Towards a User-oriented Design of a DSS for Integrated River-Basin Management: the Elbe DSS Prototype

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Abstract: The problems faced in the German part of the Elbe catchment range from poor navigation conditions and flooding vulnerability to a need for nature restoration in the floodplains. A variety of river engineering works such as large-scale dike shifting, channel dredging, and large-scale retention are in a planning or implementation stage. Usually the initiative for such measures is taken from a local or sectoral point of view. Therefore, it is not always clear how different measures will interact with each other, nor how their effects influence the natural conditions in the floodplains. In order to examine different strategies for sustainable management the German Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde) initiated a project to develop a prototype tool for integrated management of the Elbe catchment, which includes functionalities related to inland navigation, water quality, flood safety, and vegetation ecology. From the beginning of the project onwards great value was attached to the involvement of end-users in the design process. The experience of the project is that internal consistency of models and data, effective communication, and functional flexibility are essential to find a proper balance between scientific standards, the availability of models, and the requirements of users.

Keywords: Elbe; Decision-support systems; River-basin management

1. INTRODUCTION

After the flood catastrophe in 2002 the German federal government issued an action program to reduce the risk of flooding in the future and mitigate the effects. A variety of river engineering works such as large-scale dike shifting, channel dredging, and retention are in a planning or implementation stage. Usually the initiative for such measures is taken from a local or sectoral point of view. Therefore, it is not always clear how different measures will interact or how the natural conditions in the floodplains are affected. Moreover, uncertain future conditions related to climate change and land-use development may interfere with the expected results. In order to examine different strategies for sustainable management of the river, its floodplains, and the river basin the German Federal Institute of Hydrology (Bundesanstalt für Gewässerkunde - BfG) initiated a project to develop a prototype tool for integrated river-basin management, which includes functionalities related to inland navigation, water quality, flood safety, and vegetation ecology in the floodplain. The project started in the spring of 2002 and was completed by the end of 2005 with the delivery of a DSS prototype for the Elbe River, its floodplains, and the catchment. The development team included researchers of several universities, as well as consultants and software engineers, and was coordinated by the BfG. From the beginning of the project onwards much attention was paid to the involvement of end-users in the design process. This was achieved by following an iterative approach for the design, with room for regular user feedback, and an emphasis on the functional aspects of the design, as reflected by the selection of measures, indicators, and scenarios. The first version of the DSS is now being presented to a mixed audience of potentially interested stakeholders, decision-makers, and researchers involved in the Elbe River. The experience of the project learns that the main difficulty is to find a proper balance between scientific standards, the availability of models and in particular data, and the requirements of users. Both the users and their requirements may change during the design process, which can take several years if data and models are partially under development. Ideally the design of a DSS follows an iterative path which ends in an optimal balance between technical functionality, scientific quality, and user involvement (Figure 1).

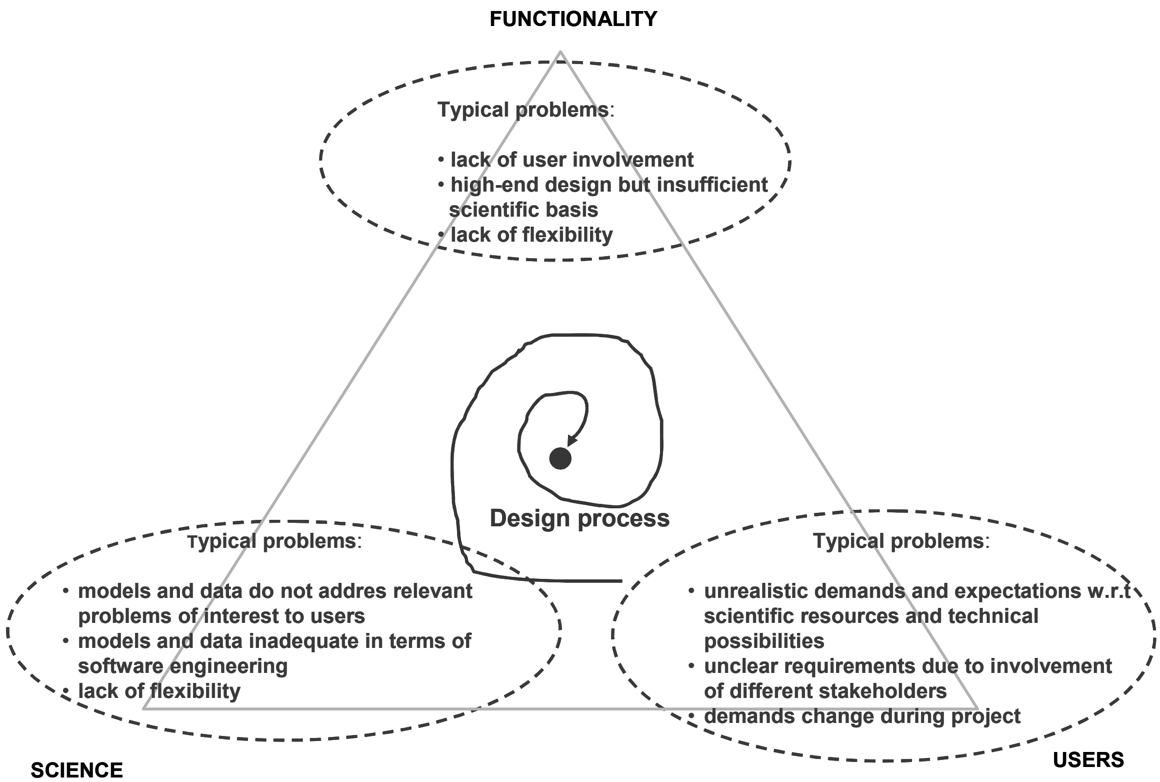

Figure 1. Iterative design of a DSS with typical problems that arise if one of the aspects of the design is overemphasized.

If one of these three aspects becomes overemphasized the acceptance of a DSS will reduce considerably due to a lack of functional flexibility (because complex research models are less easy to adapt in terms of measures and scenarios) or, on the other hand, a lack of scientific soundness (because simple and more flexible models lack scientific underpinning). Obviously practical limitations and unexpected problems are inherent to any large-scale project involving multiple users and developers. Nevertheless the acceptability of the final product and efficiency of the design process can be increased by sufficient awareness of the aforementioned trilemma. As will be explained this can be achieved by employing simple but adequate models and data, regular communication between developers, researchers and users, and striving for internal system consistency.

2. DESIGNING THE ELBE DSS

The pilot Elbe DSS is based on the interdisciplinary coupling of available models and data collected in a research program funded by the German Federal Ministry of Education and Research (BMBF) (Gruber and Kofalk, 2001). The functionalities that are included in the DSS are: water quality (point- and diffuse sources of pollution), floodplain vegetation, flooding safety, and shipping (testing stage). In view of the multi-objective nature of the prototype DSS and scale differences of models and data, the choice was made to use a modular design (Figure 2) pertaining to three scale levels: catchment, main channel (including floodplains), and river section (a section of 20 km near the town of Havelberg).

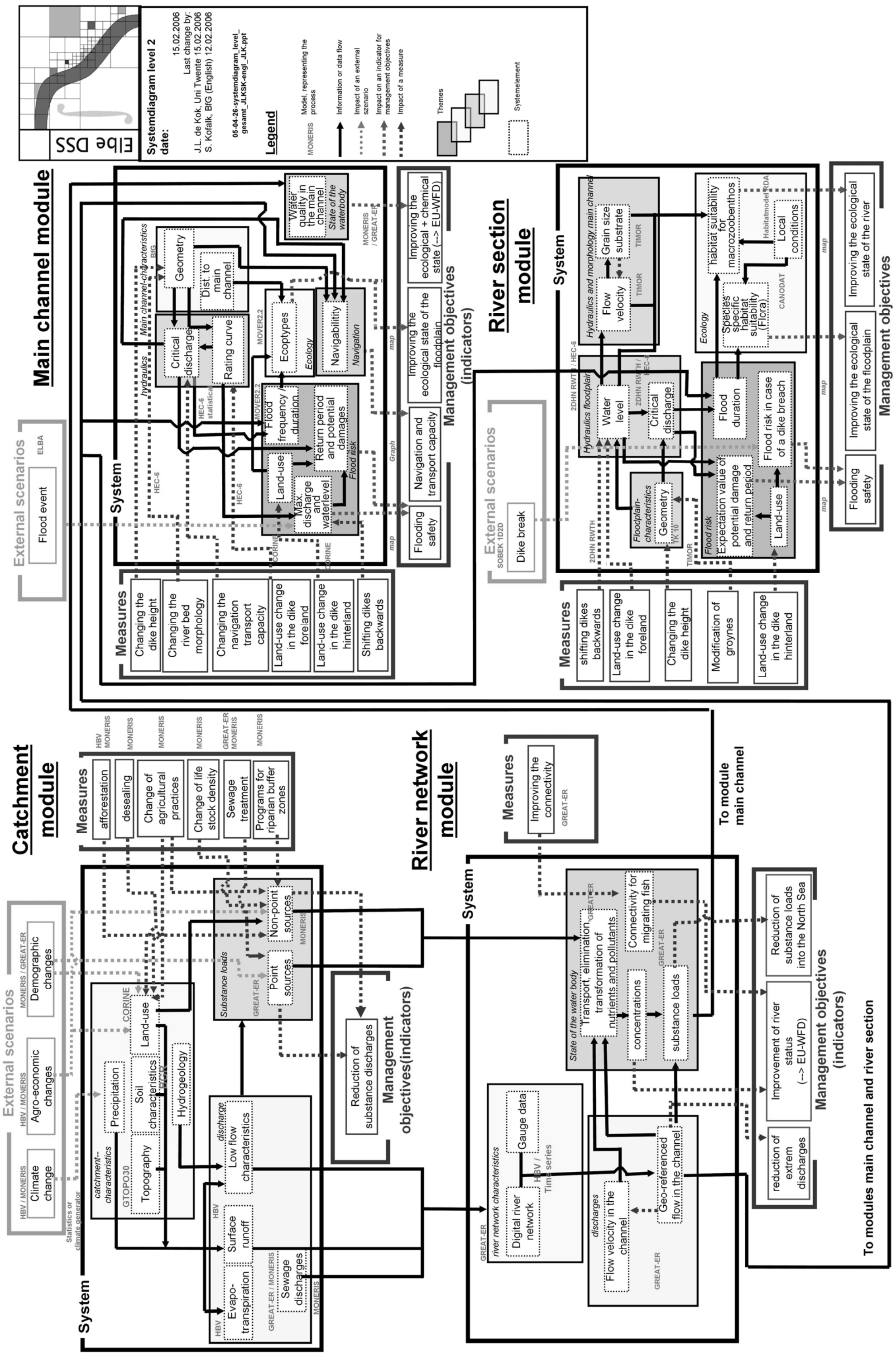

Figure 2. Modular design of the Elbe DSS, with a clear distinction between the model system, measures, indicators, and scenarios.

The development of the DSS comprised three distinct activities (De Kok and Wind, 2003). During the *problem formulation* contacts with stakeholders and users were established, and the relevant problems, indicators and tentative measures were identified. In this phase the difficulty was that the users were not known yet, and that the problems mentioned were sometimes not in line with the strategic purpose of the DSS, for example because of their local, operational or sectoral character. The measures to address the problems were even less clear at this stage. Nevertheless, a preliminary choice of problems, indicators and measures could be made. The *qualitative design* concerned the linking of measures and indicators, as shown in the causal system diagram of Figure 2. The system diagram proved a very useful tool for communication with the end-users and within the design team, and formed the basis for the user interface of the Elbe DSS (Figure 3) as well as the modeling, with a similar distinction between the system, measures, objectives, and scenarios. Due to changes in the functionality and priorities of the users the design of the system diagram was a continuous activity although most of the effort was made during the first half of the project. Absolute perfection of the system diagram was not considered meaningful. After several iterations the system diagram was considered consistent and only limited changes were implemented because adaptations become more difficult towards the final stage of the project in view of the consistency with other models and the user interface (Figure 3). Most resources, however, were spent on the *quantitative design* of the DSS: the collection of existing models and data or formulation of new models or preparation of additional data. For practical reasons the design was based on existing models and data as much as possible, although it was noticed that, for example, the elevation and dike data for the main channel module had to be completed during the project. The completion of these data turned out to be more time consuming and difficult in terms of pre-processing than was anticipated. A partial discrepancy between the functionality reflected in the system diagram and the availability of models and data proved to be a bottleneck for which a solution had to be found. Shifting resources to other project activities only temporarily solved the problem. More complex "research" models usually require more accurate and expensive data, and have a scientific, discipline-oriented purpose rather than a function as

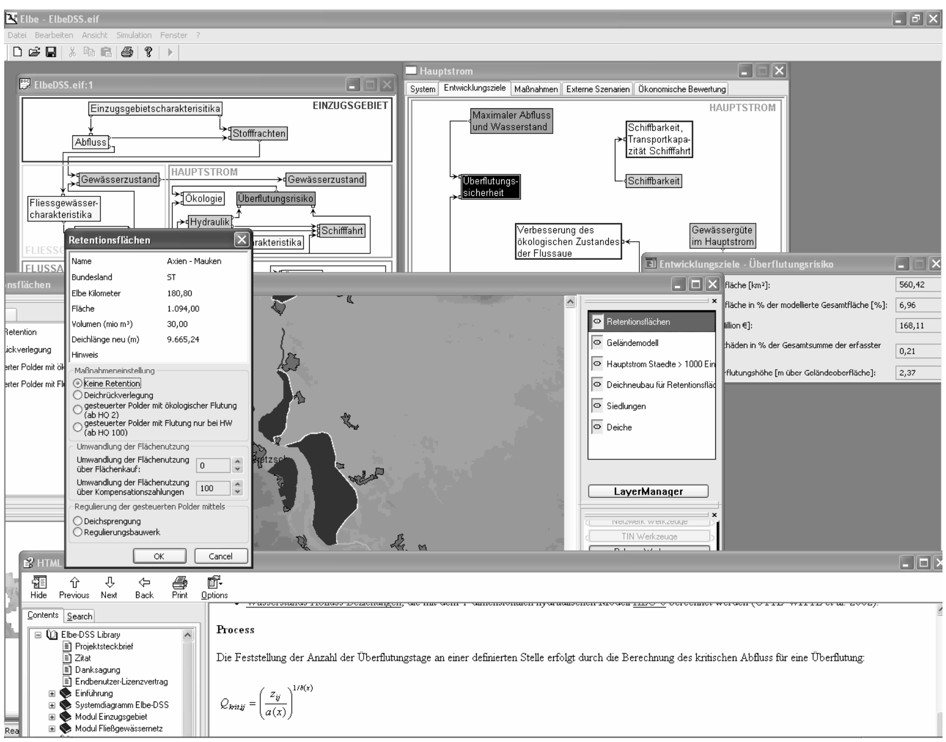

Figure 3. View on the user interface of the Elbe DSS with the system diagram, interactive maps and dialogue boxes, and part of the online model documentation (example measure of retention polders).

a part of an integrated software tool. The application of research models caused both scientific and technical challenges.

The scientific challenges were due to the interaction of models with different types and quality of input, which had to be addressed by aggregation of some models. In a number of cases the consistency of models and data was determined by means of uncertainty and sensitivity analyses. For example, the required vertical accuracy and spatial resolution of the elevation data for the floodplains could be derived from the sensitivity of the ecological model that used the elevation data as input (De Kok and Holzhauer, 2004).

The technical problems were related to the question whether "heavy" models are to be incorporated in the DSS directly or indirectly. In the first case a software integration shell is needed, whereas in the latter case a simpler (meta) model or a representation of model results can be used. Both approaches have been used in the Elbe DSS. For example, the point-source pollution model GREAT-ER (Matthies et al., 2001) and conceptual rainfall-runoff model HBV (Krysanova et al., 1998) have been integrated directly, whereas rating curves are used for the hydraulic model HEC-6 (HEC-6, 1992, Otte-Witte et al., 2001). The hydrodynamic model SOBEK1D2D™ of WL|Delft Hydraulics has been used to simulate a dike break at different locations, but only the results of the simulations have been incorporated. This limits the choice to precalculated locations, but in this case this was not a problem because these were chosen by the users. Although the direct integration of a model has the advantage that the functionality becomes fully available for the users of the DSS, a drawback is that the interface and architecture require adaptations. In addition the computational load can become too large for iterative use of the DSS in, for example, a workshop with stakeholders. Simpler models are less flexible for the users, but are easier to replace or generalize to new locations as data and calibration demands are generally smaller.

At several stages during the project iterations between the three design activities (problem formulation, qualitative design and quantitative design) were allowed for and also proved to be necessary. After the August 2002 flood, for example, the decision was made to extend the functionality of the channel module with retention polders, which affected not only the system diagram and model base, but also the user interface. At later stages of a project such changes become more and more difficult to implement, mainly for organizational and technical reasons. In addition to internal consistency of model and data, and flexibility for changes the acceptance of a DSS benefits more than from anything else from effective communication between the developers, users, and researchers. The communication with the users was organized in different forms. During the feasibility study that preceded the project the users had to be identified first. This meant that a large number of institutes and persons with an interest in the management of the Elbe River were contacted and consulted. The results of these consultations provided the basis for the problem formulation. At the beginning of the main project a steering committee was formed to monitor the progress and give feedback on the achievement of milestones. Halfway the project a stage was reached where a tentative functionality of the DSS could be shown to selected stakeholders. Their feedback has been used to adapt and improve the design. In the beginning of the project the comments would have been less detailed and useful due to the lack of concrete examples of a DSS, which again justifies the iterative approach of Figure 1. In addition to the communication with the users and stakeholders the activities of the developing team had to be coordinated in view of the different interdependent tasks allocated. This was achieved by bi-monthly meetings, during which the progress could be verified and problems discussed or prevented. These meetings were essential to ensure that the models and data provided by the different developers were integrated in a consistent way.

3. CONCLUSIONS

During the design of a DSS sufficient attention should be paid to the consistency of models and data, in addition to effective communication with users. During the application of a DSS a lack of flexibility to cope with changing priorities or different demands with regard to the functionality may endanger its acceptance among a wider audience. Our experiences with the design of the Elbe DSS lead to the following recommendations:

1. A regularly but not excessively updated qualitative system diagram is a very useful tool for communication and can form the basis for the design of the user interface.

2. The availability of models and data does not guarantee their applicability in a DSS because of the need to integrate research models not designed for this purpose. To reduce problems this applicability should be verified in addition to the availability and, when possible, uncertainty and sensitivity analyses should be carried out to ensure consistency of models with data and other models.

3. In some cases direct (online) incorporation of larger research models may not be feasible or desirable. Here the scientific challenge is to develop more flexible but simpler meta-models with sufficient scientific quality.

4. The communication with users should take place regularly during a project, and be used both to keep expectations realistic and to make a serious effort to adapt the design at a stage where this is still possible. This calls for an iterative instead of a sequential design process (see Figure 1).

5. We propose to integrate users as project partners with a certain budget in such developments. Defined responsibilities, e.g. for data deliveries and design of the user interface, can ensure the acceptance and later on the maintenance of the DSS.

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