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Lessons learnt in the development, implementation and use of Integrated Spatial Decision Support Systems

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Abstract: Over the past decade there has been a rapid development in the field of Integrated Spatial Decision Support Systems (ISDSSs). Although they are gaining traction in the planning and policy making community, there are few examples of their actual use. This paper will discuss some lessons learnt in the development, implementation and use of ISDSSs.

Based on practical experience, and more thoroughly discussed in earlier work (see e.g. Van Delden et al, 2007), there are eight elements that determine the success or failure of the implementation of an ISDSS:

1. Strategic value: to what extent does the system provide added value to the current planning practice?
2. Availability of appropriate data, knowledge and models: what is available or can easily be collected?
3. Credibility of the system: do the users have faith in underlying assumptions?
4. Domain language of the system: does it fit the users' worldview and connect to their perception?
5. Institutional embedment: where will the system be based in the organization? Who will use it?
6. Culture: are people committed to use the system and to integrate it into the planning process?
7. Ease of use: is the user interface quick and simple to use and provides easy access to all functionality? How much training is required to work with the system and interpret the results?
8. Maintenance and support: are the data and models included regularly up-dated? Is there expert support to optimally use the model and analyze/interpret the results?

Following these eight elements we will describe successes and challenges in past and ongoing work in ISDSS development, implementation and use.

In the ISDSS development community a shared understanding has grown that end-user interaction from early stages of the development process is crucial to connect the system to the context and process of policy making as well as to build ownership and support for the uptake and use of the system. Experience has shown the importance of demonstrating potential users that the ISDSS can improve their policy process by giving them examples related to their current practices that show how the ISDSS can support them. We argue that besides factors internal to the system, 'softer' factors play a crucial role in the uptake and implementation of an ISDSS. Having a champion in the user organisation(s) has proven very beneficial. Once the system is used, the step has to be taken to move from the 'early adopters' of the system to the other users in the organisation. A successful initial implementation does not guarantee long term use of the system in an organisation. Building a user group with sufficient human capacity to operate the ISDSS, link it to policy questions, interpret the results, undertake regular updating of data and identify further (research) needs is a requirement for a continued use.

Based on the lessons learnt we present an interactive and iterative development process that supports the implementation of ISDSS in user organisations.

Keywords: *Decision Support System (DSS), iterative development process, use of DSS, social learning*

1. INTRODUCTION

Integrated Spatial Decision Support Systems (ISDSSs) are rapidly gaining traction in the planning and policy making community. When introduced in the decision-making process in a controlled way, they hold a high added value by bringing scientific knowledge to the decision makers' table. Despite this high interest, only a few ISDSSs are in actual use to support policy preparation and analysis. Academic literature recognizes several reasons for this, most notably a lack of transparency, inflexibility and a focus on technical capabilities rather than on real planning problems (Uran and Janssen, 2003; Vonk et al., 2005; Geertman, 2006). In order to deploy an ISDSS as an instrument for strategic policy making, it has proven to be crucial that the system matches the perceptions, experiences and operational procedures of the policy makers and that it enhances their current policy practices rather than replace existing and well-embedded ones (see e.g. Van Delden, 2003).

We will discuss practical examples of success and failure of the use of ISDSSs based on eight factors that influence its uptake: *strategic value*, *availability of appropriate data and models*, *credibility of the system*, *domain language of the system*, *institutional embedment*, *culture*, *ease of use* and *maintenance and support*. Not all elements are of equal importance in each phase of the development and implementation process. In the early stages, the first four elements are crucial, while the latter four gain importance once a first prototype has been developed. The importance of these elements will grow even more once (potential) users are finding out the capabilities and limitations of the system by using it in their daily work. It is also important to realise that not all elements are internal to the ISDSS. The influence of of the 'softer' components, such as the culture or the institutional embedment have proven to be as critical to the actual uptake and use of ISDSS as the others. The importance of all of these factors has also been noted by Diez and McIntosh (2009).

This paper discusses the lessons learned in the design, development and use of ISDSSs using the GEONAMICA software environment for spatial modelling and (geo)simulation (Hurkens et al, 2008). GEONAMICA has been the basis for many ISDSSs that vary greatly in their application domain (urban and rural areas, coastal zones, river basins) and spatial extent (cities, countries, EU-27), based on the requirements of the user. Examples of ISDSSs developed with GEONAMICA are Xplorah (Van Delden et al, 2008), Environment Explorer (Engelen et al, 2003), MedAction (Van Delden et al, 2007), DeSurvey IAM (Van Delden et al, this conference), Elbe-DSS (De Kok et al, 2008), Creating Futures ISDSS (Rutledge et al, 2009; Huser et al, this conference), LUMOCAP (Van Delden et al, in press) and MOLAND (Barredo et al, 2003).

2. KEY FACTORS FOR FAILURE AND SUCCESS

Van Delden et al. (2007) provide an overview of eight factors that determine the success or failure of the implementation and use of an ISDSS. In this section we discuss those eight factors.

Strategic value: to what extent does the system add value to the current planning practice?

The end-users of the system are the main group to define the strategic value of the system and to give direction to the development in such a way that the ISDSS provides an added value to their policy work. However, in the early stages of the development process it is often not clear to users what they might expect and what the limitations of the underlying models are. Interaction with the knowledge providers is therefore of crucial importance. Once pilot versions are available, targeted training exercises that deal with actual planning issues and show the added value have proven to be very beneficial. Two elements are important in this context: the contribution to the planning process and the link to the planning content.

The Creating Futures project and the Elbe-DSS project both had a clear objective for the ISDSS: Support the Long Term Council and Community Process respectively fulfilling the obligations set by the Water Framework Directive. Furthermore, in the Creating Futures project emphasis was put on understanding the policy process and defining during what part(s) of this process the ISDSS could provide added value.

Conversely, in the MedAction and DeSurvey projects there were no users from the start of the project, which made it difficult to define the aims of the system and to create the connection to the important processes in the policy organisations. Moreover the models included in the ISDSS were already decided from the beginning of the project. This resulted in a very supply driven development with limited user involvement, and consequently, limited user uptake.

Availability of appropriate data, knowledge and models: what is available or can easily be collected?

The main responsibility for supplying the appropriate data and models often lies with the scientists and research organisations (although nowadays more and more user organisations manage and maintain substantial databases). During the development process, gaps in knowledge and data are identified as well as the feasibility and effort required to obtain this missing information. Building awareness of what is available now, in the nearby future, and in the long term, helps to manage the expectations of the different groups involved and avoids misunderstanding of what the system can and cannot do in its different releases.

We often experience that clearly showing what the main gaps are helps in a focused data collection or further development. In Puerto Rico the first version of the Xplorah SDSS included a land use map from the seventies. During the development it became clear that this was problematic not only for the Xplorah system, but also for integrated planning in general and this resulted in a big programme to develop land use maps.

Credibility of the system: do the users have faith in underlying assumptions?

Different factors contribute to the credibility of the system. The use of quality controlled data is an important first one. Using peer-reviewed models that are extensively calibrated and validated is another, as are robustness checks and sensitivity analysis. Furthermore, an open communication and discussion about underlying assumptions and decisions made will contribute to the trust that the involved parties have in the ISDSS. Equally important it is to identify the potential uses of an ISDSS in close collaboration with the end-users and to be clear and honest about the possibilities and limitations of the ISDSS.

For the Environment Explorer and MOLAND products, extensive calibrations and validations have been carried out. For the newer products, such as LUMOCAP and the DeSurvey IAM, only initial testing and calibration has taken place. Very often we face the problem that money is invested only in product development rather than in calibration, validation and sensitivity analysis. We expect that the main reason is that the latter are very time-consuming activities of which the results are not immediately evident for non-experts. Modelers need to take responsibility for communicating the needs for these parts of the ISDSS development process and to follow through on intentions of treating them as an integral and necessary part of the finished product.

Domain language of the system: does it fit the users' worldview and connect to their perception?

Using the proper domain language in the system is mainly the result of the interaction between the software developer and the end-user, although in the translation of model results to policy relevant indicators, scientists can very well play a role. The connection to the world of the end-users does not only lie in the strict sense of the language used, it also includes the way the GUI supports the whole policy analysis and impact assessment process and takes into account the particular culture of the end-user organisation.

In the LUMOCAP and DeSurvey systems, a dual interface has been created to support use by two different types of users: the policy interface supports the policy analyst in carrying out a policy impact assessment and provides him or her with a format to do so: setting up the drivers, creating integrated scenarios, running the system, visualising indicators and comparing results. The modeller interface supports the modeller in updating the data, fine-tuning the parameters and improving the calibration. It provides detailed information to the underlying models and access to all relevant data, parameters and (intermediate) model output.

Institutional embedment: where will the system be based in the organization? Who will use it?

Many policy organisations (the typical users of the system) are organised in sectors per discipline or along functional roles rather than in a way that stimulates integrated planning. To be able to use an integrated system in such an organisation requires thinking and discussion between the developers and the end-users. Also internal politics of organisations shouldn't be underestimated in this process.

In the Netherlands we faced problems in implementing the Environment Explorer at the provincial level, because policy makers working in different sectors did not want to be burdened with the responsibility for all sectors, while in Puerto Rico carrying out integrated analysis is seen as an increase of power, making the different unit heads very willing to host the Xplorah system.

The more embedded the system becomes in the planning processes of the organisation, the more attention will be paid to the workflow of updating information and creating scenarios. Based on user requests, the Xplorah SDSS is complemented with a scenario comparison tool that allows a quick investigation of all data and parameters that have been changed from one scenario to the next. The system also has restrictions built in as to who is allowed to update different parts of the data based. Tailoring the integrated system to policy practices like this is necessary to make it fit within the organisation using it.

Culture: are people committed to use the system and to integrate it into the planning process?

The fact that many people resist change and the experience that time available to learn and explore the possibilities of an ISDSS is often limited threatens the use and implementation of ISDSSs. Continuous enthusiasm and willingness to work with the system and adopt it as part of the planning process are therefore crucial factors for success. This can partly be stimulated by the development team, by showing what the added value could be and how easy it is to work with the system, but practical experience shows that almost all systems currently used in practice have been initiated based on a desire or request from user organisations, rather than on instigation of scientists.

Since the use of ISDSSs in planning and policy making is still very novel, it could be that implementation will become easier once a critical mass of users has been reached. According to Moore this would require a move from the early adopters of the systems (the technology enthusiasts and visionaries) to the early majority (the pragmatists). At the moment, we see a very important factor of success in having one or more champions at different levels of the organisation (Moore's early adopters). Getting key people on board and involving them throughout the development process enables a user-oriented development process in which others feel comfortable to contribute at later stages. All systems that are being used at present have such a person in their organisation. This is however still no guarantee for long term use. Several ISDSSs that were used in administrations are no longer used after the champion moved on to another position or another organization. To ensure continuity it is therefore crucial to build human capacity within the organisation during the implementation process. A critical mass of users ensures continuity after the early adopter moves on.

The Creating Futures project has a long term focus, beyond the duration of the actual project to (further) develop and use the ISDSS. This is because the project leader's organisation is the main end user and therefore has an interest in the success of the investment (of developing the ISDSS).

Ease of use: is the user interface quick and simple to use and provides easy access to all functionality? How much training is required to work with the system and interpret the results?

Users get frustrated when the system doesn't do what they think it should do and when simple tasks become very time consuming, leading to abandonment of the ISDSS as a whole. Herein lies a challenge for the GUI designer to create a user interface that is easy understandable, provides a good overview of the complete system and gives access to all relevant functionality. Only a good understanding –and close interaction– between the software developer and the user can ensure such a user friendly system.

Another aspect that should not be overlooked is proper training in the use of the system. All too often a large amount of resources is spent on development of the system, while training is expected to take place in an afternoon. In this respect it helps to have middle or top management support for the implementation of the system. When learning how to use the system is seen as a real task to which time can be devoted the chances for use greatly increase. For the Xplorah system 50 people from the Puerto Rican Planning Board attended several training courses. Attendance varied from technicians to top management, showing the importance of agency-wide uptake of the system.

Maintenance & support: are the data and models included regularly updated? Is there expert support to optimally use the model and analyze/interpret the results?

Once a decision has been made about the actual location(s) of the ISDSS in the organisation, the following questions present itself: who is responsible for updating what data and models, who is responsible for what type of scenario studies, who is responsible for the overall system, how are we going to organise the maintenance, is the developer's team willing and able to provide ongoing support, who provides the budget to finance the maintenance and support, etc. The answers to these questions then define any additional requirements for the software development.

The Elbe-DSS and Xplorah systems are all fortunate to have ongoing maintenance contracts. MedAction, DeSurvey IAM, MOLAND and LUMOCAP have intermittent development on a project basis which makes a long-term continuation less certain given the fact that each new project is acquired on a competitive basis and in the next round a new ISDSS can be chosen. MOLAND and LUMOCAP have in this respect an advantage, because they are being used by organisations that decide on the budgets for further development and maintenance by themselves, while MedAction and DeSurvey are funded through research programmes where users are not financers.

The decision not to continue with an ISDSS after several years can be a very practical one. In the Netherlands we experienced that an organisation had two systems that provided the same type of information, although the underlying models were different. After having both systems run along each other for several years, budget cuts forced them to select one. One of the main criteria the decision was based on was the number of people able to work with the system.

3. PROPOSED PROCESS FOR DEVELOPMENT AND IMPLEMENTATION

To optimally reach the goals described above, we propose a development process that can best be described as an iterative process of communication and social learning amongst three involved parties (see figure 1).

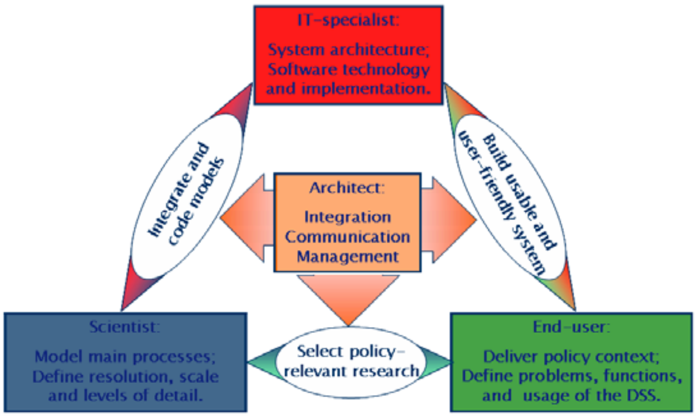

Figure 1: Main parties, responsibilities and integration issues during the development of a SDSS.

First, there are the *end-users* of the system. They provide the policy context and define the policy problems and process. They have certain demands for the functionality and usage of an ISDSS, which has to link to their personal (daily) working habits, education and professional paradigms, as well as to any legislative and institutional requirements and processes. The iterative process enables these demands to be included in the ISDSS. Second, there are *scientists* (or other experts) responsible for the main model processes, assumptions and choices of scale, resolution and level of detail (the substance of the model). These choices are based on research that meets the rigorous standards of science. Third, there are *IT-specialists* who design the system architecture and carry out the software implementation of the models and user interface.

For complex ISDSS projects, a fourth role is vital for success. The *ISDSS architect* has the main responsibility for integration, communication and management of the three other groups and assures the quality of the integrated model underlying the system. As a generalist, the architect bridges methodological and knowledge gaps between policy makers, scientists and IT specialists – both between and within groups. In order to fulfil this role, the architect needs a solid and intuitive understanding of the application domain and the purpose of the system, as well as excellent communication skills.

The interaction between the three groups involved is as important for the quality of the final product as the tasks carried out by each group individually. Policy makers and scientists select policy-relevant research and models capable of answering the problems set out by the policy makers, translate policy options and external factors into model input and translate model output into policy-relevant indicators. Scientists and IT-specialists work together to implement new models, link existing models and ensure consistency throughout the system. IT-specialists work with policy makers to set up a user interface that represents the relevant input and output in a comprehensible manner without overwhelming the user with the wealth of available information and possibilities.

The interaction helps each group to gain a better understanding of the needs of the others and the expertise they offer. For this understanding to take full effect, an iterative approach is best suited. Besides enabling social learning, the iterations help to build trust amongst the groups involved and ensure a goal directed development with inputs from all relevant parties. The delivery of prototypes is beneficial in this approach, since it shows the potential of the product under development and helps to focus the discussion on concrete topics.

Pitfalls in the development process are a lack of respect between and within the different groups, a focus on the individual work instead of on the collaborative product and miscommunication or a lack of communication. All too often, different groups think they understand each other, while they are actually talking about completely different things.

What hinders the process is that iterations are time-consuming and can frustrate some involved, because they feel that work is repeated over and over again. An opinion often heard from the user's group is that they feel used, irrelevant or ignored because they participate in the project, but do not hear back what has been done with their ideas and also do not see them incorporated in the final product. Informing participants about the time line of the development process and about what has been done with their input is therefore crucial in building trust and ongoing commitment. The Creating Futures project is an excellent example of successful communication between users and developers. Through workshop sessions and questionnaires, user input is collected and later on feedback is provided on the project website (www.creatingfutures.org.nz). The LUMOCAP project has maintained a 'strategy paper' throughout the duration of the project describing the goal, the current status, the next steps forward and the way (user) recommendations are taken into account.

The interaction between the architect and the champion plays an important role throughout the design, development and implementation phase. The champion is the direct link to the users, the architect to the development team. To succeed, both should gain the respect of the users, respectively the development team, trust and rely on each other and have excellent communication between each other.

4. DISCUSSION

Throughout the paper we have argued the need for an iterative development. Nonetheless, one should not underestimate the time and related costs for these iterations. While some iterations are crucial to establish social learning, it is important to reflect on the efficiency and effectiveness of revising earlier decisions in each iteration round. Very often resources are limited and priorities have to be defined at early stages. Setting these priorities and creating efficient and effective iteration rounds is still a topic for further research.

No handbook exists that describes what exactly should be done in each iteration round. Although this would be helpful for new development trajectories, it should be noted that the concept of iteration should be seen as guideline and not become a harness. The process does not have to follow the fixed sequence of user – scientist – IT; it should allow for interactions in all directions whenever required. Keeping the overall goal in mind is in this case a true challenge.

5. CONCLUSIONS AND RECOMMENDATIONS

Tools that incorporate and integrate information and knowledge from different disciplines can greatly assist policy development for today's complex and interconnected issues and result in better informed decision-making. Although there is a growing interest in the policy community to use these tools, there are not many practical examples of their actual use. In the introduction we have introduced eight elements that determine the success or failure of the implementation of an ISDSS and discussed these throughout the paper.

After a closer investigation of the development process of ISDSS it has become clear that this process plays a crucial role in the actual uptake of an ISDSS. Through close interaction between the different parties involved (end-users, scientists, IT-specialists and architect) and by providing prototypes throughout the development process, the ISDSS under development is greatly enhanced in its usefulness and usability. Moreover, an iterative development process leads to an improved uptake of the system in the organisations and overcomes some of the problems mentioned regarding the institutional context and the willingness of people to use and adopt it as part of their daily practice.

In the initial stages of the development process, a champion within the user organisation has proven a prerequisite. Uptake from others in the organisation is very often realised when they see the benefits of the system. A good way of showing these is by embedding the DSS in an actual process of policy development, implementation or review, because this clearly shows how and when it can be used as part of such a process and what the benefits and (current) limitations are. In introducing the system in an organisation, it is advisable to not try to change the current policy practice, but to connect to it and create added value.

An important lesson we have learned is that the implementation of the system is not achieved only by delivering a (pilot) version at the end of the project. Sufficient time should be reserved for finding a place in (or outside) the policy organisation where the system will be used and maintained and capacity has to be built within this organisation to use the system and interpret the results. Furthermore the developers should organise themselves in such a way that they can provide ongoing maintenance and support to answer question from users and to carry out the required further developments. This requires of course a financial arrangement that preferably comes from the user organisation(s).

When developing ISDSSs one encounters many scientific and technical problems, either related to linking (scientific) knowledge to policy-relevant information, to the way models could or should be integrated, or in the usability of the system. Although all these factors are crucial *when* the decision is taken to use the system, we very often experience that the 'softer' factors seem to be decisive for the decision *if* an ISDSS will be used. Given the importance of these factors, the question of course rises if and to what extent the development team can influence the social and political elements that determine if the system will be used.

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