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A Review on Decision Support System for Water Resource Development and Management

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ABSTRACT : The interactions of various components of water management systems are highly non-linear in nature. To develop the water resource utilization policy, huge and diversified data are required and then to use for the optimization which provide several scenario. These scenarios are further required to evaluate for the best solution. The Decision Support System (DSS), helps in selection of best solution among the feasible solution. Several DSS model has been developed in the past to assist in the selection of best solution. The present study reviews those efforts particularly in the field of water management. The present study deals with the historical development of Decision support systems. The components and characteristics of DSS and its successful implementation in agricultural system management and water resources development and management have been elaborated. The optimization methodologies employed in DSS are also been discussed. The study suggested that the DSS can be effectively used in solving the water management problem but careful selection and local calibration of the DSS are highly desired.

Keywords: DSS, water resources management, irrigation, crop planning, simulation model

Decision Support System is an integrated system that provides analytical solution of unstructured problems using the capabilities of database management. A decision support system essentially manages the data, models the data to specific objectives and links to supplementary tools that is necessary to make use of the model in a dynamic, day-to-day operational framework. The definition of DSS varies from authors to authors. Typically DSS has three components such as database management system, mathematical representation of decision making problems and user interface. In DSS, the database management component stores, retrieves and modifies the required data. Mathematical models analyze the behavior of the system giving basic support to the decisions on the preferable options. The user interface facilitates the end use to interact in the DSS environment. The various components of the typical DSS have been shown in Fig 1.

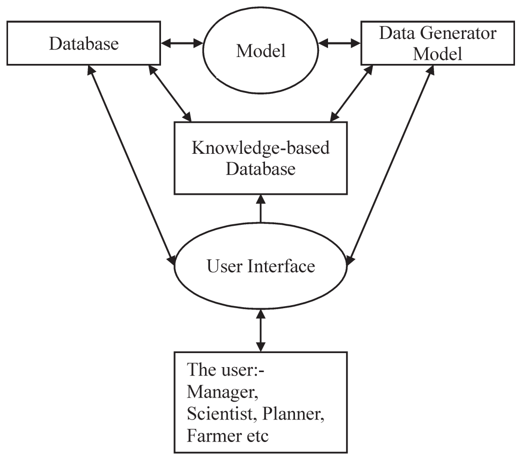

Fig 1. Various Components of the DSS

Researchers and technologists dealing with Information Systems technology have investigated and built Decision Support Systems (DSS) for more than 40 years. DSS is playing important role over the last five decades in planning and management of resources. It is also realized that the strength of DSS in handling of unstructured problem can support socio-economic development in rural area. DSS has the purpose of aiding the decision-making activities, helping to understand the problem, exploring various alternative courses of actions, predicting their impacts, facilitating sensitivity analysis, etc. A user-friendly interface allows users to manage databases and models and to visualize input data and model output.

Several DSS model has been developed in the past for various fields. These are being used by development departments, planners, scientist, consultants and industries. The DSS models essentially provide the optional solutions to the given sets of problem and conditions. The window based graphic user interfaces (GUI) are also an integral feature which simplifies the operation of various modules of DSS to the ultimate user. Integrated systems are more efficient because they allow for the simplification or automation of many of the decision making functions and allow for commands to be entered in plain English. Intelligent DSS also allow users to set decision parameters and help to develop users' decision making skills.

Characteristics of DSS

DSS provide solution of semi-structured and unstructured problem including human judgment and computerized information. The User friendly interface of the DSS make for easily accessible**.** Architecturally, the DSS has following technical components such as Data Management System (DMS), Model, User Interface, Knowledge Based Database, and the End User. The data management component manages database and data directory with query options. It support interrelates and contains data from different databases to aid the decision making process. The model management component consists of model base management, modeling language and model structures. It contains a model library which stores different classes of model based solution and decision making criteria. Model base management system aids to data manipulation interaction with the decision criteria. It provides to aid building modeling language, catalog of model and combination of several model results. There are several model used in this system such as strategic model, tactical models and operations model. The User Interface System provides interaction between the user and the DSS environment. It consists of a graphical user interface which manage the different style of decision.

Historical Development of DSS

The first computer-based support for decision making was developed in early seventies (Power, 2003). Keen and Scott Morton gave the concept of DSS in 1970s. The concept of decision support has developed from the areas of research like the theoretical studies of organizational decision making (Keen and Scott Morton 1978). In 1971, Gorry had studied the strength of computers and analytical models in enabling the user to make a key decision. Gordon Davis (1974) developed Management Information System which was defined as an integrated, man/machine system for providing information to support the operations, management, and decision-making functions in an organization. Sprague (1980), Sprague and Watson (1986) and Sharda *et al.,* (1988) further explained the DSS framework of data base, model base and dialog generation and management software. It was a practical and easily understandable framework. In 1980, Executive Information Systems (EIS), Group Decision Support Systems (GDSS), and Organizational Decision Support Systems (ODSS) developed for the single user and model oriented DSS. Beginning in about 1990, data warehousing and On-Line Analytical Processing (OLAP) began broadening the realm of DSS. Thierauf (1991) used the Decision support systems in formulating the scenarios and options. The DSS supported in courses of action with respect to different decisions on the basis of problem formulation and analysis of available information. The DSS was further described as soft technologies, because the determinants of success and failure depend on non-technical factors such as problem orientation, its evolutionary approach to system design (Holthman, 1992). In 1994, Kroenke and Hatch developed Executive Information System (EIS) which enabled the interaction of several elements such as people, procedures, information and technology. In the late 90's, the customized DSS was felt needful by the planners and system analyst as providing assistance in form of technical expertise in order to enhances the decision making process. This leads to the DSS developers to develop DSS with research focused on decision analysis tools, technique development, integrated systems, and applications. The various landmarks in DSS development is presented in Table 1.

Table 1. Landmark in DSS Development

Year	Studies
1950 & 1960	Theoretical studies laid out and technical work as computing carried out in two decades
1970s	Decision Support System
1980s	Expert Information System, Group Decision Support System, Organizational Decision Support Systems (ODSS)
1990s	Data warehousing and On-Line Analytical Processing (OLAP)
2000s	Web based DSS

Realizing the strength of DSS in data handling and aid to the system analyst, the DSS has been employed in several fields such as defence, management of resources, electronic media and various agricultural aspects.

DSS in Agricultural System Management

In the field of agriculture, Several DSS model have developed which includes water resources (Walsh, 1993); stream management (Fredericks, 1998); water delivery system (Westphal, 2003; Eschenbach, 2001, Arumugam, 1997 Pingry, 1991). Biju *et al.,* (2002) developed a user-friendly decision support system for estimation of the crop water requirement. For given data availability and climatic conditions, the developed model estimates ETo with the best available method out of the nine methods. The ETo estimation methods are based on combination theory, radiation, temperature, and pan evaporation; the model selects the best ETo estimation method. AEGIS/WIN system was developed for crop simulation model (Engel, 1995). Computer based decision support system have been developed to help understand the interaction between crop and environmental parameter. It allows the user to select farm field and various crop management options and yield prediction (Hoogenboom, 1993). There are several models in crop planning, water management, farm management, irrigation, pest management etc.

Michael R. Walsh *et al.,* (1993) had designed a DSS to solve the complex problems. The DSS consist of a user interface, model base, and data base. The SDSS concept and architecture is well suited to merging GISs and DSSs, including water resource models that are part of water resource DSSs. All of the decision tools depend upon GIS capabilities for data/model integration, map-based analysis, and advanced visualization. Veerakcuddy Rajasekaram *et al.,* (2005) developed a DSS for reservoir water management conflict resolution (RWM-CRSS) in a multipurpose single reservoir system. The system consists of a communication system, a database management system, and a model-base management system. A new approach is used in developing the communication system, in which the use of artificial intelligence markup language facilitates the task of developing human-like communication between the user and the system.

DSS in Water Resources Development and Management

The development of DSS for solving the water resources problems began to appear in the mid-1970s and have been explained in literature in abundance since mid-1980s (Georgakakos and Martin, 1996; Labadie and Sullivan, 1986; Loucks, 1985a and 1985b). In 1990s, many applications of DSS dealing with natural resource management have been developed. The authors mainly described the complications of such DSS application in water resources development and management. Decision support for natural resources is similar to business applications in many contexts as they consist of an interface to frame the problem and to define appropriate decision criteria and feasible options, database and links to models, knowledge bases, or multi-objective decision components. The DSS consisted of a user interface, model base, and database. The spatial decision support system was described by Dymond *et al.,* 2004 and the advantages of internet-based, cross disciplinary modeling for the watershed management decision were explained. The importance of GIS base and derived data is highlighted in conjunction with a description of the hydrologic, economic, and fish health model components.

DSS development for natural resource management also included simulation models to assess the possible effects of alternative decisions on the natural system. A prototype DSS is developed to evaluate an irrigation management plan by Lilburne *et al.,* 1998. This DSS integrates heuristics, a simulation model, and data in an expert shell framework. It suggested the process of developing simulation models for natural resources. It discussed the integration of crop models, yield model and simulation model in agricultural decision support to produce improved outcomes. A number of modeling efforts were described by Ahuja and Hatfield, 2007 and Ahuja *et al.,* 2002 with a systems approach emphasizing model links to both field experiments and a DSS. Many problems experienced by DSS were highlighted efforts focused on farmers (McCown *et al.,* 2002). The watershed planning was discussed [36, 90] and addressed through DSS the issues related to water resources planning, in which, some of the system inputs and outputs have been measured.

The DSS application in agriculture in the past intensively utilized in estimating irrigation demands (Heinemann *et al.,* 2002; Mateos *et al.,* 2002 and Silva et al 2001). DSS was developed to manage irrigation system by Koch *et al.,* 1986 which consisted of data files describing the water rights, water use, and hydrologic systems integrated with simulation models for soil moisture and river routing in response to irrigation diversions and inflows. The model allowed projection of irrigation demands and assessment of the effects of distribution strategies on flow in the river system. A prototype of a decision support system was developed to estimate the effects of policies on water quality and the costs of implementing such policies (Davis *et al.,* 1991). An integrated water management model was developed by combining an unsaturated flow model and a groundwater simulation model (Kumar and Singh, 2003). These combined models serve as a tool for decision making in irrigation water management to maintain the water tables at a safe depth. It was further demonstrated to integrate different work plans and components in order to assess the conjunctive use of the water resources in the watershed under different management scenarios driven by climatic changes and land use planning.

DSS was developed to evaluate water use policies (Recio *et al.,* 2005) that combine the sustainability of natural resources with regional economic development, which is effectively based on irrigation farming. Two different models were used; one was a hydro geological model, which is able to simulate the river and second was an econometric model, which is capable of predicting the crop yields and the associated prices. DSS for reservoir water management conflict resolution (RWM-CRSS) was developed in a multipurpose single reservoir system (Rajasekaram and Nandalal, 2005). The system consisted of a communication system, a database management system, and a model-base management system. A new approach was used in developing the communication system, in which the use of artificial intelligence markup language facilitates the task of developing human-like communication between the user and the system. A DSS for irrigation and water policy was designed and developed (Bazzani, 2005). This system simulated the economically driven decision processes of farmers, permitting an accurate description of production and irrigation in terms of technology and agronomics. Short and long term analyses could be conducted, the latter with endogenous investment choices. Solutions were found by applying multi-criteria mathematical programming techniques.

A study was conducted to evaluate the use of crop simulation model for estimating the spatial distribution of monthly irrigation water use for cotton (Guerra *et al.,* 2007). The Cropping System Model (CROPGRO-Cotton) simulated the temporal pattern of irrigation applications during the growing season. It described the two contexts in modeling of decentralized decision problems in water management. The first was based on analytic hierarchy process (AHP) and two group aggregation techniques. The second one assumed the AHP application in subgroups, while at a group level, aggregation was performed by the social choice (SC) voting procedures. The second methodology was considered more promising for implementation of water management strategy in real-decision situations. Decision support system was developed by Lozano and Mateos, 2008 for scheme irrigation management information system (SIMIS) integrates tools and performance indicators to facilitate the planning and management of irrigation schemes. DSS was developed for the operation of tank irrigation systems in the state of Tamil Nadu in India (Arumugam and Mohan, 1997) specifically focusing on water quality issues.

There are so many uncertainties associated with natural resource decisions that a tentative decision is made with the understanding that additional information can be collected, and the decision can be reviewed later in the light of new information. When decision makers collect data to test a working hypothesis while implementing a decision, the approach is called adaptive management. The implication of adaptive management for decision support is that decisions are not made just once, but rather are continuously refined as part of an ongoing process. Watersheds provide a good example of a natural resource area in which information for decision-making is typically inadequate. However, a watershed is a very complex system that is generally poorly understood. Watershed is explained as an ideal unit for multi-disciplinary approaches for management of land and water resources to ensure sustainable livelihood. Land and water are the most vital natural resources and these are under tremendous stress due to ever increasing biotic pressure.

Optimization Methodologies in DSS

Several optimization algorithms had been employed by the researchers in order to quantify the decision variables. (Querner *et al.,* 1997) explained the use of DSS on water management aspects describing the benefit of a physically-based model which takes into account the changing conditions affecting the hydrological system to accurately simulate the hydrological processes prior to include in the operational irrigation practice. Recio et al (1999) describe the DSS for defining water use policies, including economic impact and environmental simulators within a single multi-criteria decision-making environment. Soncini-Sessa *et al.,* (2005) and Koutsoyiannis *et al.,* (2003) developed a methodology for integrated planning and management of water resource systems with focus on water reservoir systems. The DSS includes information systems that perform data acquisition, management and visualisation, and models that perform simulation and optimisation of the hydro system. Results show that scenario analysis could be an alternative approach to stochastic optimisation when no probabilistic rules can be adopted and deterministic models are inadequate to represent uncertainty. K. Srinivasa Raju *et al.,* (2004) conducted a study for selecting the best compromise irrigation planning strategy. Study was conducted in four phase. In first phase, linear programming models are formulated for the economic benefits, agriculture production and labour employment. In second phase, nondominated irrigation planning strategies are generated using the constraint method of multiobjective optimization. In third phase, Kohonen neural networks (KNN) based classification algorithm is employed to sort nondominated irrigation planning strategies into smaller groups. In phase fourth, Multicriterion analysis (MCA) technique is applied to rank strategies obtained from third phase. Sheng-Feng *et al.,* (2000) used information on relative crop yield and water demand which allows the genetic algorithm to optimize the objective function for maximizing the benefits. The model generates daily weather data based on long-term monthly average and standard deviation data. The generated daily weather data are then applied to simulate the daily crop water demand and relative crop yield for seven crops within two command areas.

Conclusion

A great deal of attention has recently been given to what are known as expert systems and decision support systems (DSS). In the field of water management, various DSS has been reviewed. These are developed for the natural resource management, reservoir water management, integrated water management, irrigation scheduling, crop planning during drought, estimating crop water requirement and ground water management etc. Such a computer tool can give a significant contribution to the preparedness for the irrigation management in the unorganized regions. The Decision Support System would increase the decision making efficiency at various level of a system. It would provide alternate information that may be useful, while expert systems educate users on variable decision methods and automate some aspects of the decision process. Integrated systems are more efficient because they will allow for the simplification or automation of many of the decision making functions and allow for commands to be entered in natural language. Intelligent DSS also allows users to set decision parameters and help to develop user's decision making skills. These systems are having their capabilities and limitations, but both have gained popularity as a result of their ability to potentially improve decision making for development of a nation.

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