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Perceived effectiveness of environmental decision support systems in participatory planning: Evidence from small groups of end-users

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ABSTRACT

The challenges associated with evaluating the effectiveness of environmental decision support systems (EDSS) based on the perceptions of only a small sample of end-users are well understood. Although methods adopted from Management Information Systems (MISs) evaluation research have benefited from relatively large (100+) sample sizes, permitting the use of multi-criteria analysis of users perceptions, there are few examples of methods for quantifying effectiveness based on smaller groups of end-users. Use of environmental decision support systems in Integrated Water Resources Management (IWRM) has become increasingly prevalent over the passed twenty years, where their potential for facilitating the participatory process has been recognised; however, few quantitative assessments have been reported. This paper reports the application of a quantitative approach to evaluating environmental decision support systems with small groups of end-users in two case studies where the objective was to facilitate the participatory decision-making process in water management projects. The first case study involved nine end-users applying and evaluating a Bayesian network-based tool to facilitate water demand management implementation in Sofia, the capital city of Bulgaria. The second involved eleven end-users applying and evaluating an integrated tool – the Integrated Solution Support System (I3S) - during a water stress mitigation project in a European context. End-users' perceptions of effectiveness were elicited and compared using statistical analysis. The results of the two case studies suggest that end-user's employment influences their perceptions of EDSS effectiveness. We also show how the applied evaluation method is flexible enough to assess different EDSS types from a range of dimensions.

1. Introduction

The environmental outcomes of the competition for water in natural and human communities create a complex set of dependent relationships (Toope et al., 2003). In recent years research has endeavoured to aid policy-makers, water managers and water users to better understand the complexities and mitigate the risks that can arise during the implementation of integrated water resources management (IWRM) by using participatory modelling tools (e.g. Ticehurst et al., 2008; Castelletti and Soncini-Sessa, 2007).

The literature does not report many examples of EDSS evaluations based on end-user perceptions. There is a need for such studies in order to understand the perception and value gaps between researchers/EDSS developers and stakeholders/policy-makers. By reporting two examples of EDSS evaluation with small groups of end-users, we provide a 'quantitative' approach with small groups and consider a number of different dimensions to evaluation. One example draws on end-user experiences with a Bayesian network-based tool, whilst the other references a recently developed water stress mitigation tool, the I3S platform (Kassahun et al., 2008).

Among the benefits of using EDSSs in a participatory planning context is the opportunity for Social Learning (Henriksen and Barlebo, 2008) whereby each individual with a major decision stake develops a better understanding of the causes and effects of

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those decisions on them and the wider community. The context for evaluating the EDSSs used in the two case studies reported is participatory water management, so as well as other criteria such as decision confidence, reliability, etc., we were interested in eliciting end-users' perception of the EDSSs effectiveness in facilitating the participatory process.

The applied evaluation method was developed based on a review of experiences reported in the Management Information Systems (MIS) literature. During the last 25 years MIS evaluation has provided a number of methodologies that rely on eliciting and analysing perceptions of end-users to provide evidence of effectiveness and directions for improvement. Broadly speaking, researchers in MIS research have responded to the shifting emphasis from efficiency to effectiveness in EDSS evaluation by focussing either on *usage* or *perceived effectiveness*. The usage approach uses behaviour, e.g. actual time spent using the system, as a surrogate indicator of EDSS effectiveness, whilst the perceived effectiveness approach uses indicators of effectiveness, such as technical suitability, ease of use and transparency, and measures how the user judges the tool to have performed against these. Researchers have argued both for and against the use of these two approaches to EDSS evaluation. For example, early on, Ginzberg (1978) argued against the system usage approach by stating that the link between system usage and the quality of decision-making was a weak one, and that the extent of use measure would be a very misleading indicator of success. Srinivasan (1985) carried out research to explore the links between system usage and perceived effectiveness, and results emphasized the fact that the two are not always positively associated with each other.

Because of the historical arguments against the reliability of the usage approach to evaluation, the *perceived effectiveness* approach was chosen for the two case studies reported below. Separate evaluation questionnaires containing statements about the performance of each EDSS were provided to elicit end-users' perceptions of the effectiveness of each EDSS. Evaluations were conducted during two workshops (one workshop per EDSS) and the questionnaires and the preparation for these workshops (i.e. model building, data entry and model execution) is described below.

The case studies considered three dimensions for evaluating the effectiveness of each EDSS. Table 1 (below) provides a summary of those dimensions considered in each case study. The first dimension, which considered end-users' employment, has been the focus of a number of former evaluations in the MIS literature (e.g. see Sanders and Courtney, 1985; Srinivasan, 1985). In addition, there have been discussions in the EDSS research literature regarding the evolution of computer models from their initial development and use as research tools to their more recent application in a policy context. For instance, Oxley et al. (2004) propose that, "… policy models are not designed to further understanding of processes but to help explore the possible effects of policies". A comparison of different end-users (e.g. researchers vs. policy-makers) of perceptions of EDSSs, if significant, might indicate that a gap exists between the relative suitability of the EDSSs and its use for research or policy-making, and by highlighting these differences, clarify the strengths and limitations of the EDSSs.

Table 1
Evaluation dimensions.

Evaluation dimensions	Case Study 1	Case Study 2
Do end-users professional backgrounds (i.e. researchers/practitioners etc) have a significant effect on their perceptions of the usefulness of the EDSS?	yes	yes
Did the end-users perceive the EDSS to be more/less effectiveness against specific performance criteria?	yes	n/a
Did the end-users' perceptions of effectiveness of the EDSS vary significantly for different stages of a water stress mitigation project?	n/a	yes

The second dimension – specific performance criteria – was considered only in Case Study 1. End-user's perceptions of effectiveness were elicited using a set of statements relating to different performance criteria against which they scored their level of agreement/disagreement on a seven-point Likert scale. A review of the MIS literature was carried out to identify performance criteria that had been used in former studies and been shown to be significant in end-user's choice of computer-based decision support. The criteria that were used are described in further detail with source references in the methods section, and are listed in summary here as: (i) organisational receptivity, (ii) reliance on decisions, (iii) technical suitability, (iv) transparency, (v) learning, (vi) ease of use and (vii) decision stress.

The third dimension – the effectiveness of the EDSS in supporting different phases in a participatory planning process – was considered only in Case Study 2. In their evaluation of decision support systems, Adams et al. (1990) propose that 'supporting the *process* of decision making is central to the DSS approach' and that 'the degree to which these systems support the different stages of the decision making process should be the criterion on which they are evaluated (Adams et al., 1990). Other researchers, however, report that the process-based approach has been overlooked in the decision support evaluation literature (Hurt et al., 1986). For Case Study 2, a step-wise process for participatory planning in water management was used as a context for end-users to test different components of the I3S platform. This step-wise process is described in the methods section below.

2. Methods

2.1. Case study 1: EDSS construction and stakeholder engagement process

Bayesian Networks (Bns) were first developed by the artificial intelligence and machine learning community (Pearl, 1988), and have been successfully applied in the fields of medical diagnosis, evaluation of scientific evidence, market research, and more recently, to modelling uncertain and complex domains such as ecosystems and natural resources management (e.g. Bromley et al., 2005; Uusitalo et al., 2005). A triangulation approach (Silverman, 2001) was used to construct and populate three Bayesian networks during the eighteen months prior to the evaluation workshop whereby data collected from existing reports provided by the local water company and ministry of environment, and expert knowledge elicited during semi-structured interviews (described in Inman et al., 2008), were used to provide the structure of the belief networks. Historical water supply and demand data and household survey data were then collected to populate three models to support supply-demand forecasts, household demand forecasts, and economic analysis of demand management options.

The supply-demand forecasting model was developed using monthly water supply and demand data for the Iskar Reservoir collected between 1966 and 2004 provided by the Ministry of Environment and Water and the local water supplier, Sofiyska Voda. One of the outcomes of the knowledge elicitation had been a need to develop a common understanding of the causes and effects of the water crisis that impacted Sofia between 1990 and 1995. During the workshop stakeholders worked in pairs and were supplied with water demand data from the local water company up to 2006. Using the water balance model they were able to examine the hydrological conditions that led to the water crisis in the 1990s and discuss whether, given a repeat of those conditions, current demand would be met.

To develop the household demand forecasting model 600 household surveys were conducted between October and December 2006. Socio-economic data, information about water intensive devices already installed in the households, and occupant behaviour data were collected to identify the water saving potential of different water efficiency programmes. To test the household demand forecasting model during the workshop water meter data was supplied by Sofia Water Company and by adding evidence (i.e. instantiating the model) end-users were able to compare the predicted water use in the model with the data supplied by the water company and then see the potential impacts of different water saving measures on a household-by-household basis.