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DSS-large rivers: developing a DSS under changing societal requirements

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Abstract

This article discusses the development process of a decision support system for river management, named DSS-Large Rivers. It focuses on the difficulties encountered during system development with respect to (1) changing opinions in society on the nature of measures to be assessed, (2) changes in IT-technology and (3) different views of the various end user organisations.

DSS-Large Rivers is targeted at flood management by way of river landscape planning, a hot issue in the lower reaches of the Rhine and Meuse river. Since 1995, various decision support systems have been developed to assess this issue. After a short historical overview, the need for a new DSS will be discussed, followed by a description of the process to obtain functional requirements. The paper elaborates on the design and implementation process, paying attention to the difficulty to match changing end user opinions within rather fixed project conditions. A number of lessons have been drawn, both on the development of a DSS within a changing society, and on the technical design and implementation process.

1. Background and objective

Decision support systems (DSS-s) have been used for river landscape planning and management in the Netherlands since 1995 (see Table 1). For the second time in two years, a severe threat of floods occurred along the Rhine branches and the river Meuse, and it became clear that rigorous measures would be required to prevent similar occasions in the future. The first tools were composed of a basic 1D-hydraulic model to describe the water movement, a concept introduced by Nieuwkamer (1995) to translate measures into modifications of the existing geometric profiles in the model. In a later stage of tool development—some straightforward ecological models were added to address vegetation development in relation to hydraulic roughness. The latter systems included innovative DSS-features such as interactive GIS-embedded sketching of measures. A historical overview of DSS-s is provided in Table 1. A more extensive description of those historical facts can be found in Schielen (2000).

This paper addresses the development process of DSS-Large Rivers, the latest version of a Decision Support System for integrated studies for the Dutch large rivers, combining river hydraulics with ecology and socio-economical aspects. The system has been developed by joining the request of two Regional Directorates of the Ministry of Transport, Public Works and Water Management of the Netherlands (i.e. the Regional Directorate East Netherlands managing the Dutch Rhine Branches, and the Regional Directorate Limburg managing the Dutch part of the river Meuse), with the IRMA-SPONGE programme, i.e. the research programme of IRMA (Interreg Rhine Meuse Activities) to develop innovative ideas and methods to deal with flood management, flood risk and vulnerability assessment [http://www.irma-sponge.org].

1.1. Objective and structure of the paper

As indicated this paper addresses the development of the DSS-Large Rivers, focussing on the societal processes that influence the demand for decision support,

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Table 1
Historical overview of decision support systems for river management, developed in the Netherlands

Tool	IVR-DSS
Study/area	Integrated exploration of the Lower Rhine branches
Developed in	1995/1996
Features	Form based interaction with Ms-Access database MeasureModule, 1D-Hydraulic Model
Tool	VVM-DSS
Study/Area	Meuse river
Developed in	1996/1997
Features	Similar to IVR-DSS, operationalized for Meuse River
Tool	RVR-DSS
Study/Area	Room for the River Rhine
Developed in	1998/1999
Features	Similar to IVR-DSS, but extended with 'river projects' database and GIS-based selection facility
Tool	LWI-DSS
Study/Area	Land Water Information Technology programme, Rhine branches
Developed in	1997/1998
Features	GIS-based project editing facility, ecological module, 1D-core elements similar to IVR-DSS, attempts to include 2D-models
Tool	IVB-DOS
Study/Area	Integrated Exploration for Rhine and Meuse Lower Reaches and Estuary
Developed in	1998/1999
Features	LWI-DSS components extended with GIS-based sketching facility, no 2D-models, no ecological module
Tool	DSS-Large Rivers
Study/Area	Nierderhein/Rhine Branches (IRMA-SPONGE and IHRS-workgroup Hochwasserschutz), Integrated Exploration of the Meuse
Developed in	1999/2001

and the difficulties faced in meeting the continuously changing expectations from the end-users and end-user organisations. The paper also contributes directly to the IRMA-SPONGE objectives, namely promotion of public awareness and expertise, in this case targeted at river managers and experts.

Section 2 introduces the historical context of DSS development for floodplain planning and management in the Netherlands, and the need for an improved tool. The process to determine functional requirements has been described as well as the requirements themselves. Section 3 introduces the functionality of the DSS-Large Rivers, and its design and implementation process. The DSS is being used in various studies. Experiences from the employment will be discussed in Section 4, while the article concludes with some lessons learned when developing a decision support system in a rapidly changing societal context (Section 5).

2. Towards a new DSS

2.1. Historical context

Influenced by the negative public reaction on dike heightening projects, innovative ideas by NGO's—such as World Wildlife Fund—to restore the ecosystem in the river area (De Bruin et al., 1987; WL and Grontmij, 1994), the near-flood events in 1995, and the idea that climate change would result in more extreme flood events (Middelkoop et al., 2001), the Dutch government changed their opinion on the way forward to deal with river floods in the future. They replaced the common policy of dike improvement and heightening until the required safety level has been reached, by a policy in which the maximum water level is kept under control, under increasing discharge conditions, by providing more 'room for the river' e.g. (WB21, 2001).

The first studies conducted within this context addressed the river Rhine e.g. (Room for the Rhine Branches, 1999; Silva et al., 2001). Within these studies, decision support systems played a major role to provide the necessary scientific background information.

The project Room for the river Rhine turned out to be quite successful. For the successor of this study, the impression was that the applied DSS would not be sufficient due to its limited level of detail (1D only) as well as the limited geographic shell. Therefore, a new development was proposed, where the central goal was to develop an instrument, which was capable of analysing relevant questions with respect to the landscaping and maintenance of the floodplains and summer bed of the river branches. The instrument had to focus on the interchange of policy-developments (the 1D-line of the DSS) and the detailed design-activities (the 2D-line).

2.2. Inventory of functional requirements

The intention was to develop this DSS using a Rapid Application Development approach. Hence, in an early stage the end users have been included in the design process. As a first activity, several workshops were organised having potential end users as participants. Among the participants were river-engineers, DSS-developers, policymakers and GIS-specialists. These people were interviewed with the aim to make an inventory of the user-requirements of the DSS. The following questions were posed:

- What are, according to you, the key-tasks of a DSS
- What are (on the short term) the minimal requirements of a DSS, such that your organisation will use it. And what are the requirements on the long term
- What is NOT necessary to incorporate in a DSS
- What are the requirements *within* your organisation to operate and maintain a DSS.

While answering those questions, and providing information relevant to the system requirements, the interviewed persons showed, in general, a quite sceptic attitude towards DSS-s in general. Many people consider a DSS as a black box, which produces facts and figures; the user does not really have insight in or control over the way these facts and figures are produced. Therefore, many people have indicated that they want the system to produce uncertainty ranges, rather than for instance just a water level in the river. However, uncertainty is not that easy to contain in a DSS, for there are many aspects of uncertainty and they are hard to model or hard to incorporate in a work-friendly way. In addition, the view of project managers as well as scientists on the principle of uncertainty is different. Managers generally want to have explicit information on it, while scientists usually know beforehand that the aspect is difficult to handle and communicate. Therefore, they often take along the uncertainty while communicating to results towards policy makers. Within the development of the DSS-Large Rivers no priority has been given to functionality to provide additional insight in uncertainty ranges.

The inventory of functional requirements was not easy as, at the period of the interviews, it was not yet clear for whom the system should be developed, e.g. policy makers, project managers, or scientific and technical experts. Therefore, all categories were interviewed.

The first lesson drawn during project evaluation was that this fact, i.e. not knowing from the beginning who will be the end user, has been at the basis of many difficulties faced during the development process. As time went by, it became clear that the people expected to apply the system would be the scientists and technicians. This was due to the complexity of the underlying concepts and models: calculation grids, hydraulic models, different operating platforms etc. It became clear that policy makers would not operate the system themselves, but would propose questions, (parts of) which could be answered with the results produced by the DSS. Experts (scientists or technicians) would operate the DSS in practise and translate the information towards the policy maker.

While the intended users were not known beforehand, the organisations asking for a new DSS also grew from one initiator (Rijkswaterstaat Regional Directorate East Netherlands) to three commissioners (Regional Directorate East Netherlands, Regional Directorate Limburg and the IRMA-SPONGE research programme). However, all organisations were having different demands. The Regional Directorate of East Netherlands was particularly interested in detailed studies requiring 2D-models, as they had already performed an explorative study on the Rhine Branches on a 1D-base (i.e. the projects Landscape Planning for the Rhine and its follow up Room for the river Rhine). The Regional Directorate of Limburg did not yet explore the possibilities of the Meuse river to the same extend as had done for the Rhine branches. To bring the knowledge on the same level, Limburg required an update of a former 1D instrument. Putting theses two opportunities together, the base for joint development of a full-fledged DSS was made. The activities performed under the flag of IRMA-SPONGE were much more focused on technical aspects at the IT-level, enabling re-engineering of some existing modules, as well as an improved interaction between the ecological module and the hydraulic models.

2.3. Functional requirements—the outcome

The interviews have led to a number of opinions, where the intended workflow of the DSS is the key-issue. Other items raised were: interactive design of measures (GIS based), creation of calculation grids, 1 and 2D calculations, wide range of analysis and presentation options (maps, numbers and ranges), DSS-maintenance, different user levels (project manager, technicians and scientists), distinction between 'private' data and public data, wide range of data items and descriptions to be incorporated. Aspects to be included are soils, morphology, ecology, river-engineering, nature, culture-historical features and costs. However, not all aspects have been taken into consideration in the development of the DSS. (Quality of) soil and morphology are not yet considered, because the knowledge, tools and data to tackle this problem are not available or operational.

The interviews have led to the request for a user friendly, modular design of a client-server application, which can connect to existing, applied software. The system should support the workflow of the analyst by accommodating design and assessment at different scale levels, and by enabling fast iterative process to perform quick scans. Results of the DSS have to be reproducible and easy to access. Its presentation of results should accommodate chart-based presentation, at least as good as current procedures, while denoting an uncertainty range—NB this requirement has not been met. Finally, abiotic results should be simulated more accurate then the other results.

A major requirement of all end user organisations was the need to support the existing working methods within the organisation. This requires that existing procedures itself have to be formalised on the base of uniform and accepted methods and data from and towards the DSS.

The DSS should assist in the creation and evaluation of landscaping initiatives on the scale of a river branch. On the other hand, the DSS should be able to support interactive policy-making processes with the possibility of evaluation on many different aspects. This process takes place on the scale of a single floodplain.

To meet both demands, the DSS should support two scale-levels: a one-dimensional level, for evaluation and testing of landscaping initiatives on the scale of a river branch, and a two-dimensional level for the design scale at a single or few floodplains. For the 1D level, the components of the DSS are a traditional 1D-hydraulic model of the water (and sediment) movement and an ecological module. For the two-dimensional level, a more complicated 2D-model for the geometry and water movement is needed. The input and output of this module has to be tuned to the ecological module to make proper predictions of the river ecosystems, at the same level of detail.

It is essential to note that the 1D- and 2D-lines are closely connected. An interchange between the measures specified for the 1D line and the 2D-line should be possible. This is to say that a 1D sketch-design should have the possibility to be narrowed down to the scale of the individual floodplains. Hence, starting with a global design, the assessment on a more detailed level is possible. On the other hand, it is also possible that once a vision has been established for a river stretch (hence, 1D), the elaboration into detailed floodplain plans changes a number of times due to for instance changes of understanding or perhaps participation processes. The adapted plans must then be assessed against the 1D overall vision in order to see whether they are still in line with this vision. Thus, both the top-down approach (starting with 1D plans and filling in the details to 2D-design sketches) as well as the bottom up procedure (evaluating the 2D-plans with the 1D-vision in mind) must be supported.

In short, it could be concluded that the DSS should . . .

- be a GIS-application
- enable a global (hence often 1D) analysis (both in design and calculation; length scale of several kilometres), as well as a more detailed design (limited to a single floodplain, length scale several hundred meters)
- enable interactive design (the already mentioned cycle of vision, measures, and assessing against the vision), preferable direct sketch on a GIS-map
- enable comparison of different cases, with respect to a (adjustable) table of relevant effects
- have solid functionality to trace, reproduce and access results.

3. Functionality, design and implementation

As a wide range of desired functionality is available in existing instruments, but not integrated in one instrument, the Global Functional and Technical designs were based on taking up existing components from various systems and integrating them into one system for both 1D and 2D river-computations.

Given the availability of those existing software components, it was also foreseen that this development effort would mainly be an integration and re-factoring effort. Aiming at a Rapid Application Development-approach, it was foreseen that a relatively short period would suffice to make the instrument operational quite, in order to obtain 'hands-on' experience, which provides input for incremental improvement of the system functionality.

The following conditions were defined in the functional and technical design to obtain the desired system, integrating the policy-oriented application level (1D) as well as the design-application level (2D).

- Four step based workflow support (explore, define, compute, analyse) incorporated in GUI-design
- User interaction (design/definition of measures) in 'normal' river manager's language
- GIS-based (ArcView/ArcInfo)
- Half (2D)/Full (1D) automatic process to translate measures into hydraulic model input and assessment of hydraulic (and ecological) impacts ('one push' on a button)
- Computation results should be reproducible and traceable (case management)
- Computation results can be compared
- Separation of basic system data sets from measure specifications and generated output
- Clear separation between generic software components and application specific data sets.

3.1. The functionality of the DSS

The functionality is entirely centred on the working procedures of the user. The workflow is indicated in Fig. 1.

Under the 'explore' option, the DSS enables users to explore the basic topographic data available (mostly GIS-based) including a pre-assessment of potentially interesting areas for e.g. nature development. The status of the computational system can also be explored, providing information on the (combinations of) measures that have been defined, the computations, which have been completed successful etc. Finally, the DSS incorporates a so-called document information system (DIS), to share the basic documents among different type of users during the various stages of design and assessment. It can provide an exchange platform for additional ideas, objections, points of attentions, logbooks and so on, related to the underlying projects.

The 'design' option is entirely focused on the translation of the ideas from the river manager into model input. In his planning efforts, a river manager wants to assess the impact of measures such as floodplain lowering, dike relocation, nature 'rehabilitation', retention or other measures (see Fig. 2). For its assessment, a DSS user can interact using the language of a river manager, instead of the language of a hydraulic model. Using a dedicated knowledge module, these measures (or interventions) are translated, following strictly formalised rules, into the properties of a hydraulic computation model, e.g. the geometry and roughness of a river bed (see Fig. 3). Note that the user only needs to select a measure (and denote the appropriate properties) and evaluate the results after a calculation. The rest of the process in the figure is done automatically.

The measures supported can be divided in measures influencing the low flow channel, measures influencing the floodplain and retention measures outside the river channel. All measures, except vegetation development in the floodplain and a fixed bottom layer in the river bed, can be translated as a change in geometry. The two exceptions are translated as a change in hydraulic roughness. The measure dealing with vegetation development has shown to be of high interest to river authorities. The DSS enables either to specify a certain vegetation cover, or to compute a cover as an interaction between river hydraulics (flood frequency) and ecology.

To organise the development and assessment of measures in a transparent way, a hierarchical structure has been set up to combine all data into a consistent dataset for model computation (see Fig. 4).

The first few steps are sketching the location of a measure on a map, choosing the right type of measure to apply and allocating attribute values. Various measures can be grouped in a 'project'. For a river manager a project is a coherent set of (local) measures, which can be used in discussions with other stakeholders. In software terms, a project is just a container, to keep overview of the measures defined.

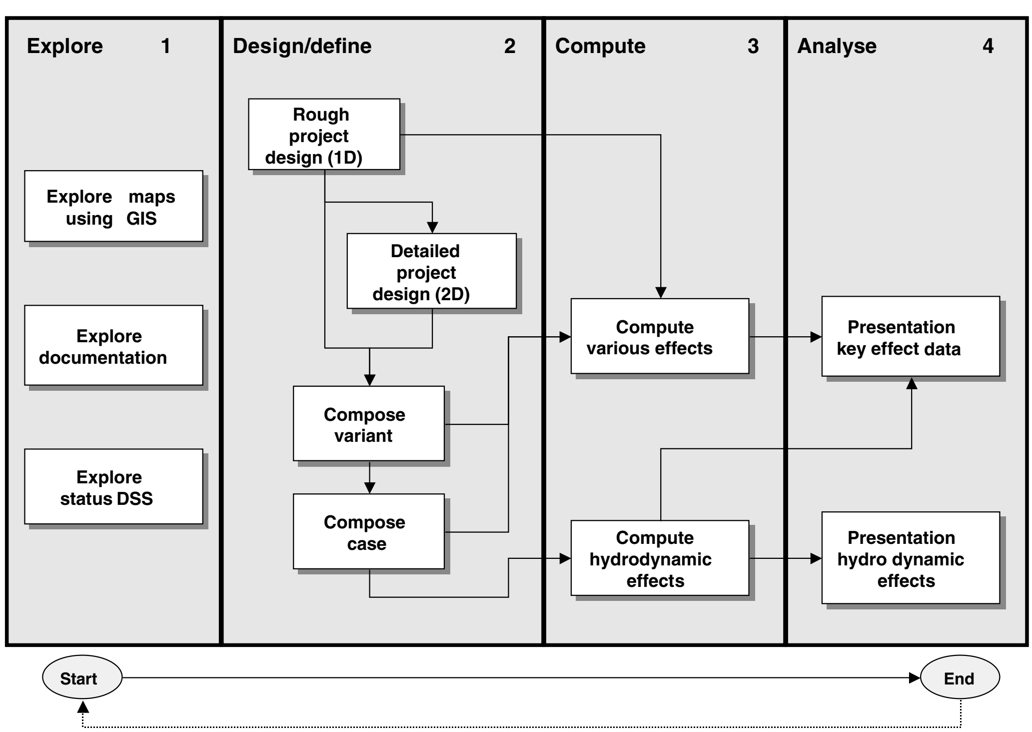

Fig. 1. Workflow of the DSS-Large Rivers.

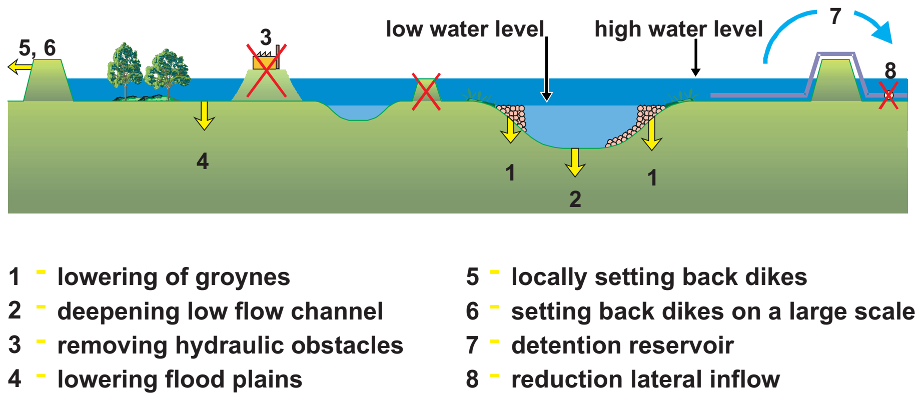

Fig. 2. Overview of proposed measures to alleviate flood risk.

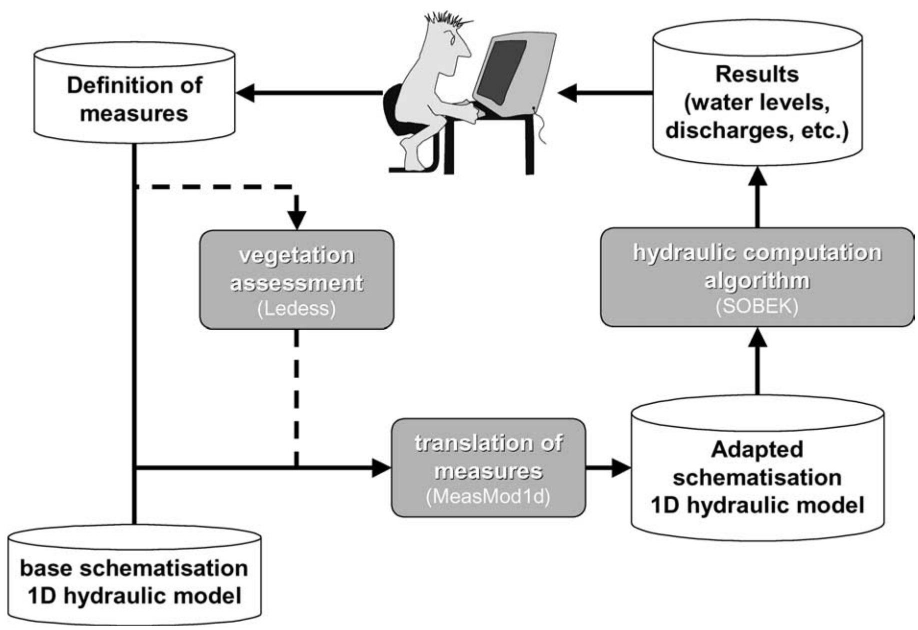

Fig. 3. From specification of measures to hydraulic result (1D assessment). In the grey boxes the associated module has been mentioned.

To enable interactive design of measures and projects, keeping the financial budget in mind, the system allows computation of costs at this stage in the design phase, without the need to perform time-consuming hydraulic computations.

After a project has been defined, it can be chosen whether the design is extended in more detail to enable impact assessment using 2D-models. If not, the design will be evaluated using 1D-models. Once projects have been defined, they can be combined in variants, i.e. another container. Such container is particularly useful in the policy-development phase when assessing multiple projects simultaneously over the entire river stretch.

To enable hydraulic impact assessment, the definition of interventions should be combined with hydraulic boundary conditions (so-called scenarios) and a base model schematisation.

This combination defines a complete set of input for the models and is called a 'case'. Consistent management of cases including its underlying definition (scenarios, schematisation, variant, projects, measures) as well as its associated results is crucial to enable reproduction of computed results.

Once a case is defined, the hydraulic and ecological impact assessment can take place. 1D-evaluation can be started directly. Its workflow is described in Fig. 3. 2D-evaluation requires a (time consuming, hence separate) conversion step to translate the measures, sketched in the GIS-environment into input for the 2D-model (see Fig. 5).

After the computation has been completed, the results can be presented and analysed, using visualisation on the map, or *XY*-graphs over time or along the river branch (see Fig. 6). Both single case data as well as

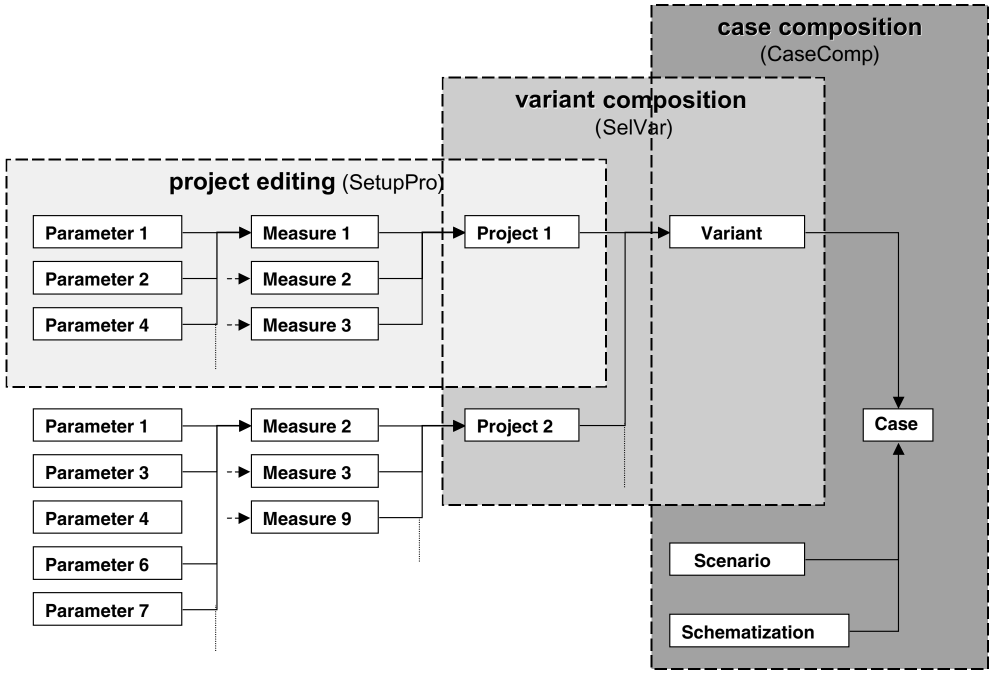

Fig. 4. Hierarchy in preparing a case, including associated components between brackets.

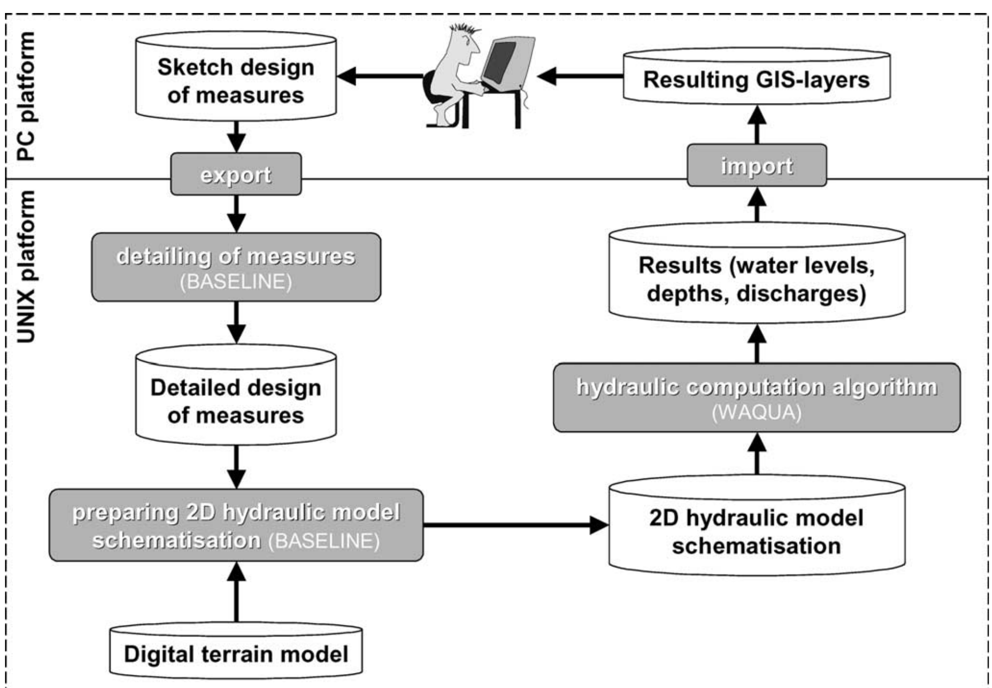

Fig. 5. From specification of measures to hydraulic result (2D assessment).

difference between cases can be analysed in detail. In addition, performance indicators are generated to create a quick overview of impacts in a score-card. These may help to perform for instance a multi-criteria analysis, or the evaluation of linear programming questions (for instance to find the most optimal variant from cost point of view). These features are presently not contained in the DSS, but may be incorporated in a future version, dependent on requests of the end-users.

3.2. The design and implementation process

The DSS-Large Rivers is a system were the main user interaction takes place in a Microsoft Windows

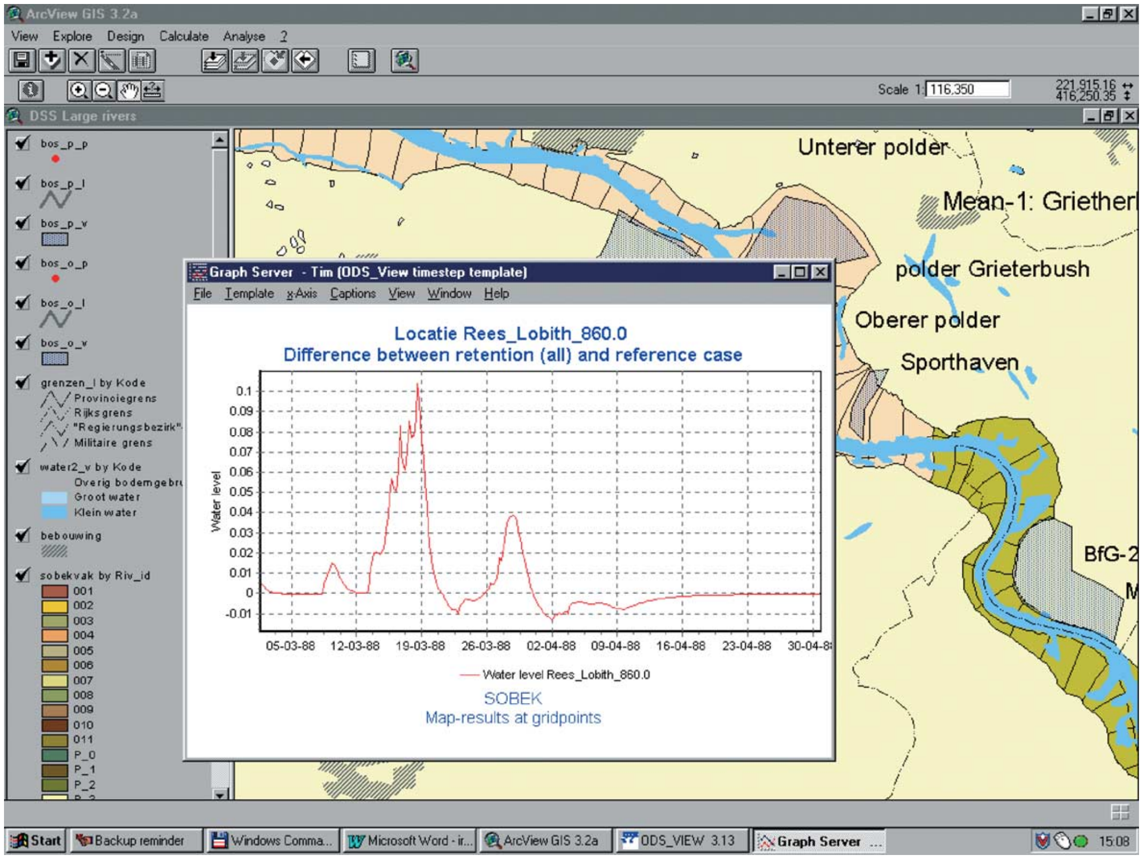

Fig. 6. Presentation of results in time graph. In this example, a map of the difference in water level between a reference case, and a proposed retention measure is superimposed on the area of interest (a part of the Lower Rhine in Nortrhine Westphalia) as it is visualised within DSS-Large Rivers.

operating system, although part of the 2D-software is operated on the UNIX-platform. This mixture of operating systems required a good design document with clear identification of work- and data-flows, as well as identification which component is responsible for what activities.

For the 2D-system, the flows as well as the associated protocols were quite well identified. During the implementation, testing and installation process, various flaws were discovered, many of them related to communication mistakes between software developers and the (computer support department) of the end user organisations. Most of these flaws were relative small in complexity, but were relative time consuming to solve.

For the 1D-chain of activities, the work was much more oriented at re-factoring existing components. During the technical design, the analysis of work- and data-flows, as well as the identification of communication protocols was not spelled out as good as the 2D-chain. As a result, some re-factoring efforts were underestimated, as not all existing essential functionality was properly reallocated (to other components) in the technical design phase.

During the implementation process (following the RAD-approach) the missing elements in the 1D-chain became clear. However, they could not be solved easily, as the project was rather limited in duration, software development capacity and financial budget. Quite often the solutions chosen give an 'ad hoc' impression which at the moment of testing and installation generates extra work in debugging and solving software errors.

In addition to these flaws in the design, the implementation process faced difficulties as the end user's views on desired support of work procedures changed quite often. At the moment of functional and technical design, the feedback from the client was rather limited. Hence, the design documents expressed the main line agreed upon, while simultaneously these documents were not very specific in the boundaries of functionality provided and the exact support of the work procedures. In a later stadium in the implementation phase, i.e. after some prototyping, feedback increased, as well as a growing inconsistencies between ideas/requirements as formulated by interviewed persons and items which could be implemented within the setting of the project (duration, capacity, budget). Discussions with the client sometimes resulted in a request for more features (e.g. in the GUI). In addition, it could be noted that the client/end-users were not very consistent in their opinion on a suitable support of their workflow.

Finally, the implementation process was hindered by the ongoing developments in external components (i.e. the hydraulic and ecological models). The developers of these tools are not sufficiently aware of the fact that the communication with these tools is very strict when incorporated in a larger system. This requires interaction between the DSS developers and the model developers as changes in the communication protocols or data structures of the external components affect the functioning of the DSS drastically.

4. Experiences in the employment

4.1. Experiences during the development

In this section we come back on the interviews that stood at the base of the development of DSS-Large Rivers, and evaluate how they have (or have not) been incorporated in the DSS. Most of these findings are derived after the introduction of the system at the Regional Directorates East Netherlands and Limburg.

While the end-user organisations were known from the beginning, the intended users were unknown until in turned out that handling the system requires quite some technological and computer-science knowledge. Hence scientists and technicians rather than policy makers, would become the actual users.

This shift towards technical users became even more clear due to an 'external' development originating from the Room for the River Rhine project (i.e. a project by one of the DSS-Large Rivers end user organisations). In 2000, a tool was developed to communicate 2D-computation results of a Rhine branches study, generated beforehand, to the policy makers. The impact of this tool, the Box of Block's, on the position and purpose of DSS-Large Rivers has shown to be drastic (in a positive sense). While the end-user organisations asking for DSS-Large Rivers did not make a clear choice with regard to the actual user, the introduction of the Box of Block's clarified the issue. The Box of Block's would become the communication tool to meet the demands of the policy makers, while the DSS-Large Rivers is becoming (one of) the data generators to provide information towards the Box of Block's.

The meet the demands on the work floor, the end-user organisations requested a system where one party could sketch the measures, and another party performs and checks the calculations. This implementation of known working procedures has been facilitated by the relatively simple menu-structure (explore, design, calculate, analyse), and is highly appreciated by the people on the work floor. In addition, end users have shown appreciation for the DIS, as it improves communication about river projects.

The way the basic data and calculation results have been made accessible has, with some minor changes, been appreciated.

During functional design phase it was decided that reproducibility of results was that important, that any project incorporated in a computed case could not be changed anymore. Recent experiences in the employment however, have shown that this restriction is not always desirable, especially if one is working on repeated assessment of projects for e.g. hydraulic tuning of project features. In such situation, one currently has to save the adapted project under another name and compose a new variant and case. So, in this situation two strong user requirements are conflicting, where one (reproducibility) has been noted before hand, while the other (repeated assessment for tuning purposes) has been noted in the employment.

The intended diversity of the system is also recognised, although not all aspects mentioned during the interviews are implemented yet. For instance, sufficient room is available to extend the use of GIS-data in the analysis of non-river engineering aspects.

4.2. Application in practice

After a turbulent period to get the system running properly, and producing sound output, a stage of maintenance and support has been reached, while various organisations (both consultants as well as governmental organisations) apply the system for their studies concerning the Meuse and Rhine. Findings on the application of the DSS-Large Rivers will be presented in Schielen and Gijsbers (2002). During the first months, some small inconveniences and requests were fulfilled, while some algorithms to translate measures into modifications of the hydraulic model also required some fine-tuning to capture unforeseen critical cross-sections. In general however, the users, i.e. technicians, are satisfied (although they always want more features than available).

5. Lessons learnt

Looking back on the development track, a few remarks can be made. Some of them are dealing with technological development aspects, others are dealing with human or social conditions.

5.1. Social developments

The functionality of the DSS is partly overruled by recent decisions made by policy-makers. For example, up to one or two years ago, policy makers were mainly focused on measures in the flow channel and the floodplain. Measures implemented at the land side of the dikes, such as green rivers (i.e. short cuts getting in operation under flood conditions), detention ponds and dike-relocations, were not to be taken into account to tackle the problem of increasing discharge. The reason was twofold: on the one hand, it was not expected that these rigorous measures were needed, but on the other hand, they were much too delicate from social point of view. It should be noted that this is mainly due to the associated claim on the available space. Nowadays, only one and a half year after starting the development of DSS-Large Rivers, green rivers are almost commonly accepted as a possible measure to solve hydraulic bottlenecks (for instance cities, which are built very close to the river). Retention ponds are now at least under consideration, mainly because they have shown to be very effective while the problem of increasing discharge is much larger that one could expect a few years ago. However, the development of the DSS-Large Rivers has not been able to fulfil those changed requirements completely (e.g. the measure 'green river' does not yet exist in the DSS).

Another example in the field of information content, is the cost-module. In the first interviews, it was denoted that a cost module may come in handy, to get a first insight in the costs of individual measures, projects and cases. In a later stage, this idea was already extended in the sense that also insight in the uncertainty of those estimates would be convenient. Therefore, a Monte-Carlo analysis was requested, either by linking the outcome to an existing tool or by developing a new one. In the project Integral Exploration of the river Meuse, it is even the wish to perform a societal cost-benefit analysis or a multi-criteria analysis. As a result of this discussion, part of the development effort was focused on a linkage to an external Monte-Carlo tool, while other parts, e.g. to obtain relevant information from GIS-data, have been neglected.

A major difficulty of this DSS development project was the uncertainty about the intended end user. The introduction of the Box of Block's ended the time of uncertainty and might even be considered a salvation for DSS-Large Rivers, as its purpose became clearly focused, namely information generation.

Within the DSS-Large Rivers project, the development of the DSS was hindered by inappropriate communication with the end user organisations during delays. Although pretty obvious, it is recognised that these kinds of projects, i.e. with many people from different organisations working together on the same product, require strict regulations concerning both timeframe and technical contents of software components and necessary data. At the first stage of the project, the RAD-method brings together the developers and end-users. Later on, when the outline of the system was more or less clear, the development, testing and debugging took much longer than expected. As the developers were busy to solve these problems, the contact with the end users diluted. Meanwhile however, the end-users continued in developing expectations about the DSS, some of which they obviously could not recognise in the subsequent releases. A clear framework were the overall functionality is described and constrained is very helpful in these circumstances.

5.2. Technical developments

First of all, the intended Rapid Application Development has not functioned properly. In the beginning, much information was collected from the end-users, and incorporated in the design documents and also implemented. However, a proper RAD approach requires frequent feedback with the end users during the entire process. Except for the period that the design documents were developed, this frequent feedback was partly missing. The functional design document served well as communication for the main line of discussion. The technical design was deliberately not elaborated in too much detail, to be able respond on recent developments. However, the benefits of this open formulation did not fulfil the expected purpose, as repeatedly discussions arose on the details of functionality and interaction procedures. Besides, the technical design was not sufficient specific to describe the details of the functionality, the communication mechanisms and GUI-support. Although the RAD-process is partly meant to stimulate this type of discussion, the setting of the project (system complexity, allowed duration in time, software development capacity, budget, project management) was not sufficiently in balance with this approach, while previous DSS developments already had generated a lot of insight in the desired features. Therefore, the technical design should have been defined in a more strict way, leaving as little room for discussion as possible.

In this case, the technical design was not tailored for software-implementation. Protocols, component-functionality and dataflows were not described in sufficient detail. Therefore, some parts in the implementation process have a strong 'ad hoc' character.

Furthermore, development time stretched out over two years. During those years, IT-technology proceeds. Versions of software change and even versions of operations systems change. The organisations for which the DSS was developed did not always follow these general updates in IT-technology. And if an update was foreseen (e.g. from Office 95 to Office 2000), the DSS still had to comply to Office 95 rules even if the system would run only a few weeks in this environment.

As external autonomous components (e.g. hydraulic and ecological models) become part of a larger system, sufficient interaction between the DSS developers and the model developers is necessary, as changes in the communication protocols or data structures of the external components affect the functioning of the DSS drastically.

Putting things together, some pitfalls are quite typical for IT-projects of this scale. They are listed below:

- The total phase of design, implementation and maintenance has to be made at the beginning of the projects. Intermediate changes in these phases are undesirable.
- Reservation of capacity and resources is essential.
- Dedication to the project is essential. Too often, there are too many things an employee has to do, and hence, the actual work has to go in between.
- The projects are approached as technical problems. During the projects, the wishes and demands of the end-users are insufficient taken care of. Hence, the support for the end-product vanishes.
- Quality is often only directed towards the technological aspects, instead of towards the satisfaction of the possible end-users.
- A correct implementation of several individual substeps does not necessarily lead to a correct end-product. Hence, the overall goal has to be kept in mind at all stages of the project.

In this respect, the results of the American Standish Group (1998) should be mentioned, as they already noticed that the top four of success-factors are: participation of end-users, commitment of the management, experience of the project leader and a clear goal. Also in the development of DSS-Large Rivers, these factors turned out to play an essential role. Some of them were quit clear from the start onwards, others have led to time-consuming delays. Nevertheless, current experiences and requests for application indicate that DSS-Large Rivers will show its value in the near future in forthcoming river-management issues in the Rhine and Meuse river basins.

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