Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Environmental Modelling & Software 20 (2005) 639–649
Environmental Modelling & Software
www.elsevier.com/locate/envsoft

EDSS for the evaluation of alternatives in waste water collecting systems design

B. Adenso-Díaz*, J. Tuya, M. Goitia

E.P.S. Ingeniería, Universidad de Oviedo, Campus de Viesques, 33204 Gijón, Spain

Received 2 September 2002; received in revised form 6 June 2003; accepted 26 March 2004

Abstract

The design of new wastewater treatment systems in rural areas is a highly complex problem given the numerous possible alternative connections with pre-existent collection networks and the different criteria that affect the correct choice of the sought-after solution. This article presents a (GIS-based) decision support system that aids this design work and which considers the criteria of cost, environmental quality and social cost underlying these infrastructures. This innovative system was developed for the Government of the Principality of Asturias, and an example of its application in rural agglomerations in this region is presented here.

Keywords: Environmental decision support systems; Environmental management; Wastewater treatment

1. Introduction

A set of laws has been passed in the European Union that obliges Member States to comply with certain objectives with respect to wastewater treatment. According to this regulation (EEC, 1991), all rural 'agglomerations'[1] with a 'population-equivalent' (a value that not only includes the human population, but also that of animals and other focuses of pollution) of over 2000 must have an environmental infrastructure that enables their wastewater to be adequately treated by the end of the year 2005.

These types of measures are obligating European governments to carry out major investments, which are likewise accompanied by the technical complexity of designing the new networks to be built, mostly in dispersed rural areas with a reduced number of inhabitants per inhabited agglomeration.

Within this framework, the engineers responsible for these activities must consider numerous possible alternatives for treating the wastewater of these agglomerations, including the different possibilities of connection to the previously existing network, the corresponding need to enlarge pre-existent treatment plants, the construction of new treatment plants, etc.

All these alternatives must be evaluated not simply from the economic viewpoint of cost, but employing diverse criteria such as the repercussion in the quality of the water in the rivers that the chosen solution will suppose, or the social repercussion of said measures (neighborhood opposition to the construction of these kinds of installations, for instance).

Usually, these decisions are made by hand by the chief engineer or the team members. This leads to a series of difficulties:

- The difficulty of achieving an initial overall view, due to the copious volume of information to be handled, and the spatial relationships between the elements: rivers, urban agglomerations, hills, etc.
- The technical complexity of the calculations, and therefore of costs.
- Errors in calculation as a result of the volume of data to be handled.

* Corresponding author. Fax: +34-985-18-2150.
E-mail address: adenso@epsig.uniovi.es (B. Adenso-Díaz).

[1] According to the European Union laws, 'agglomeration' is defined (EEC, 1991) as "an area where the population and/or economic activities are sufficiently concentrated for urban waste water to be collected and conducted to an urban waste water treatment plant or to a final discharge point."

1364-8152/$ - see front matter
doi:10.1016/j.envsoft.2004.03.008

- The multiplicity of solutions, which complicates the work of the analyst due to the time needed to evaluate alternatives.

In light of the complexity of the process of evaluation of all these alternatives, this article presents a decision support system that aids design decision making for these systems developed for the Government of the Principality of Asturias. This region, in the north of the Iberian Peninsula, possesses very mountainous terrain, with a highly dispersed population in hundreds of small rural agglomerations, on many occasions in groups of only 10 or 15 houses.

Employing the information contained in a GIS as a starting point, the goal of the system is for chief engineers to have at their disposal an initial set of information with respect to the possibilities of treating the wastewater of the areas under study and their associated costs, both economic as well as social. From among the selected solutions, they will be able to subsequently carry out more detailed studies that 'fine-tune' the calculation of the real costs.

The following section introduces the characteristics that these DSSs present in the environmental field. The models and algorithm that make up the system, as well as the system architecture, are presented in Section 3. The usefulness of the system is discussed in Section 4, together with a test case and the discussion of its results. We end up with the conclusions.

2. Review of DSS in environmental management

Decision support systems (DSS) may be considered to be a new generation of information systems, the goal of which is to try to discover what would happen if a series of decisions are taken, or going even further, by automatically providing the decisions or suggestions that assist the manager. These types of systems began to appear in the 1970s. Sprague (1980) defines them as: (1) computer-based systems (2) that help in decision making (3) in poorly structured problems (4) via direct interaction (5) with data and models of analysis.

The architecture of a DSS is based on the concept known as DDM (Data, Dialog, Model) coined by Sprague and Watson (1996) and made up of *Data* (the information that serves as the starting point for decision making), *Dialog* (which presents the information to the user in a user-adapted format), and *Model* (which enables information to be generated that will help the user make decisions).

The generic character of the term DSS has given rise to specific systems aimed at concrete types of problems, such as for instance enterprise information systems (EIS), group decision support systems (GDSS), management support systems (MSS) or executive support systems (ESS). All of these have the five aforementioned points in common.

When they are applied to environmental issues, they receive different names, the most widespread being that of *environmental decision support systems* (EDSS) (Rizzoli and Young, 1997). As defined in Haagsma and Johanns (1994), "an EDSS is an intelligent information system that ameliorates the time in which decisions can be made as well as the consistency and the quality of the decisions, expressed in characteristic quantities of the field of application."

There exist multiple fields of application and techniques to use in supporting decision making. Cortés et al. (2000) present a series of applications of EDSS based on artificial intelligence techniques applied to different fields, such as impact management and analysis in the field of water resources, weather forecasting, pollution modeling or decision making when faced with emergencies. Other applications include environmental impact assessments in agriculture (Howells et al., 1998), the management of irrigation systems (Martín et al., 1999) and water resources (Young et al., 2000), waste management (Chang and Wang, 1996) or the selection of technology for underground pipe systems (Gokhale and Hastak, 2000).

Many of the applications of EDSS require the use of copious spatial information, both for visualizing the results as well as for aiding decision making itself. Geographical information systems (GIS) are an invaluable aid in this task, and may be used single-handedly as a flexible EDSS. However, as well as being used for land inventory purposes, consultations and visualization, they may also be integrated with specific algorithms for decision making related to spatial data (West and Hess, 2002).

Among the possible fields of application of GIS-based EDSS (in which our paper can be classified) may be included, for instance, territorial planning (Matthews et al., 1999; Lukasheh et al., 2001), forest management (MacLean et al., 2000), pest management (Power and Saarenmaa, 1995), water management (Vadas et al., 1995), agricultural management (Grabski and Mendez, 1998), or emergency management (Chang et al., 1997). Rolland and Gupta (1996) analyze the optimization problem using GIS systems.

There are a multitude of factors that must be taken into account in the design of an EDSS (Lam and Swayne, 2001). As for any other kind of information system, one of the key factors among these is the choice of the appropriate technology. Although generic EDSSs exist, such as for instance the RAISON system (Booty et al., 2001), which incorporate reasoning models and GIS functionalities, in order to solve specific applications which have to include reasoning that takes the terrain into account, a sound option is to make use of prior investment in commercial GIS via integration of