

Ten years of experience in Designing and Building real Environmental Decision Support Systems. What have we learnt?

These matters that with myself I too much discuss
Too much explain
T.S. Elliot

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Abstract: The complexity of environmental problems make necessary the development and application of new tools capable of processing not only numerical aspects, but also experience from experts and wide public participation, all which are needed in decision making processes. Environmental Decision Support Systems (EDSSs) are among the most promising approaches to confront this complexity. The fact that different tools (artificial intelligence techniques, statistical/numerical methods, geographical information systems, and environmental ontologies) can be integrated under different architectures confers EDSSs the ability to confront complex problems, and the capability to support learning and decision making processes. In this paper we present our experience, obtained over the last ten years, in designing and building two real EDSSs, one for wastewater plant supervision, and one for the selection of wastewater disposal systems for communities of less than 2000 inhabitants. The flow diagram followed to build the EDSS is presented for each of the systems, together with a discussion of the tasks involved in each step (problem analysis, data collection and knowledge acquisition, model selection, model implementation, and EDSS validation). In addition, the architecture used is presented, showing how the five levels on which it is based (data gathering, diagnosis, decision support, plans, and actions) have been implemented. Finally, we present our opinion about the research issues that need to be addressed in order to improve the ability of EDSSs to cope with complexity in environmental problems (integration of data and knowledge, improvement of knowledge acquisition methods, new protocols to share and reuse knowledge, development of benchmarks, involvement of end-users), thus increasing our understanding of the environment and contributing to the sustainable development of society.

Keywords: Environmental Decision Support Systems, Artificial Intelligence, Wastewater Treatment

1. INTRODUCTION

1.1 Statement of the problem

The increasing rhythm of industrialisation, urbanisation and population growth that our planet has faced for the last few hundred years has forced society to consider whether human beings are changing the very conditions that are essential to life on Earth. Environmental pollution affects negatively the quality of water, air, and soil, and

hence plant, animal and human life [Sydow et al. 1998, El-Swaify and Yakowitz, 1998]).

Whenever we attempt to tackle these issues, we are immediately confronted with complexity. There are at least two important reasons for this:

- *Uncertainty, or approximate knowledge.* Some of the sources of this uncertainty can be tamed with additional data or further investigation. Such is the case of uncertainty arising from random processes or from deficiencies in knowledge (lack of data, unsuitable datasets, etc.). But in other cases uncertainty is insurmountable. This is the

case for chaotic behaviour, or for self-organisation processes. It is also typical of socio-ecological systems, which involve numerous players, each with their own goals.

- *Multiplicity of scales.* Environmental problems have been associated traditionally with distinct spatial scales (i.e., local, national, global), each associated with specific timescales. However, interactions among these scales are becoming increasingly clear. Therefore, advocating a single perspective that encompasses everything in a system is becoming increasingly difficult—plus ineffective.

The consensus is developing that, in order to account for these caveats, environmental issues must be considered in terms of complex systems. But not all environmental systems present the same level of complexity in terms of both the degree of uncertainty and the risk associated with decisions. If the degree of complexity is represented as a function of uncertainty, on one hand, and the magnitude or importance of the decision, on the other hand, then we might distinguish three levels of complexity [Funtowicz and Ravetz, 1993, 1999]:

- The first level of complexity would correspond to simple, low uncertainty systems where the issue at hand has limited scope. A single perspective and simple models would suffice to provide satisfactory descriptions of the system. With regard to water issues, this level corresponds, for example, to the evolution of oxygen in a pristine stream after a pulse input of assimilable organic matter. In the context of industrial processes, an example is the design of a single treatment operation where the input is perfectly defined. In these cases, the information arising from analysis may be used for more wide-reaching purposes beyond the scope of the particular researcher.

- The second level would correspond to systems with enough uncertainty that simple models, applicable to different situations and manageable by any competent practitioner, can no longer provide satisfactory descriptions. Acquired experience becomes then more and more important, and the need to involve experts in problem solving becomes advisable. In the case of water issues, this level would correspond to a general model of water quality, where the need arises to establish which factors are the most important. In the case of an industrial process, this level would correspond to the installation of a wastewater treatment plant, where goals for the quality of the output are well established but these

can be reached through different schemes, and it is the responsibility of the designer to choose the most appropriate configuration.

- The third level would correspond to truly complex systems, where much epistemological or ethical uncertainty exists, where uncertainty is not necessarily associated with a higher number of elements or relationships within the system, and where the issues at stake reflect conflicting goals. It is then crucial to consider the need to account for a plurality of views or perspectives. In the case of water issues, an example would be the problem of water quality in a stream catchment. Here, a variety of factors (economical, technical, ecological, etc.) are at play, and associated with each factor is a different set of goals. Thus, different kinds of expertise need to be taken into account. In the case of an industrial process, this level of complexity is associated, for instance, with the environmental aspects of sewage treatments, which are discussed at the level of the company's policy. Thus the problem is not the design of end of pipe installations for the treatment of specific outputs, but a more global view on the problem that would contemplate, for example, the installation of cleaner technologies in the production process itself.

In this sense, it is important to realise that environmental problems are characterized by dynamics and interactions that do not allow for an easy division between social and biogeophysical phenomena. Much ecological theory has been developed in systems where humans were absent, or in systems where humans were considered an exogenous, simple, and detrimental disturbance. The intricate ways in which humans interact with ecological systems have been rarely considered [Kinzig, 2001]. Embracing a socio-economical perspective implies accepting that all decisions related to environmental management are characterised by multiple, usually conflicting objectives, and by multiple criteria [Ostrom, 1991]. Thus, in addition to the role of experts, it becomes increasingly important to consider the role of wide public participation in the decision making processes. Experts are consulted by policy makers, the media, and the public at large to explain and advise on numerous issues. Nonetheless, many recent cases have shown, rather paradoxically, that while expertise is increasingly sought after, it is also increasingly contested [Ludwig, 2001].

In our opinion, this third level cannot be tackled with the traditional tools of mathematical modelling. To confront this complexity, a new

