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Requirements for Decision Support in Integrated Water Resources Management

Mariele EVERS

As. Prof. Mariele Evers, University of Lüneburg, Institute of Environmental Strategies, Herbert-Meyer-Str. 7, 29556 Suder-burg, evers@uni-lueneburg

1 INTRODUCTION

Since 1972 at the United Nations Conference on the Human Environment at Stockholm the global im-plications of water problems is voiced. During the last three decades this issue was raised continuously and discussed on national and international level. For example one of the eight principles and concepts concluded by the Agenda 21 and the Dublin Principles specifically referred to "integrated water re-source management, implying an inter-sectoral approach, representation of all stakeholders, all physi-cal aspects of water resources, and sustainability and environmental considerations" (UNCED 1992).

Despite these conceptual formulations, the term IRBM is more precisely defined by the Global Water Partnership (GWP) as attempted to consolidate the two broad conceptual requirements of "integration" and "sustainability," and provide a comprehensive scope for IRBM, which was summarized as, "a process which promotes the coordinated development and management of water, land and related re-sources, in order to maximize the resultant economic and social welfare in an equitable manner with-out compromising the sustainability of vital ecosystems" (GWP/TAC 2000).

So IRBM can be seen as a complex concept which embodies the integration of natural and human sys-tems or we can say physical and societal world. Within the natural system, integration is sought be-tween "freshwater and coastal zone, land and water, surface water and groundwater, water quantity and quality, and upstream and downstream". Similarly in the human system, integration is required between demand and supply, across various water use sectors, among various stakeholders and in nu-merous socioeconomic considerations (Bandaragoda 2002). Following this broad definition the com-plexity of IRBM becomes more than obvious. So we have to raise the question how an appropriate approach can be realised?

For this issue like IRBM a kind of technologies, which is applied on an interdisciplinary basis, is more than helpful to understand the system's behaviour and develop appropriate strategies and cooperative action programmes in response. Thus kinds of socio-technical instrument as Decision Support Systems (DSS) are required.

This paper will discuss requirements for DSS to support a comprehensive approach in IRBM along following areas as examples of the natural and human system:

1. Fresh water quality and quantity

Fresh water of sufficient quality is becoming a scarce resource in an increasing number of regions throughout the world. Water scarcity, and human interventions to handle it, has become a potential source of conflict, partly caused by competitive water uses between sectors and between geographic regions. The European Union adopted the Water Framework Directive (WFD) to manage this field.

2. Flood risk management

The extreme increase of flood events and flood damages during the last decades makes it obvious that an integrated approach of IRBM has to include flood protection. Many issues such as technical measures, aerial and spatial management, retrofitting, rising risk awareness as well as environmental and land-use management have to be incorporated into the complex field. A crucial point of course is to optimize the retention potential of the river basin.

3. Flood plain management

Flood plains are diverse landscapes where various requirements, which increasingly compete with one another, can be observed. Water related biotopes and especially flood plains are not only extremely important but also rich ecosystems with a huge variety of species and functionalities. "Freshwater ecosystems, when scored on the area they cover and the number of species they harbour, are in fact the most species-diverse habitats on Earth" (IUCN, 2005).

These areas belong to the natural system of IRBM. As part of the human system we can consider e.g.

4. Stakeholder involvement and public Participation

IRBM is a challenge for cooperation, integration and support. As known, water is rapidly emerging as a serious limitation on meeting human needs while protecting the environment. Cooperation between all stakeholders' at all organizational levels is required to reach agreement on integrated management plans, as well as appropriate allocation strategies for available resource. Balancing water resources, including issues such as increasing use compared to the availability or deterioration of water quality is becoming increasingly complex and diverse. Appropriate decision making requires specific knowl-edge from both technical and non-technical perspectives (Abbott 2005).

These complexities create the need to understand and comprehend the more detailed technical compo-nents, as well as broader managerial and societal issues, therefore asking efficient integration of vari-ous disciplines, sectors, countries, and societies (Somlyódy et al. 1995).

Economic issues should be mentioned here as a extra issue in the human system which has to be rec-ognised but which are not further discussed in this context

The framework of management processes of the different elements of IRBM are mainly based on legal regulations (acts, environmental standards, conventions et cetera) or other environmental or other goals (e.g. the concept of sustainable regional development). For IRBM purposes numerous regula-tions emerged during the last years. However, integration remains a difficult issue. A number of gaps and barriers still need to be resolved.

2 MANAGEMENT OBJECTIVES AND LEGAL INSTRUMENTS OF IRBM

2.1 The natural system

As described earlier relevant issues are, amongst others, the quality and quantity of water, the decline of water related ecosystems and flood risk management. One crucial problem in most European coun-tries is, that there are too many actors responsible for and involved in water management. The jurisdic-tion over water is often very fragmented and there is not always a single institution ensuring coordina-tion between the different managing agencies.

Water quality and quantity management is mainly the issue for the water management agencies. The coordination with agriculture and nature conservation actors is quite poor.

Wetlands management is considered as a nature conservation issue. This leads to uncoordinated ac-tions in managing wetlands and missed opportunities for fully exploiting their positive role in water management. National wetland restoration policies are almost non-existent, although the international framework should lead to a national wetland protection policy (WWF 2003).

For flood risk management usually water management agencies are again responsible as for water quality and quantity. Although very often another department is concerned with this issue and coordi-nation and collaboration between them often is not enough institutionalised but depends on personal contacts.

An increasing number of legal frameworks and guidance both on international and nation levels came into force during the last years. Table 1 shows an exemplary overview about legal frameworks and objectives in IRBM concerning water quality and quantity, flood risk management and flood plain management in Europe. All these jurisdictions are not implicit conflictive but the interlinkages can be considered as little. Water quality and wetlands are considered separately. Water quality and flood risk management tends to be coordinated by the new European directive which is planned to be agreed upon in 2007. The designed flood risk management plans which are one basic element in the designed Directive should include not only water management aspects but as well spatial planning, nature con-servation and other spatial and land use relevant issues. But we have to wait for the final wording of the law to critic about is finally.

	legal frameworks	**General target**	**Environmental objective**	**Environmental standards**
Water quality and quantity	EC Water Framework Directive, National standards	Good status of water bodies	Good ecological status of surface waters (includes biological,	e.g. reference status of river type

			hydro-morphological and chemical status) Good status of groundwater (includes quantitative and chemical)	e.g. max 50 ml N/l max
Flood risk management	EC Directive for flood risk management (draft), German Act for mitigation of flood risk Guidelines	Minimising of flood risk	raise retention potential	HQ 100 / 1,0 % HQ 1000 / 0,1 %
Flood Plain Management	RAMSAR Convention, NATURA 2000 Directive, National acts (e.g. Germany: BNatSchG)	Protection and development of wetlands and its biodiversity	Endangered biotopes Endangered species	Protection of FFH Appendix species and biotopes BNatSchG § 20c Red lists

Table 1: Legal frameworks and objectives in IRBM (exemplary)

Flood risk management and floodplain management is handled more or less parallel. A little approach is done with the German Act for preventive flood management. With an instrument the “flood risk plans” it could be possible to include aspects of flood plain restorations and dike shifting. But this is not formulated explicitly thus it realisation will depend on the respective planning authorities.

Rather all biotope types of flood plains are protected by laws like FFH Directive and national nature protection acts. But what is missing is a comprehensive and mid- or long-term strategy for sustainable protection and development. For this paradigm a catchment based approach is crucial. The only catchment based approach is demanded by the WFD concerning water quality and quantity. The draft of the flood directive for flood risk management shall be abutted along this methodology and time structure (EC 2006).

Only rarely we can consider established organisations for IRBM in Europe. In general it is organised along administrative boundaries. With WFD the first catchment based organisation structure has been established. Theoretically these are the right structures to coordinate IRBM. Future will tell whether they have enough competences to achieve a successful collaboration. Despite these structures some transnational River Basin Organisations exist. They try to coordinate actions and measures in the catchment basin but very often they have not enough competences for effective coordinated manage-ment.

Another facet of IRBM is that synergies in data management are poor despite it would be more than useful to match up a common data pool. Since implementation of the WFD and its GIS guidance a big step is done towards common standards and exchange of geographical data. But a lot of other steps can still be done.

2.2 The human system

For integration the societal aspects of IRBM public participation is a crucial element which has to be considered. Public participation in water management is rather poor in Europe, especially in Southern and Eastern Europe. (UNEP 2005). The most critical aspects of public participation are the lack of pro-active information provisions to non-governmental stakeholders and the quality of the means to enable the active involvement of interested parties in decision-making processes. Stakeholders often lack specialist knowledge and human capacity to get involved in decision-making for water manage-ment measures. It is difficult for non-governmental water stakeholders to contribute and influence the decision-making process because the issuing of consultation documents and the participation of inter-ested parties often take place only towards the end of the process. There is often low transparency for specific projects.

Participation is more and more not only demanded by political and societal concepts for sustainable development. Participation aspects are integrated as a central part or declaration of legal frameworks as the Aarhus convention or Water framework Directive of the European Union.

For instance from the perspective of a NGO like the WWF some other aspects are important for an IRBM and its successful implementation (WWF n.d.) as shown in chapter one. The WWF states as additional crucial elements inter alia:

- a long-term vision for the river basin, agreed to by all the major stakeholders,
- strategic decision-making at the river basin scale, which guides actions at sub-basin or local levels,

- Effective timing, taking advantage of opportunities as they arise while working within a stra-tegic framework.
- Adequate investment by governments, the private sector, and civil society- organisations… and
- solid foundation of knowledge of the river basin and the natural and socio economic forces that influence it.

3 THE ROLE OF DECISION SUPPORT SYSTEMS (DSS) IN IRBM

Bringing together the natural and the human system is one crucial aspect of IRBM. However decision making in a river basin context is a complex process due to the many stakeholders involved, each with different interests, objectives, evaluation criteria, information needs and competency. Cooperation and sharing of information and ideas might enhance the harmonisation of water use and allocation. Sharing models and analytical methods, and the mutual exchange of information can be an appropriate basis for co-operation in research and analysis. Computer based systems for decision making processes are specially developed to support this multifaceted approach.

A wide range of possible DSS definitions and core functionalities exist. Hahn & Engelen (2000) dis-tinguish two types of computer-based DSS:

1. Data-oriented DSS are primarily concerned with retrieval, analysis and presentation of data.
2. Model-oriented DSS include activities such as simulation, goal seeking and optimization.

Generally a DSS consist of a data base, GIS and other tools or services and the user interface with all the central functionalities and often models are included. It is a striking fact that many DSS exist but only a few are really taken into use in practise or used as intended. The reasons are very often not be-cause the technical realisation is not good enough but because the needs of (potential) users were not met adequately.

During the last years some studies were undertaken to find out reasons for this phenomenon. In the following the analysis of three different studies and their key results and messages will be revealed and discussed. With a synopsis and analysis of two workshops and one evaluation about factors of success and failure for DSS four main reasons for failed development have been worked out (Hare 2004, FEEM 2005, Uran 2002):

- complexity: the system is either too complex or too simple; user interface is not easy enough to use/not intuitive
- transparency: the documentation of data and models is not adequate and uncertainty of results is not transparent
- appropriate functionalities: the needed requirements like scenario building or evaluation of al-ternatives are not satisfactory realised
- flexibility: the system is to inflexible, models cannot be changed, data base interface is not suitable

The most important problem to overcome is to bridge the gap between the developers and the users. Therefore the phase of requirement elicitation has to be done thoroughly. Different elicitation tech-niques exist like interviews, questionnaires, workshops, prototyping and so forth. Each of them has it pros and cons so some different techniques should be used. An iterative and interdisciplinary devel-opment process together with the future user group (or representatives) for gathering requirements is considered as ideal.

Because the importance of including the future DSS users in the development process has to be emphasised for a successful development and implementation a new structure of DSS is proposed here. The DSS can be seen as a sociotechnical instrument with three main components:

1. the interface which includes the user interface and the user specific information, structure and processing
2. the technical component with database, knowledge base, models, GIS, and other possible tools
3. the social component which consists of the interdisciplinary developer team that works out DSS requirements in a discourse.

The DSS for IRBM can be understood as a sociotechnical instrument for analysing, visualising and collaboration for a better understanding and handling of complex system for a coherent and transparent management process.

4 REQUIREMENTS FOR A DSS

In this paper not all requirements for IRBM DSS which should to be regarded can be revealed. The focus here lays on two issues: the aspect of participation in IRBM and technical support for it and key functionalities for DSS.

4.1 Participation

First of all we have to consider that no blueprint for excellent or appropriate public participation ex-ists. Thinking about a reasonable way of pp covers a variety of tasks: Learning how to participate or to organise participation, developing new management styles and attitudes, learning about the river basin to be managed, building up trust between participants, representing and sharing perspectives, develop-ing new partnerships, social learning.

Using several sources (Abbott 2001), Kleinhückelkotten 2002, Baumann et al. 2005, eParticipation, Kingston, EU Water directors (2003), von Haaren et al. (2005), Selle & Rösener (2003)) and own experiences some general requirement - which are certainly not all-embracing - can be stated:

- First of all a change of paradigm has to be take place: Decision makers have to change their role from decision maker to knowledge provider to act as moderators between experts and general population as the stakeholders. This is the most important and most difficult point.
- The communication structure and strategy is crucial in pp.

  i. A multi-channel communication should be realised (not only one type of communication but a cascade of approaches to public with a set of types and instruments.

  ii. A mutuality with and between stakeholders should be possible.

  iii. Address of different milieus, groups and different communication measures tailored for individual milieus (different milieus oriented along main milieus.

  iv. Gender sensitive approach

  v. Participation on a consultation level is the minimum to have be realised. A feedback must be possible.
- It must be clear how participants can influence the planning process.
- Possibility for Citizens to engage themselves is context dependent and preferable informal /anonymous if desired.
- Transparency: information about who is involved, how are the comments are used, how are the decision structures are important.
- Gain new target groups by new media (young people, business people, people living in the countryside).
- Using Internet and e-participation tools because of

  vi. Permanent accessibility of information

  vii. Profoundness and clearness/visualisation options

  viii. Interactivity

  ix. Easy to keep information actual

  x. Quick feedback is possible

  xi. Possibility of Cross-linking

Eventually a tight spot exist in the phenomena that public participation is most asked and reasonable on the local level where discussions are undertaken and measures agreed upon and impacts are per-ceived but information or model results are often too abstract or imprecise for adapting on the local scale. We ca argue that anyway general information can be interesting and appreciated to regard the whole complex. But when is comes to local decision a high level of information aggregation of infor-mation can produce scepticism on local level. This experience is described by evaluation participatory modelling projects in Sweden (Jonsson & Alkan-Olsson 2005, p. 16).

A DSS for IRBM has to provide at least information and provides possibilities for consultations. An active involvement of stakeholders should be as well possible. It is to advocate if functionalities for shared decision making are implemented. This is especially important for DSS tailored for the local level where concrete measures have to be discussed and traded off. For generic DSS this option seems to be not as important as for the local level.

4.2 System requirement specification

An important step to be undertaken for a thorough DSS development and construction is the formula-tion of system requirement specification (SRS). As an appropriate structure the formulating the guide-lines for DSS development the composition of the Institute of Electrical and Electronics Engineers (IEEE) recommendations practise for software requirements specification (IEEE 1998) seems to be adequate for DSS.

The following issues are proposed as SRS structure:

a) Functionality. What is the software supposed to do?

b) External interfaces. How does the software interact with people, the systems hardware, other hard-ware, and other software?

c) Performance. What is the speed, availability, response time, recovery time of various software func-tions, etc.?

d) Attributes. What is the portability, correctness, maintainability, security, etc. considerations?

e) Design constraints imposed on an implementation. Are there any required standards in effect, im-plementation language, policies for database integrity, resource limits, operating environment(s) etc.

In this paper only one issue shall be described more in detail. Several studies were undertaken by the author with almost 200 peoples from different working fields of IRBM. These people came from five countries in the North Sea region. In the time period from 2004-2006 different workshops with inter-national and interdisciplinary groups, questionnaires, interviews, evaluation of a DSS prototype were conducted for identifying general requirements for DSS in IRBM (Evers i.p.).

Some aspects of the first requirement issue, the functionalities, will be described here.

4.3 Set of general DSS requirements – functionalities

a) Compilation of data, information and knowledge with easy and quick access

This means issues like:

- compilation of data in a central data base which is regularly updated with easy, free and fast access.
- make available all relevant information on various aspects and the best available current knowledge
- data / information for identification of pressures - state – impacts - response
- showing missing information and gaps
- showing information and special analyses with maps with explanations

b) Support of planning/decision-making process

This includes following steps typical for decision making processes:

- Problem definition (problem identification, seeking/defining objectives/goals, identifying knowledge required, Identifying possible bottlenecks, Defining evaluation criteria)
- Developments of what-if scenarios including the ranking of scenarios
- Development of alternatives (search for ready-made alternatives, screen ready-made alterna-tives, Developing individual alternatives, showing ways of how to meet goals)

- Effects (simulating and or estimating effects of remaining alternatives, presentation of effects, interpretation of effects, visualisation results interpretation, showing key issues, risk areas)
- Evaluation (concernment analysis, evaluating alternatives according to set of criteria, visuali-sation results of evaluation, prioritise criteria, identify synergies between different measures, cost-benefit-analysis / enhanced cost-benefit-analysis, multi criteria analysis)
- Operational management (provides guidance through the planning process, provides a logical structural approach which ensures that key stages are not omitted)

c) Handling of complexity/better understanding/future perspectives

- combining information and showing complex mid- and long-term interrelations
- Visualisation of scenarios, measures and alternative options with maps, graphs, tables etc.
- Users can learn from other examples and new information (info boxes, dta base about good practise examples, measure pool)
- make possible a link/exchange between catchment and sub-catchment
- integrate a interactive learning tool
- provide library with information about the system

d) Communication/participation /explanation/justification

- give easy and structured access to all relevant information
- including communication platform (chat rooms, transactional functionalities..)
- storing of local and generated knowledge
- transparency of information and process
- supply of tools for stakeholder involvement
- setup of a platform for support and discussion
- possibility to give feedback (or judge) to stated problems, planned measures etc. (discourse Management) Include negotiation tool
- stakeholder Analysis

5 CONCLUSIONS

IRBM is a broad and complex field which combines not only the elements of natural systems but as well the human system. In general Decision Support Systems can assist the integrated managing ap-proach of IRBM but most of the developed systems are not used in practise or to whom it was de-signed for. Lots of DSS projects deal only with designing the natural world – which is often complex enough – but neglect the real user demands. Until now no standards exist that ensure that DSS have certain qualities and that missing functionalities would belong to the past.

Three aspects shall be stressed to improve this situation: coordination of management objectives, re-garding minimum user requirements for DSS development, and collaborated research and develop-ment work to generate more synergies in DSS development.

Divers legal frameworks have to be considered to meet the objectives of integrated water resources management as described in this article. It would be very helpful to coordinate these management fields on catchment levels. The clearer the management objectives are the easier the implementation in a DSS can be realised.

More emphasis must be given to optimise the user interface and certain users' requirements of DSS. Several evaluations were carried out to find out some key issues which have to be regarded by devel-oping DSS for IRBM. One key issue which is trivial but rarely respected is to bridge the gap between users' purposes and the developers. A close link between the developers and the users and especially an interdisciplinary development and continuous evaluation of the system together with users is stated as extraordinarily important. For emphasising this issue a new DSS structure as a sociotechnical in-strument is proposed.

Two important issues of requirements are presented: facilities for participation and DSS functional-ities. Because of the multi-purpose demands of integrating water, environment and socity, establish-ment of a network centred, modular structured system might be a solution for more cooperation and synergies in developing DSS.

6 REFERENCES

ABBOTT, Michael: The water knowledge initiative. http:\\wiki.waterknowledge.org, 2005

BANDARAGODA, D. J.: “Water-land linkages: A relatively neglected issue in integrated water resources management.” Paper presented at the “SaciWATERs” workshop on “IRBM in South Asia: Global Theory, Emerging Practice and Lo-cal Needs” held in Colombo, Sri Lanka (20-22 December 2002).

EUROPEAN COMMISSION: An EU policy on flood risk management. http://ec.europa.eu/environment/water/flood_risk/index.htm, 2006

EUROPEAN COMMISSION: "Directive 2000/60/EC of the European Parliament and of the Council establishing a frame-work for the Community action in the field of water policy" - The EU Water Framework Directive - integrated river ba-sin management for Europe, 2000

EVERS, Mariele: Decision Support (Systems) for Integrated River Basin Management. Requirements for appropriate tools and structures for a comprehensive planning approach. i.p.

EVERS, M., Brock, J. Rubach, H. & Urban, B.: Integrated spatial management in floodplain landscapes: development of a DSS to conflate different land use demands in planning processes (iFMH). Integrated Land and Water Resources Management: Towards Sustainable Rural Development (International Commission on Irrigation and Drainage 21st European Regional Conference, Frankfurt/Oder, Germany), 2005

FEEM: Results of the International Workshop on “Success and failure of DSS for integrated water resources management”. Venice, Italy, 6 - 7 October 2005

GEERTMAN, S. & Stillwell, J.: Planning Support in Practise. Springer Verlag, Berlin, Germany, 2003

GWP/TAC (Global Water Partnership, Technical Advisory Committee). Integrated water resources management. TAC Background Paper No. 4. Stockholm: GWP, 2000

HAAREN, von, Christina, Bettina Oppermann, Karl-Ingo Friese, Roland Hachmann, Jutta Meiforth, Arne Neumann, Simone Tiedtke, Bartlett Warren-Kretzschmar, Franz-Erich Wolter: Interaktiver Landschaftsplan Konigslutter am Elm. Ergeb-nisse aus dem E+E-Vorhaben „Interaktiver Landschaftsplan Konigslutter am Elm' des Bundesamtes für Naturschutz. Naturschutz und Biologische VielfaltHeft 24, 2005

HAHN, B. & ENGELEN, G.: Decision Support Systems (DSS) for river basin management. International Workshop 6 April 2000, Koblenz, Bundesanstalt für Gewässerkunde, Koblenz-Berlin, 2000

HARE, Matt: The use of Models to Support the Participatory Elements of the EU Water Framework Directive: Creating a dialogue between Policy Makers and Model Makers”, 2004 …

IUCN (International Union for Conservation of Nature and Natural Recourses): Wetland Problems. www.iucn.org/themes/wetlands/wedlands.html, 2005

ALKAN Olsson J. and ANDERSSON L.,: Possibilities and problems with the use of hydrological models as a communica-tion tool in water management, International Journal of Water Resource Management (special issue /WARM/ Advances in Global Change Research), 2005

IEEE (Institute of Electrical and Electronic Engineers): Recommended practice for software requirements specifications, IEEE Std 830-1998, 1988

LOUCKS, D.P.: Developing and implementing decision support system: A critique and challenge. Water Resources bulletin, 31(4), 571-582., 1995

SAVENIJE, H. G.; and VAN DER ZAAG, P.: The management of shared river basins: focus on Development, Ministry of Foreign Affairs, The Hague Revised and published as “Conceptual framework for the management of shared river ba-sins; with special reference to SADC and EU”, in Water Policy, Vol. 2, Nos. 1-2, The Hague: Elsevier Science Ltd., 1998

SOMLYÓDY L., VARIS O., YATES D. : Freshwater Management: Dilemmas and Challenges, IIASA WP-95-37, Laxen-burg, Austria, 1995

TUMWESIGYE, E., VOJINOVIC, Z., JONOSKI, A. & ABBOTT, M. B.: Towards a new business model in urban drainage modelling and hydroinformatics. 10th International Conference on Urban Drainage, Copenhagen/Denmark, August 2005.

UNITED NATIONS – Economic and Social Council: Sustainable Flood Prevention. http://www.unece.org/env/water/ publications/ documents/guidelinesfloode.pdf, 2000

UNITED NATIONS ENVIRONMENTA PROGRAMME (UNEP) : Global resource information database (UNEP GRID): Europe - participation http://www.grid.unep.ch/product/ publication/freshwater_europe/pol.php, 2005

UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT (UNCED): Agenda 21. Rio de Janerio, Brazil, 1992

URAN, Oddrun: Spatial Decision Support Systems for Coastal Zone and Water Management. Dissertation at Vrije Univer-siteit Amsterdam. ISBN: 90-9016270-4, 2002

WORLD WILDLIFE FUND (WWF): WWF`s Water and Wetland Index. Critical issues in water policy across Europe, 2003

WORLD WILDLIFE FUND (WWF): Integrated River Basin Management (IRBM); http://www.panda.org/about_wwf/what_we_do/freshwater/our_solutions/rivers/irbm/index.cfm (n. d.)