This process may be undertaken in a group (e.g. the decision makers and the stakeholders together) using the framework to structure discussion between those who decide and those who are involved in the problem. In this paper, we describe the MULINO approach, focusing on the experience gained with the end users involved in the project in applying the mDSS software. In particular, we present the use of the DPSIR approach to structure and communicate their decision context and the potentials for stakeholders' involvement.

***Keywords*:** Environmental tools, decision support system, DPSIR, Water Framework Directive

## 1. INTRODUCTION

Since 1992 and the signing of the Rio Declaration on Environment and Development and Agenda 21, where a plan of action to achieve the sustainable development into the 21st Century was set out, the concepts of public participation and stakeholder involvement have had a growing influence on policy formation and decision making processes. There are still large knowledge gaps and culture clashes, which make the realization of participatory processes problematic for most governing bodies. The increase in the number of actors, both public and private, affirms the need for capacity building to define mediation techniques and co-operative approaches appropriate for active stakeholder involvement. At the present time however, the situation is complicated for authorities that are obliged to execute participative planning procedures.

Like environmental planning in general, Integrated Water Resources Management (IWRM) is usually characterized by the involvement of numerous decision-makers operating at different levels and the large number of stakeholders with conflicting preferences and different value judgments [Lahdelma *et al.* 2000)] This makes the development of policy implementation strategies and decision making in the context of IWRM a very complex issue, also because it requires a broader integration with other sectors such as environment, energy, industry, agriculture, tourism.

Adequate methodologies and tools become therefore necessary in order to measure how a specific policy meets the objectives established by the various actors, to identify and understand the possible conflicts that may arise between these actors and, finally, to design possible paths and courses of action to arrive at a sustainable solution. The need for adequate methodologies and tools calls for a strong role to be played by science and research. The commitments made by the scientific community of the 2002 World Summit on Sustainable Development was in fact to make science more policy relevant [ICSU, 2002].

Environmental problems and in particular those related to water resources are usually very complex and therefore the decision making process requires high background in environmental, economic and social disciplines. Moreover, there is quite often a dramatic gap between those who analyse and provide disciplinary expertises and those who decide, not only in the knowledge but also in the aims and the way of thinking and the language [Luiten, 1999].

The European Water Framework Directive (WFD) [EC, 2000] specifically addresses public information and consultation in Article 14. It is obligatory for the Member States to involve the public in the implementation of the Directive by publishing specific information relevant to the River Basin Plans and to be open to comments made by the public about the planning process. Member States are also to encourage the active involvement of all interested parties, which would require more than the publication of information.

The WFD is laying the groundwork for social sustainability by establishing public involvement in planning procedures as common practice. Even if the level of obligatory participation is the most basic, for some European countries this is a necessary first step as it may be that citizens have had no legitimate role in the management of water before.

The participation of a range of stakeholders in the planning process might take on a number of forms, including public forums, focus groups, and the use of specialized workshop techniques or software for group decision making. All of these alternatives however have social implications for the understanding of how rights and responsibilities are distributed with society.

The amount of decision control that is devolved to the community for the management of natural resources and the role that public authorities play determine to a great extent the socio-political character of a society. For some Member States, Article 14 may represent a "business as usual" scenario in that this kind of information exchange between the citizens and the public authorities already takes place in some form. This means that the communication infrastructures are already in place and that both individuals and stakeholder groups expect the opportunity to comment on planning proposals. For other Member States, it is possible that there is little history of such exchanges, making the implementation of this Article more difficult. It may be costly to establish new lines of communication and the facilities for collecting and recording public opinions, and such procedures may be incompatible with current planning approaches. Moreover, there may be resistance to what may seem like a step towards a redistribution of power that threatens the freedom of individuals or organizations to make decisions in a non-transparent way.

## 2. DECISION MAKING IN IWRM

### 2.1 The role of public participation in IWRM

In a decision making process, it is possible to identify people, groups or institutions that can play a meaningful role in the final decision. In general, we can classify these main actors as decision makers, people and groups affected, and analysts. But normally in the real life, not all of these actors are always involved in the decision making process.

The decision maker is situated in the centre of the decision making process and is the one who has the institutional power and responsibility to select and implement a solution for a specific problem. People affected are all those whom will be influenced by the consequences of the solution adopted and implemented by the decision maker. The analyst is the person/group that helps and guides the decision maker to analyse and represent their preference structures and those from other interested groups.

One of the main issues in the field of environmental decision making is the need, sometimes the obligation imposed by the legislation, to communicate the decision process and make it more comprehensible and transparent. For the reasons described above, there is no doubt that public participation has become a major issue in IWRM. In order to facilitate the active involvement of all the stakeholders in water decision problems there is a challenge that has to be faced: the integration of scientific knowledge and public participation. This is not an easy task.

Facing water problems, decision makers find public participation important for various reasons, first of all because it is required by legislation (e.g. the WFD). Moreover, decision makers are responsible of the selected decision and also its acceptance, for which public participation is essential. Nevertheless, major problems in IWRM like the lack of available information, the uncertainty about future effects or the incomplete knowledge of experts, create more difficulties on obtaining these goals. Decsion makers have in general, little experience in sustainable water management. Because of this inexperience and the uncertainty inherent to these decision problems, public preferences need to be included in a more direct way by sharing part of the responsibility and trying to find compromise solutions that facilitate acceptance.

Another reason for public participation is the role that water plays in our society. Water can be considered an important primary good, and is closely related to social and economic development. In addition, environmental sustainability is critical. One possibility to better understand and implement common interests is public participation.

In contrast, some disadvantages have to be also taken into account and to be solved. Public administrations, that normally have the responsibility to make decisions in IWRM, are not always experienced applying public participation. In addition, the public involvement could represent a problem to the restrictions in cost and time that normally guides administrative procedures.

## 2.2 Integration of public participation in IWRM

Once the crucial importance of the public participation in the decision making process in IWRM has been recognized, the next step must be to clarify the way public participation, decision making and science knowledge can be integrated. For this integration, all the meaningful information has to be collected, structured and presented in an understandable way to help decision makers to integrate all the actors involved in the decision making process and all the scientific knowledge available. Several decision support systems have been developed in the last years to satisfy this need, for specific water resource planing activities such as prevention of water shortages (drought), surpluses (floods) and water impairment (pollution). Examples of such DSS are WATERWARE [Fedra, 1994], [Jamieson and Fedra, 1996a; Jamieson and Fedra, 1996b], AQUATOOL [Andreu et al., 1996], NELUP [O'Callaghan, 1995], [Dunn et al., 1996], FLOODSS [Catelli et al., 1998], DSSIPM [da Silva et al., 2001], STEEL-GDSS [Ostrowski, 1997].

A decision making process normally implies the following steps (Figure 1): identification of the alternatives that can solve the problem; the selection of the criteria against which alternatives are going to be compared; the estimation of the performances of the alternatives related to the criteria; the selection of the aggregation procedures of the information derived from performances and the relative importance of the criteria in the final decision.

As described above, decision makers do not have information enough about the perceptions of the problems by the society due to the complexity of water problems. The role of public participation at this level could be helpful to identify the main relevant criteria and their societal targets in the decision process. However, the general public also has problems to identify these criteria, normally represented by physical, social and economic issues, out of specific and comprehensive data. For this reason, indicators available from scientific knowledge can provide crucial guidance for decision-making. They can translate physical and social science knowledge into manageable units of information that can facilitate the public participation in the decision-making process. Indicators may provide a means of measuring, monitoring and reporting on progress towards societal goals (e.g. quality of life, welfare, etc.) . It may be thus possible to assess effectiveness of policy measures by analysing causality between a policy and its impacts in terms of changes in indicator values. Still, getting the public to understand such scientific information is daunting.

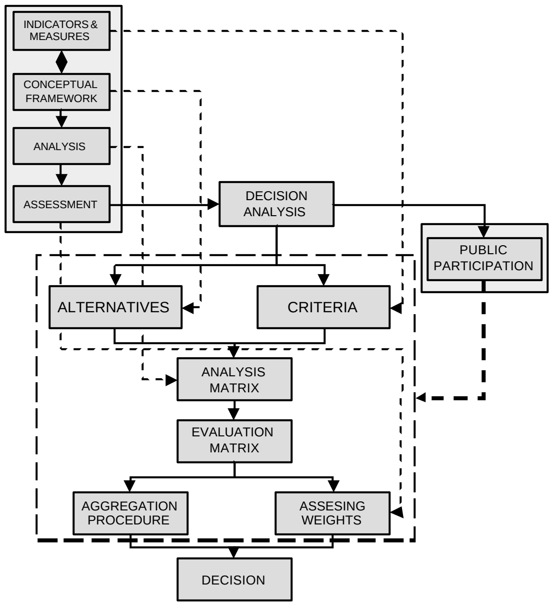


**Figure 1:** Knowledge and decision making for IWRM and sustainable development.

## 2.3 Using conceptual frameworks for public participation

In order to assess whether policies will be working and to fine-tune them in order to reach the ultimate objective, conceptual frameworks are needed. They facilitate the understanding and exchange of information between policy-makers, stakeholders and technical and scientific support.

Public participation could be also involved in the identification of alternatives. But as political decision makers, they need an overall view of the problems. Frameworks that structure collections of indicators and that communicate their application are being developed, at different analytical levels. For the purposes of IWRM, the frameworks for environmental reporting and monitoring may play a positive role. A relevant example is the DPSIR framework (Driving Force – Pressure – State – Impact – Response), developed by European institutions: the EEA and Eurostat [EA, 1999]. This conceptual framework applied to water management is reported in Figure 2 and presented in more detail.

The DPSIR framework is widely used to structure indicators to allow for a holistic and multi-dimensional view of causal relationships in human-environmental systems. Within the DPSIR framework, indicators are used to assess different states of the interaction between man and his environment. The integrated set of indicators is assumed to simplify for the decision-maker and stakeholders the comprehension of the complex interlinkages between multisectoral human action and the coevolutions of ecological, economical and social states.

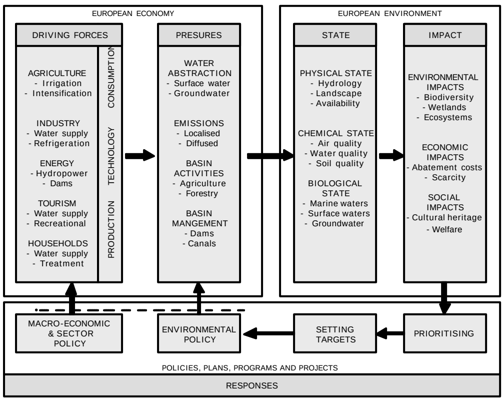


**Figure 2:** DPSIR framework applied to water management [adapted from NERI 1997]

As the example shown in Figure 2, conceptual frameworks could help to identify the decision level related with the specific problem and the range of alternatives that could solve it. This conceptual framework allows to have a common understanding of the problem that is a basic step for an effective decision making process and the basis to propose.

In order to obtain the analysis matrix, decision makers have to reflect their value judgements and preferences by the public utility functions. As in the selection of the criteria, decision makers have the problem of lack of information about this point. That is why at this point public participation is needed. By public participation, asking directly all the actors involved in the decision process about their individual preferences, the general form of the public utility function for each criterion previously selected can be obtained.

Public participation is also needed in the selection of the aggregation procedure. Several aggregation methods are available and the analyst should help to select the most suitable method based on the preferences of the actors involved and, depending on the problem faced. Not all the problems are the same and each specific context requires a specific method.

The last point where public participation could play an important role in the decision process is in the assessing of weights to aggregate all the information. In this step, some conflict may arise because of the different interest of the actors involved in the process. Public participation could increase the acceptance of the final decisions, making clear the individual preferences and giving the basis for possible compromise solutions

We believe that public participation could play an important role in the decision making process related to IWRM, where the environmental tools could be also helpful. There is not a consensus about the involvement of public in the decision process. Different levels of public participation have their advantages and disadvantages and they must be clearly established for each particular type of problem.

## 3. MULINO DSS

A methodological approach and a DSS tool have been developed within the MULINO Project [Giupponi et al., 2004] for integrating the four steps described above, in the context of decision making in IWRM. The next paragraphs describe how indicators and indices are managed within a conceptual framework and how they can be utilized in specific forms of analysis, for the implementation of IWRM principles in decision making.

### 3.1 The conceptual framework and the role and management of indicators

Within the IWRM context the initial task of decision makers is usually that of acquiring or consolidating knowledge about the territory they manage by collecting information about human activities and their relationships with the environmental systems. This may be based upon the identification of suitable indicators, which may provide concise quantification and temporal monitoring of the main human and environmental variables interacting within the given territorial systems, typically a river basin.

The whole informative and decision process should be then formalized within a conceptual network, in this case based upon the DPSIR approach. In such a conceptual framework related to natural resources management and, in particular to IWRM, the Impacts describe the existing problems arising from the change detected in State variables, which affects their economic value, environmental function and social role (either in quantitative, or qualitative terms), thus allowing to support decision making within the perspective of sustainable development. Such a conceptual structure can support the establishment of new lines of communication between different actors and help to facilitate the collection and recording of public opinions..

The level of the responses has to be related to the magnitude of the impacts. These different responses need different planning processes and different decision makers could be involved. The different planning levels could be policies, plans, programs and projects, from macro to micro level. A crucial aspect of implementing the DPSIR approach in a methodology for implementing the principles of IWRM in decision making is the transformation of a static reporting scheme in a dynamic framework for integrated analysis and assessment. The next two paragraphs present how Integrated Assessment Modelling (IAM) combined with a Multi-Criteria Analysis (MCA) methods can provide methodological support for analysis and assessment procedures.

### 3.2 Analysis methods: modelling and evaluation

The implementation of IAM in the DPSIR framework is approached in the proposed methodology by focusing on the DPS part of the conceptual framework. These three elements were considered as explicit formalizations of driving variables, model parameters and outputs, respectively. In the case of water pollution models, for instance, D's represent the forcing variables ruling the behaviour of the simulated system (i.e. the catchment). P's may be represented by parameters that express the rate of pollution processes and S's are the output variables quantifying the dynamic evolution of the catchment system, as affected by the considered pollution sources and processes. Integration of models may occur at various levels and in different ways and thus relationships along the chains could be expressed by parallel one-to-one flows, or one-to-many (e.g. one activity affecting various environmental compartments), or many-to-one (e.g. various sectors affecting the same environmental indicator), or even many-to-many, in the case of multi-sector integrated models.

In the context of environmental decision making, IAM can support the identification of the correct Responses by providing sets of indicator values. These values are derived from subsequent simulation runs in which model(s) are parameterised to represent the expected consequences of a set of possible alternative responses. The development of a set of evaluation indices is a crucial step. It should be targeted to evaluate Impacts deriving from the State indicators provided by IAM. Evaluation procedures may be implemented by focusing on the link between S and I and between I and R by adapting concepts and methods derived from MCA literature, Multi-Attribute methods in particular [Hwang and Yoon, 1981]. Within this disciplinary context a preliminary phase of Problem Structuring is targeted to the identification of the criteria to be considered for choosing among previously defined options. These factors are expressed as indicators deriving from output variables of IAMs or monitoring activities. The step between the quantification of State variables and the identification of Impact evaluation indices can be conceptualised according to MCA theory as the conversion of the Analysis Matrix into an Evaluation Matrix (EM), which expresses the estimated impacts.

Having identified the impacts as they vary under the effects of alternative response options, the decision maker has to apply a decision rule to aggregate the values stored in the EM to identify the preferred option, filling therefore the gap between I and R. In the simplest case, the rule can be expressed by the weighted sum of values stored in the columns of the EM. Various iterations are possible and needed at this step to refine the weights, or apply alternative decision rules by considering the results of the sensitivity analysis to select a robust response. Parallel procedures are also possible in multi-stakeholders group decision making.

### 3.3 Assessment methods: a dynamic and integrated DPSIR-DSS tool

A DSS is ideally suited to answering questions arising from policy changes on water resources by providing the understanding of the processes involved, evaluating the consequences and delivering advice. Moreover, communication about how decisions are reached is greatly facilitated using a DSS in which effects of alternative options can be explained and their impacts assessed in a form which can be comprehended by the non-expert. In accordance with the WFD, the DSS developed by the MULINO project adopts the DPSIR as a well known intuitive graphical interface and integrates hydrological and socio-economic approaches in order to assist water authorities in the management of water resources. From a practical viewpoint, mDSS manages social, economic and environmental criteria, by formalising them as D, P, or S indicators and then by considering them as decision factors within the AM.

## 4. CONCLUSIONS

There is a clear need for methodologies and tools to put IWRM principles into practice, in an application context in which decisions and choices are assessed in terms of their sustainability not only over the long term but also with regards to their day-to-day contribution to the perspective of sustainable development.

The need mentioned above may also be described in terms of the implementation of an integrated methodological framework allowing decision makers to choose first and then to monitor the process induced by their decisions.

Various methods and tools, such as modelling, environmental impact assessment and decision support, have shown to provide rational insight in the system's behaviour and the problems addressed. However, integration remains a difficult issue.

The conceptual framework briefly described above may contribute to provide methodological support to cope with the general problem of IWRM implementation, by supporting in particular:

- the management of the complexity of decision contexts typical of IWRM;
- the management of large amounts of multi-sectoral and multidisciplinary information;
- the communication between the scientific and the policy sector and between decision makers and the involved stakeholders.

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