DECISION SUPPORT FOR ENVIRONMENTAL MANAGEMENT

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Contents

Summary

Decision support systems are information systems meant to help managers make more efficient and effective decisions for problems evincing an imperfect structure. These systems are very suitable information tools to apply to environmental management problems that are complex and complicated. The contribution first surveys, from an information technology perspective, several largely accepted concepts in the field of decision support systems. Several artificial intelligence methods such as expert systems, fuzzy logic, neural networks, and case-based reasoning and their applicability to

environmental management problems are reviewed, too. The combination of artificial intelligence technologies with traditional numerical models within advanced decision support systems is discussed. Possible further developments are finally presented.

1. Introduction

Environment protection and sustainable development have in the last three decades been paid an ever higher attention from governments, academia and educated people. Most countries and international organizations are now aware of the fact that environmental management has become a top priority question, because of the global impact of some phenomena and processes. The scope of environmental management is comprehensive, including interrelated activities such as continuous monitoring and surveillance of the environment, prediction and analysis, emergency management, post-incident damage control and recovery planning, and, environmental impact assessment for great infrastructures or industrial projects, i.e. planning environmentally benign human-made industrial products and processes.

At the same time, environmental management is not only highly complex because of the system's high dimensions and fuzzy borders, but also very complicated because of the various factors involved, such as ecological, business, social and political factors. The interests of various factors are, in many cases, contradictory. In this context, the development of appropriate information systems with a view to facilitating communication and decision- making is highly desirable.

A Decision Support System (DSS) can be roughly defined as an information system meant to help managers, on various management levels, make better (or more efficient) decisions and also stimulate them in taking effective measures. In the particular context of environmental management, an effective decision should at once be reasonable, justifiable and legally and morally correct.

This contribution sets to be, from an information technology perspective, a balanced survey of well-established concepts and of lately reported results in the field of DSS. General concepts as well as particular aspects concerning their applicability to environmental management will be presented (with a view on setting the stage for the article level contributions that follow). The remaining part of this paper is organized as follows: Section 2 surveys the decision-making models and some general aspects of DSS such as historical perspective, architecture, technologies used and peculiarities of their development process. Section 3 summarizes the basic methods of artificial intelligence AI and their applicability to environmental management problems. Section 4 provides some aspects concerning the integration of AI and DSS technologies. The Conclusion section suggests possible further developments.

2. DSS- Basic Concepts

The DSS appeared as a term in the early 1970s, when managerial decision support systems came up in literature. As with any new term, the significance of DSS was in the beginning a rather fuzzy one, in that it was viewed as either a new redundant term used to describe a variant of MISs (Management Information System), or a new label abusively stuck by some vendors to their software products, to take advantage of a term

in fashion. Since then, a lot of research and development activities and applications have come to prove, that the DSS concept definitely meets a need and that a market is tapped for it. This Section refers some generally accepted occurrences of the DSS concept.

2.1. Decision-Making Process

Decision-Making (DM) process is a specific form of information processing aiming at setting up an action plan under specific circumstances. There are some examples related to environmental management problems:

- to design "green" products and operate an industrial complex so that it is environmentally benign;
- to take the most adequate measures for controlling damages in case of a natural disasters (earthquake, forest fire, flood, hurricane, etcetera);
- to plan and control a complex transportation system in the rush hours so that the pollution level be not beyond an acceptable level, etcetera.

Several models of DM are described in the sequel.

2.1.1. H. Simon's Process Framework

Nobel Prize winner H. Simon identified three steps in a DM process, namely:

- "intelligence", consisting of activities such as data collection and analysis in order to recognize a decision problem;
- "design", including activities such as problem statement, production and evaluation of various potential solutions to the problem;
- "choice", or selection of a feasible alternative to the implementation.

If a decision problem cannot be entirely clarified and not all possible alternative decisions can be fully explored and evaluated, before a choice is made, then the problem is said to be "unstructured " or "semi-structured". If the problem were completely structured, an automatic device could have solved the problem without any human intervention. On the other hand, if the problem has no structure at all, nothing but hazard can help. If the problem is semi-structured, a computer-aided decision can be envisaged. G. Vansteenkiste identified, in the 1980s, some drawbacks common to environment-related problems such as:

- problems are badly defined (system borders are fuzzy, characteristics can change with time in an unpredictable manner, properties are distributed);
- data are often scarce, scattered and corrupted by measurement noise;
- system modeling is difficult (complex systems are too complicated to handle and subsystems cannot easily be isolated, so that false conclusions can be avoided, important variables are hardly recognizable, etcetera).
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The above peculiarities indicate that the use of the DSS technology may be beneficial in environment-related applications.

2.1.2. Other Models

The "econologic" model of DM assumes that the decision-maker is fully informed and

aims at extremizing one or several performance indicators in a rational manner. In this case the DM process consists in a series of steps such as: problem statement, definition of the criterion (criteria) for the evaluation of decision alternatives, listing and evaluation of all available alternatives, selection of the "best" alternative and its execution.

It is likely that other DM models are also applied in environment-related problems such as:

- The "bounded rationality" model, that assumes that decision-making considers more alternatives in a sequential rather than in a synoptic way, use heuristic rules to identify promising alternatives and make then a choice based on a "satisfying" criterion instead of an optimization one;
- "implicit favorite" model, that assumes that the decision-maker chooses an action plan by using his/her judgment and expects the system to confirm his choice.

While the DSS based on the "econological" model are strongly normative, those systems that consider the other two models are said to be "passive".

In many environment-related problems, decisions are made by a group of persons rather than by an individual. Because "group decision" is either a combination of individual decisions or a result of the selection of one individual decision, this may not be "rational" in H. Simon's acceptance. Group decision is not necessarily the best choice or combination of individual decisions, even though those might be optimal, because various individuals might have various perspectives, goals, information bases and criteria of choice. Therefore, group decisions show a high "social" nature, including possible conflicts of interest, different visions, influences and relations. Consequently, a group DSS urgently needs communication facility.

2.2. History, Definitions and Classifications

In the last three decades practitioners and researchers have proposed various solutions and definitions of DSS. Because they cover what a DSS is, and even what it is not, this may affect the scientific content and the credibility of evolutions and products meant to support the DM activities. Several important definitions will be reviewed in the sequel, with a view to provide a historical perspective and to highlight several features which can matter in environment-related applications.

Initial definitions identified DSS as an information system meant to support (not to replace) human decisions for semi-structured or unstructured problems. Therefore, most of the early DSSs were meant to support decisions by adding "more structure" to the problem, to an acceptable or technologically possible extent, encouraging the user to deploy his/ her talents and creativity in the DM activity. Another early definition of the DSS was associated with the term "decision calculus", a model-based set of procedures for processing data and the judgment to assist a manager in his/her decision-making.

Later, in the early 1980s, it was noticed that the attribute of "structuredness" of a certain decision situation heavily depended not only on the problem itself but also on the skills of the decision maker. Consequently, the DSS was defined as an extensible system able to support ad-hoc analysis, and planning problems and meant to be used by managers at

irregular time intervals. At the same time, the DSS was supposed to contribute to improving the cognitive abilities of the user. During the early 1980s it was admitted that the class of DSS users included, beside top managers, middle level managers and also professionals, that prepared decisions being ratified and eventually taken up by top level managers.

While those two main approaches were centered on the "decision" and "support" aspects, another trend, inspired by software engineering, highlighted the "system" facet. Some authors stated that a DSS was an information system resulting from the merging of database technology and computerized optimization and simulation models, stored in a model base. Other authors, apparently inspired by Artificial Intelligence technologies, said that DSSs were information systems that necessarily included three essential components or subsystems such as: "language (communications) subsystem" (LS), "knowledge subsystem" (KS), and " problem processing subsystem" (PPS).
Current definitions of DSS reveal the abilities of the system to support and simulate human intellectual activities based on learning, recognition, judgment and creation, besides memory and calculation. Consequently, new information technologies such as artificial intelligence techniques and "fuzzy logic" are intensively considered and embedded in modern DSSs. In this context, the DSS role can be viewed as evolving from a job aid to a knowledgeable assistant.

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Biographical Sketches

Florin Gheorghe Filip was born in Bucharest, Romania, in 1947. He received his M. Sc. and Ph. D. degrees in Control Engineering from the Technical University of Bucharest in 1970 and 1982, respectively. He was elected as a Corresponding Member of the Romanian Academy in 1991. Since 1970, F.G. Filip has been with the National Institute for R&D in Informatics (ICI), Bucharest. He was the managing director of ICI in the period 1991-1997. At present he is the President of the Scientific Council of ICI. He is also a professor in "Applied Informatics" at the State University "Valahia" in Targoviste. He is the author / co-author of four books and over 200 technical papers. His main scientific interests are: optimization and control of large-scale systems, decision support systems, systems analysis, modeling and simulation, and artificial intelligence.

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