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ABSTRACT

The purpose of this paper is to present the conceptual DSS framework for the strategic planning and decision support. It considers water quality, quantity, and the ecological status of surface. As the basis of this conceptual model were used a list of management objectives, measures, and external scenarios. System diagrams for the catchments and the river network were adopted. They describe the properties, processes, and data influencing the water flow and substance load. The interaction of management objectives, external scenarios of climate, agro-economic and demographic change, and selected measures to achieve the desired state of good water quantity and quality are investigated

Keywords: Decision Support Systems, Quality Control, System Analysis and Design

INTRODUCTION

The Nakdong River is the second largest river system in South Korea containing a large drainage basin and a long main channel. The flow of the Nakdong River is highly regulated by 4 multi-purpose dams in the major tributaries and an estuary barrage, which were constructed in the mouth of the river to ensure efficient use of water resources. Especially, the lower Nakdong River shows a river-reservoir hybrid type due to the stagnation of water flow during the dry period. Also hypertrophication was occurring within the Nakdong River over eutrophication because of the continuous inflow of raw nutrients from industries that have populated the middle part of the river (Joo et al. 1995). Since 1992, the low supply of water resources and the massive change in the aquatic community have caused cyanobacterial blooms every summer and the flourishing of diatoms during the dry winder period (Lee et al., 2005).

Numerous studies on the management and the status of the water quality in the Nakdong River have been undertaken. Water quality indicators such as oxygen content, heavy metal and persistent chemical concentrations as well as biotic indices have been monitored to track the effects of collapsing industry, sewage treatment improvements, and engineering measures.

Besides the monitoring aspects, geographical databases, simulation models, and experimental results have been collected so far. For the strategic planning we need various effective and efficient decision makings. Information systems make possible to support scientific decision making. One of them is decision support system. This paper suggests a conceptual DSS framework for the water quality control of the Nakdong River basin. The paper is focused on system analysis and design of DSS. The measure/scenario approach allows people to make scientific and rational decision making.

CHARACTERISTICS OF THE NAKDONG RIVER BASIN

The Nakdong River (Figure 1) is the longest river that reaches 521.1 km in its total length (river basin 23,817.3 km^2), from Bonghwa, Kyung-Buk province to the Nakdong estuary dam. The Nakdong River basin shows monsoon characteristics by frequent heavy rainfall from late June to early July every year. The mean annual precipitation is 1,272 mm at the lower Nakdong River. Over 60 percent of the annual rainfall is concentrated in summer (June-August and the remaining period, especially winder (December-January), is classified as the dry period. The mean annual water temperature is 12-16ºC. The mean annual cold water temperature is 2.5ºC in January and the mean annual hot water temperature is 29-30ºC in August (Kim et al. 2001)

In 1987, an estuary dam was constructed at the mouth of the Nakdong River to avoid salt-water intrusion. The lower part of the river became a river-reservoir hybrid due to these changes in hydrology (Joo et al. 1997; Kim et al. 1998). Because the cannel slope is very slight and the flow rate is slow, the retention time assumes similar aspects of a reservoir. Also, considering the present condition of pollution in the lower part of the river, the pollution load of the Keumho River is 9.89 billion ton per day and is the principal depositor of pollution, occupying 39.2 percent of total pollution load in the lower Nakdong hydrosphere.

Figure 1. Nakdong River basin

Between 1996 and 2005, the government ran the comprehensive measures to improve water quality and got it being improved from 74 in 1996 to 80 in 2005. A new 10-year project with 32.7 trillion won allocated by the government has been launched in beginning this year. It aims to improve water quality in Han, Nakdong, Geum and Youngsan Rivers. 30 percent of the budget will go to the Nakdong River (Shin, 2006).

SYSTEM ANALYSIS AND DESIGN OF THE NAKDONG-DSS

Background

Decision-support system – computer-based information systems that combine models and data in an attempt to solve nonstructured problems with extensive user involvement through a friendly user interface (Turban et al. 2005). In addition, a DSS is built by an interactive process (often by end-users), supports one or more phases of decision-making, and it may include a knowledge component (van Delden, 2000). Originally developed to support business managers, DSS have attracted much interest in the field of environmental quality management (Guariso and Werthner, 1989).

Such DSS as low-flow management of the Nakdong River (Lee, 1999), risk-based management of surface water quality (McIntyre and Wheater, 2004), and restoration of flood- plains (BfG, 2004) or management of coastal zones (RIKS, 2003) have been developed for specific purposes. Recent developments integrate spatial information using Geographic Information System's (GIS) functionality with a variety of environmental models and databases. For instance, Newham et al. (2004) developed a framework for integrated hydrologic, sediment and nutrient export modeling for catchments scale management. Schlu¨ter et al. (2005) integrated a hydraulic network model with a habitat suitability index to assess the restoration of riparian forests in the Amurdarya delta. Economic valuation tools have been integrated into DSS to take ecosystem services and benefits into account for decision support (Klauer et al., 2001). The implementation of the EU Water Framework Directive initiated the development of several river basin management and decision support systems, e.g. MULINO (Mysiak et al., 2005). A Special Issue of Environmental Modelling and Software is in preparation and covers various fields, concepts, and realizations of Environmental Decision Support Systems (Matthies et al., in press).

The major components required for decision support are shown in Figure 2. They were adopted from Matthies study in 2006.

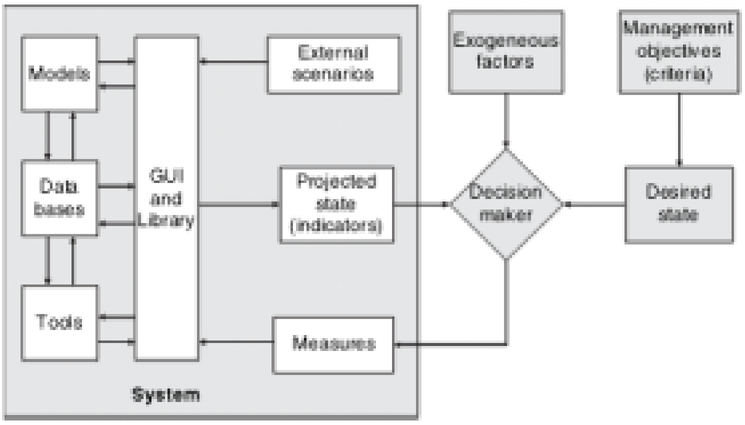

Figure 2 Decision support for environmental policy making

The DSS consists of various models, databases and assessment tools, which are integrated under a Graphical User Interface (GUI), often realized by using GIS functionality. Management objectives (criteria) describe the desired state, which should be achieved to meet legislative or other goals. The decision maker (user) communicates with the DSS and compares the projected state (indicators) with the desired state given by the management objective. Exogenous factors such as societal or political requirements might also influence decisions. Users select several measures to analyze how to achieve the objective. External scenarios such as climate, agro-economic and/or demographic changes are often provided as pre-processed information.

The measure/scenario-oriented approach has been chosen for the communication between a user and the DSS. This approach starts from a specific measure or a selected external scenario or both, calculates the influence on a related model-based indicator, and compares it with the corresponding management objectives.

Management objectives

Analyzing previously developed DSS systems for the water quality management (Matthies et al., 2006) and having oral interviews with a researcher involved in water quality research, the following objectives have been identified. These objectives are related to the water quantity and quality management

1. Good status of surface water should be achieved
    a. Good chemical status: a list of priority and specific chemicals has to be routinely monitored.
    b. Good ecological status including biological water quality: achievement of a natural or near-natural state
2. Reduction of substance load to the South Sea
   Reductions in the emissions of nutrients, pesticides, heavy metals, and persistent, bio-accumulative and toxic substances are demanded.
3. Flood protection
   Provision for flooding risks, which tackles improvement the flood protection and lowering flood damage potential

External scenarios

The authors want to concentrate on three major external scenarios that can be developed:

1. Climate change – describing potential changes in the pattern of distribution of temperature, precipitation and other parameters in the Nakdong River catchments

2. Agro-economic change – impact of various legislative requirements, economic developments on agricultural production
3. Demographic change – projections of the demographic development

Other scenarios can be also developed.

Measures

Water quantity and quality is influenced by selected measures. Measures can consist of various options.

1. Reduction of pollution from urban areas:
- Reduction of impervious areas in urban-industrial areas to favor the infiltration of rainwater.
- Increasing fraction of separate sewer to prevent overflow water from treatment plants in case of storm weather.
- Increasing fraction of inhabitants connected to sewage treatment plant to reduce the input of raw sewage
- Upgrading of storage volume of sewer water systems to prevent overflows from treatment plants in the case of storm weather
- Enhancement of efficiency of treatment plants to reduce emissions

2. Modification of agriculture land allocation:
- Reforestation of arable land or grassland
- Renaturalization of drained agriculture land for retrieval of swampland
- Building of riparian buffer zones to prevent input of pollutants from agricultural land

3. Changes in agriculture practices:
- Application of soil protection methods like minimal tillage to prevent soil erosion

- Application of different distribution techniques to advance the efficiency of organic fertilizer
- Application of feeding methods to reduce the nutrient concentration in organic fertilizer
- Application of eco-farming methods

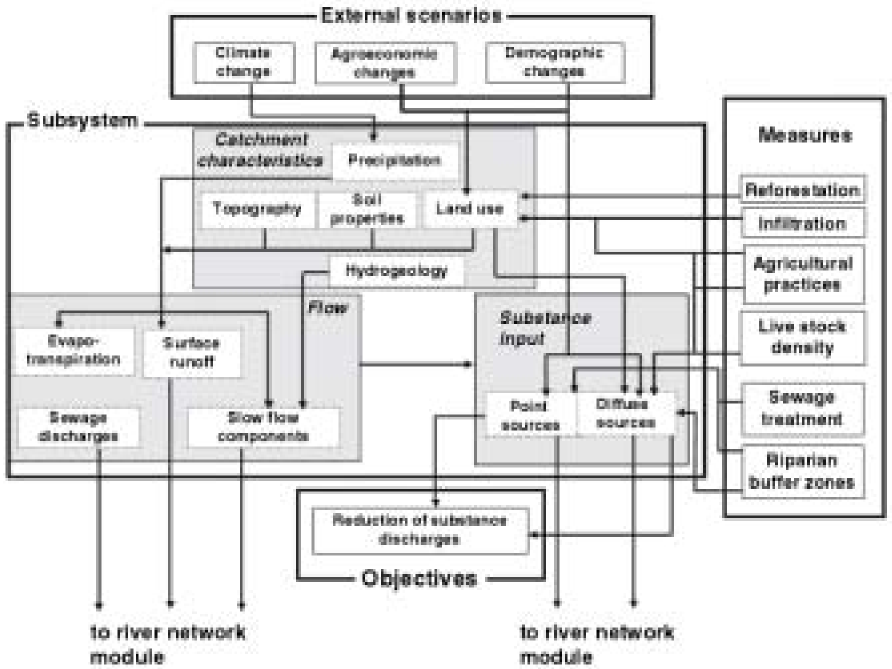

Figure 3. System diagram of the catchment module with external scenarios, measures, and management objectives

4. Political and legislative requirements regarding waste water
- Direct discharge cut-off
- Gray water treatment and facilities

The following system diagram has been adopted from the

research of Elbe river basin (Matthies et al., 2006)
Both modules, the catchment and the river network module, consist of a subsystem with three internal blocks and exogenous driving forces (Figure 3 and Figure 4).

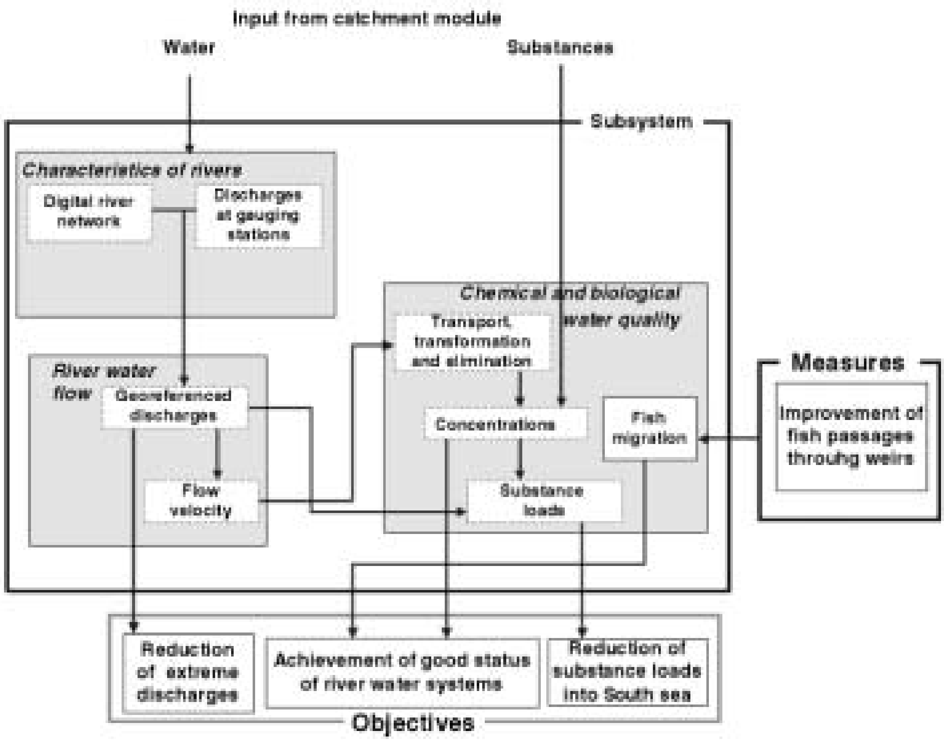

Figure 4. System diagram of the river network module with measures and management objectives

SYSTEM DIAGRAM

Catchment module (figure 3)

Important catchment characteristics are the topography, soil properties, precipitation, land-use, and hydrogeology. Various hydrological processes such as evapotranspiration, infiltration, and surface runoff determine the quantity of discharges. In addition, discharges from treated and untreated sewage water are considered. The third block describes the quality of discharges into the river network, which are driven by substance runoff from land (non-point sources of agrochemicals, i.e. nutrients) as well as from point sources (sewage treatment plants). Indicated at the bottom of Figure 3 are the management objectives, namely the reduction of substance input into surface water. Three sets of predefined scenarios (top of the diagram) can be investigated: climate change, demographic change and agro-economic change. They influence the land-use, water cycle, and substance impact on water systems. At the right hand side various measures are indicated, which the water manager can select to reduce nutrient or other substance discharge. Point as well as diffuse sources can be investigated. Typical measures are the regional change of agricultural practices to minimize nutrient input, reforestation, or construction of riparian buffer zones.

River network module (figure 4)

The river network receives the discharges from the catchment. A digital geo-referenced river network is attributed with the locations of the point sources. The long-term historical time series from gauging stations are statistically analyzed to derive mean and variability of the discharges. Moreover, with a rainfall-runoff model daily discharges can be calculated for future climate scenarios. Water quality is determined with a transport, elimination, and transformation model to deliver substance loads as well as concentration patterns along the river network. There are three management objectives in Figure 4, namely achievement of good status of river water systems, reduction of extreme discharges (high water) and reduction of substance loads into the estuaries of the South Sea. Only one measure operating on the river network is indicated at the right hand side. The migration of fish to head waters for spawning is hindered or prevented by weirs, dams, and floodgates.

Model base

While selecting models, the following criteria are to be taken in account:
(1) Appropriate for the intended purposes of the Nakdong-DSS,
(2) Available for the Nakdong River catchment,
(3) Calculation of water flow and discharges from historical and projected time series,
(4) Estimation of substance loads from point and non-point sources,
(5) Consideration of nutrients, pesticides, persistent, bio-accumulative or toxic substances,
(6) Ability of combination with external scenarios and measures,
(7) Standard technical implementation without using proprietary software,
(8) Easy-to-use with acceptable run-time on a standard PC.

Data support

Data are collected from various data sources:

- Soil properties, hydrological and meteorological data from Federal Agencies
- Census data from Federal Statistical Office
- Wastewater treatment data and discharge consents from Federal and State Environmental Agencies
- Monitoring data from various source and, in particular, Kumoh National Institute of Technology

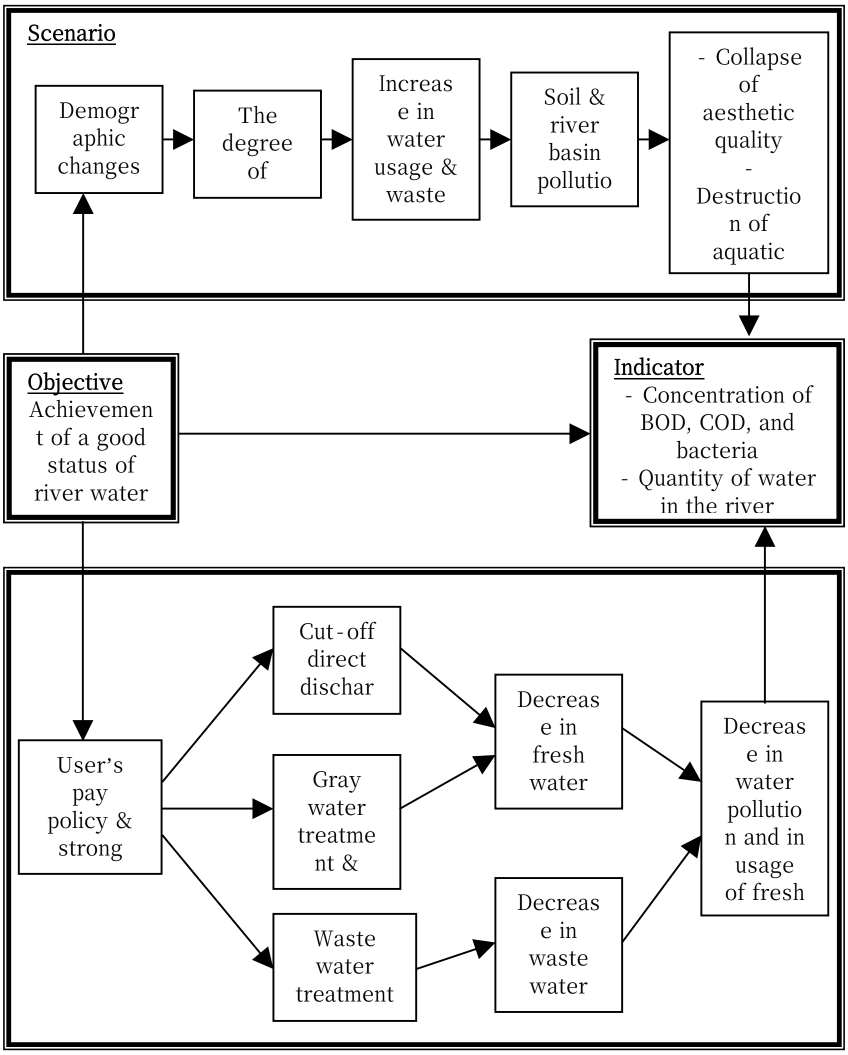

Figure 5. Interaction of management objective, external scenario, and selected measure to calculate an appropriate indicator for evaluation of the projected state

MEASURE/SCENARIO APPROACH

A user can communicate with the Nakdong-DSS using a

measure/scenario-oriented approach. Measures and pre-processed scenarios are selected. Running the system, indicator values are compared with the management objectives.
Figure 5 is one of many possible options. It has been derived from the system diagram of the catchment module and river network module. It shows an example of the interaction of the external scenario, management objective, and measure with the system.

The following scenario is examined. There are demographic changes along the Nakdong River. Changes in the degree of urbanization entail the increase in fresh water usage and waste water production. It can be the reason for the soil and river pollution. All these changes will bring about the collapse of aesthetic quality, destruction of the aquatic ecosystem and decrease in usable water.

To restrain the negative influence of the demographic change user's pay policy and strong legislation are passed. This can cut off the direct discharge of waste water and make users pay for its treatment. Building additional waste water treatment plants can make the situation better. Also gray water treatment and usage of facilities should be encouraged. All these will lead to the decrease in fresh water demand and waste water discharge into the river. In its turn, pollution of water in the river can be decreased.

Both user's policy and strong legislation and simultaneously a scenario of demographic changes influence the concentration of

BOD, COD, and bacteria, and the quantity of water in the river systems. The users can investigate how changes indicator part by manipulating scenario data and measure data.

CONCLUSION, FUTURE RESEARCH AND LIMITATION

This paper proposes a conceptual DSS framework for the strategic planning and decision support. This framework is just a theoretical approach to resolve the given problem. While in the implementation phase, the revision of the model might be necessary, when the empirical data is used.

The system analysis and design give the topic for the future research in selecting models and building a model base. User's input and feedback can play essential roles in selecting spatial and temporal scales of models. Another issue is gathering data from different sources and building effective data support with the relative and up-to-date data.

The limitation of the paper is minimal involvement of the potential users. More discussions should be done on every aspect of the proposed Nakdong-DSS, which can help to tackle the most important objectives, measures and scenarios, and increase acceptance of the system by potential end-users.

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