



## Development of a web-based decision support system for supporting integrated water resources management in Daegu city, South Korea

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### ABSTRACT

Demands on fresh water by human beings have been continuously increasing due to population growth, living standard improvement, and economic development. At the same time, many regions are suffering greatly from floods and droughts. Those are the results of ineffective management of water resources due to the associated complexities. In this study, a decision support system (DSS) was developed for supporting integrated water resources management in Daegu city, Republic of Korea. The developed DSS contained four subsystems including database, modelbase, and knowledgebase, as well as general user interface (GUI). It was then connected with the National Water Management Information System (WAMIS). A flow prediction could be conducted through the incorporated HEC-HMS Version 3.0.1. Also, an urban water demand forecasting model was developed using an artificial neural network (ANN) based model. At the same time, a water resources management model based on genetic algorithm (GA) was developed in the DSS, facilitating efficient allocation of water resources among different regions within a city. The result indicated that the developed DSS is very useful to deal with complex water resources management problems and could be further applied to similar cities in South Korea.

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### 1. Introduction

In many regions across the world, demands on fresh water by human beings have been continuously increasing due to population growth, living standard improvement, and economic development (Cai, Huang, & Tan, 2009; Huang et al., 2010; Tan, Huang, Wu, & Cai, 2009; Zahraie & Hosseini, 2009). At the same time, climate change is exerting great impacts on water systems, and has caused great variations in water resource availabilities due to its direct effects on various hydrological processes such as precipitation, evapotranspiration and runoff generation (Alipour, Shamsai, & Ahmady, 2010; Andersen et al., 2006; Easterling et al., 2000; Tan, Huang, & Cai, 2010a, 2010b). Combination of water demand growth and climatic and hydrological variances has forced decision makers and/or water managers to contemplate comprehensive strategies for water resources management under changing climatic conditions. Moreover, the management practices are further complicated by increasing concerns over a number of water-related issues such as floods and droughts, as well as conservation of aquatic ecosystems. These complexities are posing great

challenges to decision makers and/or water managers at multiple jurisdictions in many countries particularly those that are newly developed ones and in economic boom such as South Korea, and are under dual pressures of maintaining their economic boom and protecting environment. It is thus desired to developed effective decision support tools for supporting integrated water resources management with consideration of human intervention and changing climatic conditions.

Generally, possible ways for facilitating integrated water resources management include the adoption and improvement of water-related technologies, policies and regulations (Cai, Huang, Lin, Nie, & Tan, 2009; Cai, Huang, Yang, & Chen, 2009). Successful and sustainable management of water resources system needs well understanding of the natural processes as well as the associated economic and social services. The concept of Integrated Water Resources Management (IWRM) was thus defined by the technical committee of the Global Water Partnership (GWP) as “a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (Higa Eda & Chen, 2010). Operationally, they believed IWRM involved the application of knowledge from various disciplines as well as the insights

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from diverse stakeholders to devise and implement efficient, equitable and sustainable solutions to deal with practical water and development problems. Given the multi-disciplinary and complex nature of an IWRM problem, Liu, Gupta, Springer, and Wagener (2008) proposed a multi-resolution and multi-disciplinary integrated modeling approach, which consisted of a series of modules such as problem definition, conceptual model formulation, strategy identification, and scenario analysis. Particularly, in order to deal with the associated complexities, computer-based decision support systems (DSS) are desired due to the associated features such as efficiency and user friendliness (Liao, Xu, Wang, Lu, & Hannam, 2011; Nasser, Moeini, & Tabesh, 2011; Wen, Wang, & Wang, 2005; Wen, Wang, & Wang, 2005).

According to Grigg (1996), DSS is a computerized management advisory system that utilizes databases, models, and dialog systems to provide decision makers with timely management information. The adoption of DSS benefits the decision makers in understanding and further managing water resources under multiple scales. After being introduced into management practices, DSS were widely used for supporting water resources management (Mysiak, Giupponi, & Rosato, 2005). As a pioneer work in this area, Loucks, French, and Taylor (1985) discussed how to develop a DSS for water resources management based on an interactive water resources model. More recently, various specific applications of DSS for water resources related problems were reported. For example, Camara (1990) developed a DSS for facilitating estuarine water quality management. Davis, Nanninga, Biggins, and Laut (1991) advanced a DSS for analyzing impact of policy scenarios adopted by multiple scales of watershed authorities. Simonovic (1992) described the application of a DSS to support reservoir operational management. McKinney, Maidment, and Tanriverdi (1993) discussed the application of a DSS in supporting regional water-resources planning. Weng, Huang, and Li (2010) developed an integrated scenario-based multi-criteria decision support system (SMC-DSS) for planning water resources management in the Haihe River Basin. Opricovic (2011) utilized the fuzzy VIKOR (Vise-kriterijumska Optimizacijai KOMPromisno Resenje) method to study a reservoir system which was employed for the storage of surface flows in the Mlava River and its tributaries for securing regional water supply. Also, there were several studies that focused on the introduction of commercial software packages for river flow forecasting (Bender & Simonovic, 1994), drought monitoring and management (Chang, Kleopa, & Teoh, 1996; Palmer & Tull, 1987; Palmer & Holmes, 1988), water allocation (Koutsoyiannis et al., 2003), flood management (Ahmad & Simonovic, 2001), and water quality management (Dingfei & Stewart 2004; Paredes, Andreu, & Solera, 2010). At the same time, geographic information system (GIS) is an effective computer-based tool that could facilitate storage, analysis, and graphically display complex spatial information. Particularly, the combination of DSS and GIS technologies aid decision-makers in dealing with problems that would require spatial analysis and modeling. Staudenrausch and Fliigel (2001) developed a water resources management system based on a variety of techniques including database management, remote sensing, GIS, and water systems modelling. Holmes, Young, Goodwin, and Grew (2005) described the development of the Low Flows 2000 system, which was based on a Flow Duration Model and a GIS framework, and could offer flexible strategies to water managers in managing both natural and artificially influenced flow regimes in un-gauged watersheds across UK. Comparatively, in South Korea, it has experienced water crises in most of its river basins due to frequent occurrences of severe floods and droughts. A few researchers conducted studies related to water resources management. For example, Kim (2001) presented a GIS-supported water resource management information system in a watershed of Korea. Park, Choi, Wang, and Park (2006) developed a decision support system

for optimally designing water quality monitoring networks in Korea. Chung and Lee (2009) developed an alternative evaluation index (AEI) to determine the priorities of a range of alternatives using both hydrological simulation models and multi-criteria decision making (MCDM) techniques.

Despite current progress in water resources management, there has been a growing awareness among the scientific community that new approaches and tools would be necessary to allow public access and use of environmental information for participating in decision-making processes (van Asselt et al., 2001). Thus, it is desired that decision-making models could be accessible in the internet and could be directly used by various participants. Particularly, this could facilitate in-depth analysis of various policy alternatives in large-scale watershed (Salewicz and Nakayama, 2004). However, most of the previous studies focused on an individual component of the water system such as water supply, flooding control, hydropower generation, they scarcely encompass most of the components into a general decision support framework to generate comprehensive decision alternatives. Also, there were few studies focused on investigation of the impacts of climate change and human intervention on water system, particularly in an economically boom country like South Korea. Moreover, there were no reports that could seamlessly connect water management with evolutionary algorithms such as genetic algorithm (GA), artificial neural network (ANN). Therefore, this paper firstly introduces the water resources system of Daegu city, Republic of Korea, and presents the architecture design of DSS for water resources management. Base on the case study, the following main objectives are identified in this paper: to develop an architecture of decision support system for water resources management in Daegu city, based on the National Water Management Information System (WAMIS); to develop river flow or flood forecasting method based on hydrologic software HEC-HMS; to develop an urban water demand forecasting model using artificial neural network; and to develop a mathematical model for optimal water resources allocation using genetic algorithm.

## 2. Overview of Daegu city

Daegu city is located in southeastern part of Korea peninsula. It is between 35°36'–36°01' North Latitude and 128°21'–128°46' East Longitude, with the area of 884.5 km<sup>2</sup>. It is the third biggest city in South Korea, with the number of population of about 2.5 million and per person production of about 9,943,000 Korean Won (Daegu city Statistics, 2006). It contains seven districts ("Gu") and one county ("Gun"), which are showed in Fig. 1. The city is surrounded by several mountains such as Palgongsan in the north, and Dae-deoksan and Biseulsan in the south. There are also some low mountains located to the west and east. Sincheon River runs through the central area of the city. In the northern area of Daegu, Geumho River flows from east to west and joins Nakdong River which is the longest one in South Korea.

Annual precipitation in Daegu city is scarcely except that is during the rainy season of summer from June to September. It is sunny throughout much of the year. Statistics of annual rainfall from 1971 to 2000 indicates that the annual average rainfall of Daegu city is about 1028 mm. The installed capacity of water intake of Daegu city is  $1963 \times 10^3 \text{ m}^3$  per day. Among them, river flow accounts for 76% (i.e.,  $1486 \times 10^3 \text{ m}^3$ ), lake and reservoir accounts for 24% (i.e.,  $477 \times 10^3 \text{ m}^3$ ). The water system in Daegu city can be simplified as Fig. 2. The entire city is considered as one large system with five input elements, including three dams (i.e., Unmoon, Gachang and Gongsan dams), and two rivers (i.e., Nakdong River, and Geumho River). At the same time, they also represent as the output elements of the water system.

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