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A methodology for the design and development of integrated models for policy support

H. van Delden[a,*], R. Seppelt[b], R. White[a,c], A.J. Jakeman[d]

[a] Research Institute for Knowledge Systems, P.O. Box 463, 6200 AL Maastricht, The Netherlands
[b] UFZ – Helmholtz Centre for Environmental Research, Department of Computational Landscape Ecology, Leipzig, Germany
[c] Memorial University Newfoundland, Newfoundland, Canada
[d] Fenner School of Environment and Society and National Centre for Groundwater Research and Training, Australian National University, Canberra ACT 0200, Australia

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ABSTRACT

The development of Decision Support Systems (DSS) to inform policy making has been increasing rapidly. This paper aims to provide insight into the design and development process of policy support systems that incorporate integrated models. It will provide a methodology for the development of such systems that attempts to synthesize knowledge and experience gained over the past 15–20 years from developing a suite of these DSSs for a number of users in different geographical contexts worldwide.

The methodology focuses on the overall iterative development process that includes policy makers, scientists and IT-specialists. The paper highlights important tasks in model integration and system development and illustrates these with some practical examples from DSS that have dynamic, spatial and integrative attributes.

Crucial integrative features of modelling systems that aim to provide support to policy processes, and to which we refer as integrated Decision Support Systems, are:

- Synthesis of relevant drivers, processes and characteristics of the real world system at relevant spatial and temporal scales.
- An integrated approach linking economic, environmental and social domains.
- Connection to the policy context, interest groups and end-users.
- Engagement with the policy process.
- Ability to provide added value to the current decision-making practice.

With this paper we aim to provide a methodology for the design and development of these integrated Decision Support Systems that includes the 'hard' elements of model integration and software development as well as the 'softer' elements related to the user-developer interaction and social learning of all groups involved in the process.

1. Introduction

Integrated Decision Support Systems (DSS) are rapidly gaining attraction in the planning and policy-making community. When introduced into the decision-making process in a controlled way, they can create high added value by bringing scientific knowledge to the decision makers' table. Despite this high interest, only a few DSS are in actual use to support policy development 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 a DSS 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 (Van Delden, 2003; Van Delden et al., 2007; McIntosh et al., 2007; Te Brömmelstroet and Bertolini, 2008).

For integrated models to be able to provide useful support to policy making, they should be able to represent the complex

* Corresponding author. Tel.: +31 43 350 1750; fax: +31 43 350 1751.
E-mail address: hvdelden@riks.nl (H. van Delden).

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interactions taking place in the human–environment system. Over the past decade the science on model integration has gained in importance and has been facilitated by the improved software capabilities that allow for the development of DSS featuring integrated models. Integrated modelling has evolved from the early integrated assessment models (Rotmans et al., 1990) and ecological economic models (Low et al., 1999) to the current spatially explicit and complex systems as described, for example, by Forsman et al. (2003) on linking farmer's behaviour with air and water quality, by Amann et al. (2004) on air pollution and by Van Delden et al. (2007) on regional development and desertification. This paper builds on practical experience of Integrated Spatial Decision Support Systems (ISDSS) development over the past decades but much of the discussion is also relevant to systems with modest or no spatial representation. It provides a methodology for the design and development of integrated DSS that includes both 'hard' and 'soft' factors. Hard factors relate to the selection and development of a model, model integration, model evaluation and the selection of the software platform. The 'softer' factors relate to linking scientific knowledge to information relevant to policy support, emphasis on social learning of the different groups involved, the role of champions and the implementation of DSS in (policy) organisations. The need for this kind of approach in which both factors are incorporated is also recognised by McIntosh et al. (2007), Van Delden (2009) and Volk et al. (in press). The methodology builds on principles of software engineering, product design and DSS development and incorporates techniques such as evolutionary design and rapid prototyping (Cross, 1994; Marakas, 1999; Robertson and Robertson, 1999). It incorporates elements from the domain of integrated assessment modelling (IAM) by including multiple issues and stakeholders, integrating the human and the natural sciences and by incorporating multiple scales of system representation, spatial and temporal behaviour and cascading effects (Rotmans and Van Asselt, 1996; Parker et al., 2002; Jakeman and Letcher, 2003). The methodology makes use of interaction design methods (Gullikson et al., 2003; Moggridge, 2007) to ensure a user-centred and demand-driven approach and builds on psychology and organizational theory (Weick, 1979; Langley et al., 1995) to understand the process of decision-making, providing insight into both the co-creation of DSS by developers and users and its implementation in organisations. Although literature on the design and development of decision support and other software systems is already widely available we aim to provide added value to this by focusing explicitly on the core characteristics of developing integrated models for policy support: the science-policy interface, the integration of models from different disciplines and the collaborative effort of users, scientists and software developers.

2. Integrated models for policy support

Integrated modelling systems for policy support can be found under a diversity of names, amongst others (Spatial) Decision Support Systems or (S)DSS (Turban, 1995), Planning Support Systems (Geertman and Stillwell, 2003) and Policy Support Systems or PSS (Van Delden et al., 2007). Although they differ in their specifics, for the purpose of this paper we will group them all under the name of Decision Support Systems (DSS) since they have sufficient characteristics in common (for examples of good recent discussions see, e.g. Pettit, 2005; Pettit and Klosterman, 2005). Several authors have mentioned the following common characteristics:

- able to support policy-relevant questions (Parker et al., 2002; Geertman and Stillwell, 2003; Van Delden et al., 2007),
- pay particular attention to long-term problems and strategic issues (Geertman and Stillwell, 2003; Van Delden et al., 2007),
- aim to explicitly facilitate group interaction and discussion (Geertman and Stillwell, 2003; Newham et al., 2006),
- apply in complex and ill-structured or wicked decision domains, characterised through a large number of actors, factors and relations, a high level of uncertainty, and conflicting interests of the actors involved (Rittel and Webber, 1973; Van Delden, 2000; McIntosh et al., 2007),
- are user friendly in entering input, viewing output and analysing results (see for instance Volk et al., 2007, 2008),
- incorporate actual data and process knowledge from different disciplines (Van Delden et al., 2007);
- operate on different scales and resolutions where required (Van Delden et al., 2007; Volk et al., in press),
- may be fully dynamic with feedback loops between individual models (Van Delden et al., 2007, 2008a),
- built as a flexible component-based system that can be extended with additional modules over time (Argent, 2004; Van Delden et al., 2009).

The methodology proposed in this paper is developed for the design and development process of DSS with the above-mentioned characteristics. Although the DSS described in this paper mostly focus on dynamic spatial simulation models that integrate biophysical and socioeconomic model components, the methodology is not limited to this type of systems. It can also be applied to systems that include for example non-spatial models, such as Bayesian networks (Farmani et al., 2009; Ticehurst et al., 2007), models that calculate an end-condition rather than simulating temporal dynamics, or models that focus on optimisation instead of simulation (Seppelt, 1999; Seppelt and Voinov, 2002, 2003).

The examples in this paper come from DSS that were developed using the Geonamica software platform for spatial modelling and (geo)simulation (Hurkens et al., 2008). Geonamica has been the basis for many DSS 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 DSS developed with Geonamica are WadBos (Engelen et al., 2003a), Environment Explorer (Engelen et al., 2003b), MedAction (Van Delden et al., 2007) and its predecessor MODULUS (Oxley et al., 2004), DeSurvey Integrated Assessment Model (IAM) (Van Delden et al., 2009), Xplorah (Van Delden et al., 2008a), Elbe-DSS (De Kok et al., in press), LUMOCAP (Van Delden et al., in press), WISE (Rutledge et al., 2008) and MOLAND (Barredo et al., 2003). Although different in their application domain, they are built on very similar principles. They feature complexly linked multi-scale, spatial-dynamic models and have a user interface that enables interactive access to all drivers and individual models representing the processes. Thus, the user may enter and change driver or parameter values to specify their inputs, can invoke tools for the analysis and visualisation of the model outputs, and can access the integrated help system which clarifies the underlying assumptions and formal definitions of the models and the data used.

In Section 4 of the paper, examples will be provided from the development process of the following DSS:

- The MedAction PSS and its successor the DeSurvey IAM, aiming to provide support to regional development and desertification and having a main focus on sustainable farming, water resources and land degradation in arid and semi-arid regions (Van Delden et al., 2007, 2009; Kok and Van Delden, 2009; RIKS, 2009a).