Implementation of the Web-based Decision Application WATERDSS: Water Decision Support System with Knowledge-Driven

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Abstract: A wide variety of specific Decision Support Systems have been and can be built using Internet and Web technologies. This paper was focused and developed application of water DSS (Building Web-based and Inter organizational Decision Support Systems for water management). This paper aims at presenting an application for decisions in ecosystem analysis. We consider contemporary Decision Support Systems (DSS) as knowledge repositories that can be expanded to KMS using the Web software development technologies and tools. The main contribution of our study is to provide an efficient tool that helps users find information resources available as an online service within Internet. This study describes the development methodology and progress of web DSS, a decision support system for water management that has been developed under the research. The main issues addressed in our case study is the evaluation of water quality of Tigris River within Baghdad city area and the DSS was designed to address and support multiple water pollution causes and multiple decision makers, in several places in Baghdad. The evaluation of the DSS discusses the effect of water quality index management on the water pollution. The system detects the pollution causes and type and suggests a decision for cleaning the water so that it can be used by human. The frame of the water pollution and water quality DSS are based on a mathematical model. The results support the primary decision in emergency cases and offer a suggestion to apply a suitable method for treatment the polluted water. Machine learning and data mining is Artificial Intelligent technologies that are used for reasoning to build decision making system in this paper. The results show that the river water isn't within the standard quality criteria of (WHO) standards and Iraqi standards.

Keywords: Decision Support Systems (DSS), water management, web-based DSS, Knowledge management system, Water decision support system, Water management.

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1. Introduction

An application uses to support decision making is usually known as DSS and can be categorized into three categories which are passive DSS, active DSS and proactive DSS [1]. Passive DSS is a traditional DSS with functionalities to react as a personalized decision support built-in knowledge, no content and only for static user preference. Besides that, the components of passive DSS are Data warehouse, OLAP and rule-based. The second category of DSS is active DSS which is known as a personalized decision support with learning capability, no content and for static user preference. Expert system, adaptive DSS, knowledge-based system (KBS) are categorized as part of Intelligent DSS (IDSS). In this category, agent and machine learning are the main component of active DSS [1]. Decision Support Systems (DSS) form a specific class of computerized information systems that support business and managerial decision-making activities. Making the right decision in business primarily depends on the quality of data. It also depends on the ability to analyze the data with a view to identifying trends that can suggest solutions and strategies. A "cooperative" decision support system means the data are collected, analyzed and then provided to a human agent who can help the system to revise or refine the data. It means that both a human component and computer component work together to come up with the best solution [2].

There are many studies reporting build web-based decision support system. Among these, we remind, develop a web-based decision support system that integrates the expert knowledge, analysis model and GIS to assist farm-level agronomic decision-making and that is fit for any circumstances in agriculture production region with efficient knowledge support. The core technology involved includes expert knowledge representation, model organization, software data exchange standard and integration of GIS, expert knowledge and analysis model [3].The Combination between Web services and software agents provides a promising computing paradigm for efficient service selection

and integration of inter-organizational business processes. Proposes an agent-based Web DSS to provide an efficient tool that helps users find information resources available as an online service within Internet [4].

The objective of this paper is proposes a web-based Web DSS; the system's development is driven by the experience acquired in case study selected in Iraq country (Tigris River) to build an appropriate web-based DSS in Iraq to handle the water pollutants problem .The development of WATERDSS is compares the effect of water pollution instruments or strategic plans in Iraq on the basis of well-defined, comprehensive indicators expressing the three major principles of Integrated Water pollution Management underlined in the Water Framework Directive: environmental sustainability, risk of human health and water treatment technologies. The development of a decision support system for water quality management in Tigris River in Baghdad city detect the types of pollution and will generate an appropriate decision for the suitable technique to treat the water in order to make it drinkable. Although the main aim of the WATERDSS project is to help with increasingly complex decisions of general water management.

2. Recent research in Web-based Decision Support System

A number of studies discuss architectural issues, frameworks, usability, and other technology topics that are generally applicable to Web-based DSS. [5] Developed a DSS metadata model for distributing decision support systems on the Web. [6] Conducted an empirical study to investigate customers' satisfaction with a Web-based decision support system. [7] Studied model management for decision support in a computing environment where enterprise data and models are distributed. [8] Proposed Structured Service Models that use a variant of structured modeling. This proposed approach can help users find information resources available as an online service within in Intranet. [9] Applied Software Architectures to the design of Web-based DSS. [10] provided an overview of Web- based optimization for model-driven decision support, discussed two paradigms (ASP and e-Services), and articulated technology issues for an e-Services model.

Many researchers have reported Web based DSS case studies and the development of prototype applications. [11] Reported a case study of a Web-based DSS for hospital management called Physician Profiling System (PPS). [12] Developed and implemented a Web-based DSS that used a model based on fuzzy set theory to perform risk analysis for e-commerce development. [13] Developed a Web-based DSS framework for portfolio selection. [14] Identified key issues in managing service contracts and developed a prototype that can support a manager's planning process. [15] Reported a case study that demonstrates the implementation of Web-based decision support technologies. [16] Developed a Web-based DSS, called Movie Forecast Guru, to help decision makers in the movie industry.

2.1 water management issue

In recent years, the management of natural resources has become an increasingly challenging issue for several reasons. First of all, the problems themselves are characterized by intrinsic complexity as a consequence of the complex spatial and temporal features of water and related ecosystems. This is particularly true for ecosystems in which natural drivers interact with evolving human activities, within the context of what is often defined as the social-ecological system or simply socio-ecosystem [17]. Secondly, environmental issues are always the object of diversified, and often conflicting, interests (economic, social, cultural ones). As the general public has shown increasing attention for environmental matters, groups and individual citizens are becoming important actors in planning and decision-making processes, further complicating the problem. Thirdly, knowledge about socio-ecosystems is often fragmented and owned by a multitude of experts, practitioners and stakeholders. Finally, environmental policies and regulations, from local to international, have become more articulated and complex, calling for strengthened support from scientifically robust methods and tools to assist managers and policy makers.

The complexities inherent in the management of natural resources require the integration of scientific knowledge and economics with social problems, such as conflict management, the settlement of disputes and the mitigation of divergent interests and values. However, competing values and contradictory beliefs increasingly dominate the policy-making discourses, as different scientific disciplines are not always able to give unambiguous responses to complex issues, such as climate change, biodiversity loss and environment-related diseases. Furthermore, fundamental uncertainties and the risk of irreversible environmental changes make natural resources management an even more challenging task, giving rise to different perspectives about the problems, their policy implications and possible solutions. For these reasons, decision problems related to the management of natural resources are characterized by contradictory identification and multiple definitions, possible interpretations and solutions [18].

2.2 Decision Support Systems (DSS)

Implementing the Decision Support Frame work (DSF) entails development of a computerized decision support system (DSS). A generic DSS architecture (Fig. 1) must include a knowledge base, analysis tools, and inference engine. Other

components such as user interface and stakeholder participation tools greatly improve the DSS function but are not considered fundamental. Specific structures for a DSS are contingent on its intended purpose. An information-based DSS provides structures that support the intended functions of the DSF conceptual model. Information-based DSSs maintain database architectures such as relational and data types e.g., geographical information systems (GIS), of varying complexity, to provide information appropriate to the DSS needs.

The main components of the DSS are the DSS database, the user interface, and the DSS software system. The DSS database is a collection of current data from a number of applications and groups. Alternatively, the DSS database may be a data warehouse that integrates the enterprise data sources and maintains historical data. The DSS user interface permits easy interactions between users of the system and the DSS software tools. Many DSS today have Web interfaces to take advantages of graphics displays, interactivity, and ease of use. The DSS software system contains the software tools that are used for data analysis. It may contain various data mining tools, or a collection of mathematical and analytical models that easily can be made accessible to the DSS users [19].
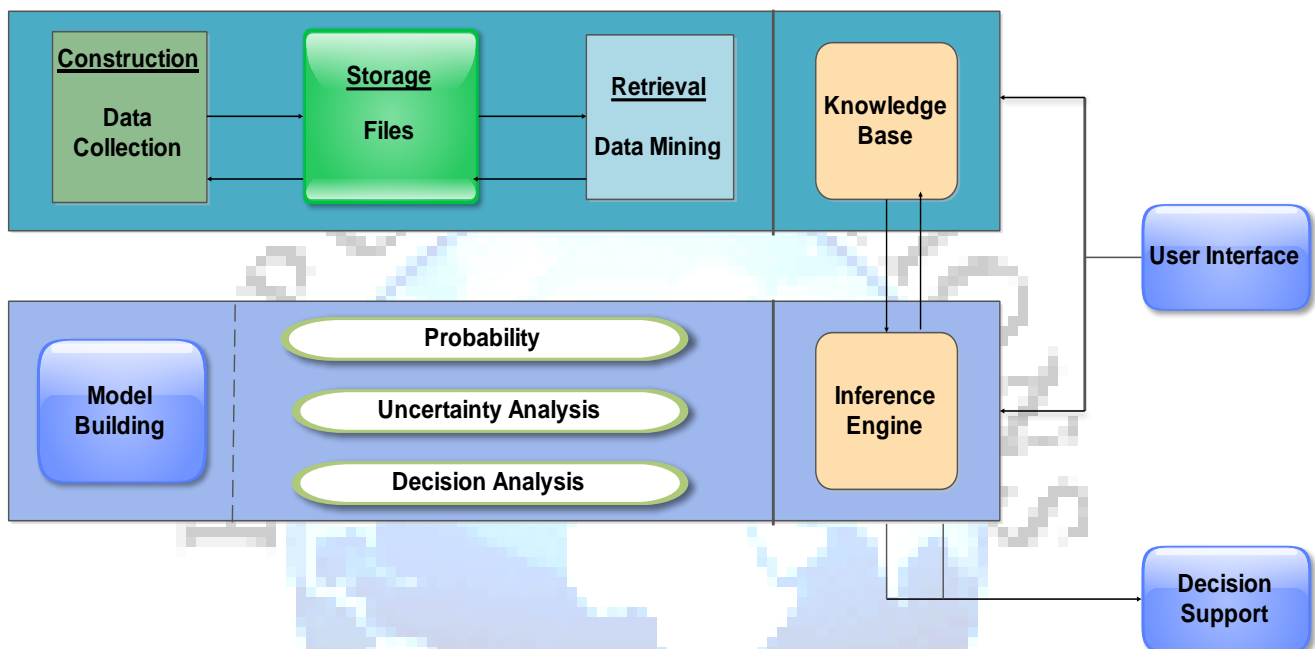

Figure 1: Generic Architecture for a Decision Support System [19]

2.3 Knowledge management And Decision Support System

The AI representation principle states that once a problem is described using an appropriate representation, the problem is almost solved Well- known knowledge representation techniques include rule-based systems, semantic nets and frame systems [21]. KM refers to the set of business processes developed in an organization to create, store, transfer and apply knowledge. KM increases the ability of the organization to learn from its environment and to incorporate knowledge into business processes. There are three major categories of KMS: enterprise-wide KMS, knowledge work systems (KWS), and intelligent techniques [21, 22].

Enterprise-wide KMS are general purpose, integrated, firm-wide efforts to collect, store, disseminate, and use digital content and knowledge. Such systems provide databases and tools for organizing and storing structured and unstructured documents and other knowledge objects, directories and tools for locating employees with experience in a particular area, and increasingly, Web-based tools for collaboration and communication. KWS (such as computer-aided design, visualization, and virtual reality systems) are specialized systems built for engineers, scientists, and other knowledge workers charged with discovering and creating new knowledge for a company. Diverse group of intelligent techniques (such as data mining, neural networks, expert systems, case- based reasoning, fuzzy logic, genetic algorithms, and intelligent agents) have different objectives, from a focus on discovering knowledge (data mining and neural networks), to distilling knowledge in the form of rules for a computer program (expert systems and fuzzy logic), to discovering optimal solutions for problems (genetic algorithms). It is said that effective KM is 80% managerial and organizational, and 20% technology. One of the first challenges that firms face when building knowledge repositories of any kind is the problem of identifying the correct categories to use when classifying documents. Firms are increasingly using a combination of internally developed taxonomies and search engine techniques. Organizations acquire knowledge in a number of ways, depending on the type of knowledge they seek. Once the corresponding

documents, patters, and expert rules are discovered they must be stored so they can be retrieved and used. Knowledge storage generally involves databases, document management systems, expert systems, etc. To provide a return on investment, knowledge should become a systematic part of the organizational problem solving process. Finally, new knowledge should be built into a firm's business processes and key application systems. KMS and related knowledge repositories should facilitate the problem solving process (Figure 2). During the process of solving problems managers engage into decision making, the act of selecting from alternative problem solutions [22, 23, 24].
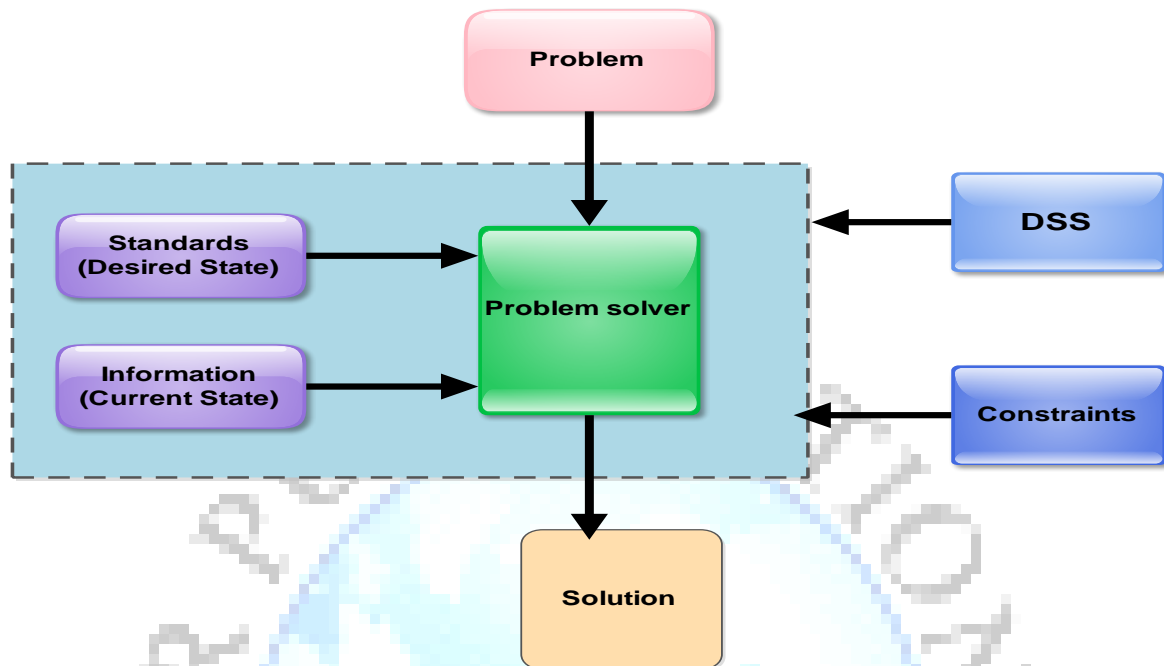
Figure 2   Elements of the problem solving process

There are many kinds of DSS. The first generic type of DSS is a Data-Driven DSS. These systems include file drawer and management reporting systems, data warehousing and analysis systems, Executive Information Systems and Spatial DSS. Data-Driven DSS emphasize access to and manipulation of large databases of structured data and especially a time-series of internal company data and sometimes external data. Relational databases accessed by query and retrieval tools provide an elementary level of functionality. Data warehouse systems that allow the manipulation of data by computerized tools tailored to a specific task and setting or by more general tools and operations provided additional functionality. Data-Driven DSS with Online Analytical Processing (OLAP) provide the highest level of functionality and decision support that is linked to analysis of large collections of historical data.

A second category, Model-Driven DSS, includes systems that use accounting and financial models, representational models, and optimization models, and optimization models. Model-Driven DSS emphasize access to and manipulation of a model. Simple statistical and analytical tools provide an elementary level of functionality. Some OLAP systems that allow complex analysis of data may be classified as hybrid DSS providing modeling, data retrieval, and data summarization functionality. Model-Driven DSS use data and parameters provided by decision-makers to aid them in analyzing situation, but they are not usually data intensive. Very large data bases are usually not needed for Model-driven DSS. Knowledge-Driven DSS or Expert Systems can suggest or recommend actions to managers. These DSS are human-computer systems with specialized problem-solving expertise.

The expertise consists of knowledge about a particular domain, understanding of problems within that domain, and skills at solving some of these problems (AI algorithms and solutions can be used). A related concept is data mining. It refers to a class of analytical applications that search for hidden patterns in a database. Data mining is the process of sifting through large amounts of data to produce data content relationships. Tools used for building Knowledge-Driven DSS are sometimes called Intelligent Decision Support methods [24].

Document-Driven DSS are evolving to help mangers retrieve and manage unstructured documents and Web pages. A Document-Driven DSS integrates a variety of storage and processing technologies to provide complete document retrieval and analysis. WWW provides access to large document databases including databases of hypertext documents, images, sounds and video. Examples of documents that would be accessed by Document-Driven DSS are policies and procedures, product specifications, catalogs, and corporate historical documents, including minutes of meetings, corporate records, and important correspondence. Search engines are powerful decision-aiding tools associated with Document- Driven DSS. DSS (DSS) came first, but now a broader category of Communications-Driven DSS or

groupware can be identified. These DSS includes communication, collaboration and related decision support technologies. These are hybrid DSS that emphasize both the use of communications and decision models to facilitate the solution of problems by decision-makers working together as a group. Groupware supports electronic communication, scheduling, document sharing, and other group productivity and decision support enhancing activities. A DSS model that incorporates Decision Support and AI is shown on Figure 3.
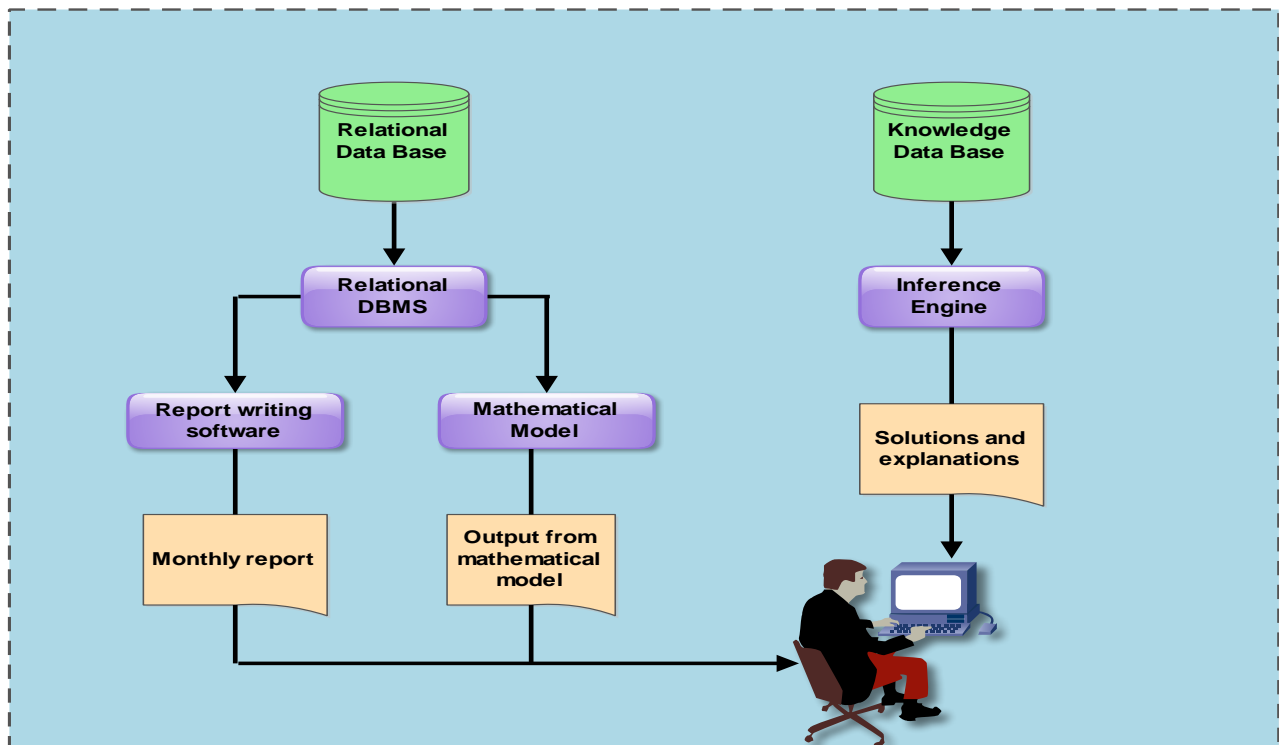
Figure 3   A DSS model that incorporates DS and AI.

DSS facilitate the decision-making. Decision making is an integrated part of the overall problem solving process. KMS should facilitate the problem solving process. [24]

2.4 Intelligent techniques in IDSS

Recently, there are quite a number of computer applications that have applied intelligent techniques and used DSS concepts and components. There are various types of Artificial Intelligent technologies that are used for reasoning, machine learning, automatic programming, artificial life, data mining and data visualization. For example, the reasoning process can use specific rules, categorization, past experience, heuristics and expectations approaches. Computer can do the reasoning through frames (e.g.: Semantic Network), rule- based, case-based and pattern recognition. In addition, the examples of machine learning approaches are Artificial Neural Network (ANN), genetic algorithms and fuzzy logic [25]. IDSS is expected to incorporate specific domain knowledge and perform certain types of intelligent behavior such as learning and reasoning, in order to support decision making process.

Intelligent behaviors presented by an intelligent system are related to the abilities of gathering and incorporating domain knowledge, learning from the acquired knowledge, reasoning about such knowledge and when enquired, being able to issue recommendations and justify outcomes. These intelligent behaviors are potential intelligent techniques that can be corporates with intelligent component in IDSS. IDSS has consolidated the intelligent behaviors in its inference engine component. IDSS applications can have abilities to do learning and reasoning. These abilities are used to support the decision making processes. From the literature study, we found that most applications use Knowledge Based System, especially for rules based approach in their methodology and system implementation. In fact, most researchers agree with the advantage of using this technique. Not only it is easier to understand and implement, but the KBS using rule-based also supports the basic reasoning capabilities. However, intelligent system and soft computing technologies are new technological platforms, where by intelligent logic is now usually inherent in the processing of all decision support tools [26].

3.   WATERDSS Web Application Framework

3.1 WATERDSS knowledge representation (rule based).

Forth is case study, a set of thirteen water-quality parameters (n) were used to calculate WQI. These are: pH value (pHunit), Alkalinity (mg/L), Turbidity (NTU), Dissolved Solids (mg/L), Hardness(mg/L),Calcium(mg/L),Magnesium (mg/L), Chloride (mg/L), Sulphate (mg/L), Ammonia (mg/L), Fluoride (mg/L), Iron (mg/L), Aluminum (mg/L), and they are the most important for the water quality. Work flow for processing WQI, Water quality management and generates an alertasan email message about the state of water quality was presented in figure 4. There are five conditions to know the state of water quality. DSS should be send a messages as following, such as, (if wqi<50) (the water is excellent), (if wqi>=50 and <=100) (the water is good), (if wqi>100 and<=200) (the water is poor), (if wqi>200 and <=300) (the water is very poor) and (if wqi>300) the message is (the water unsuitable to drinking).
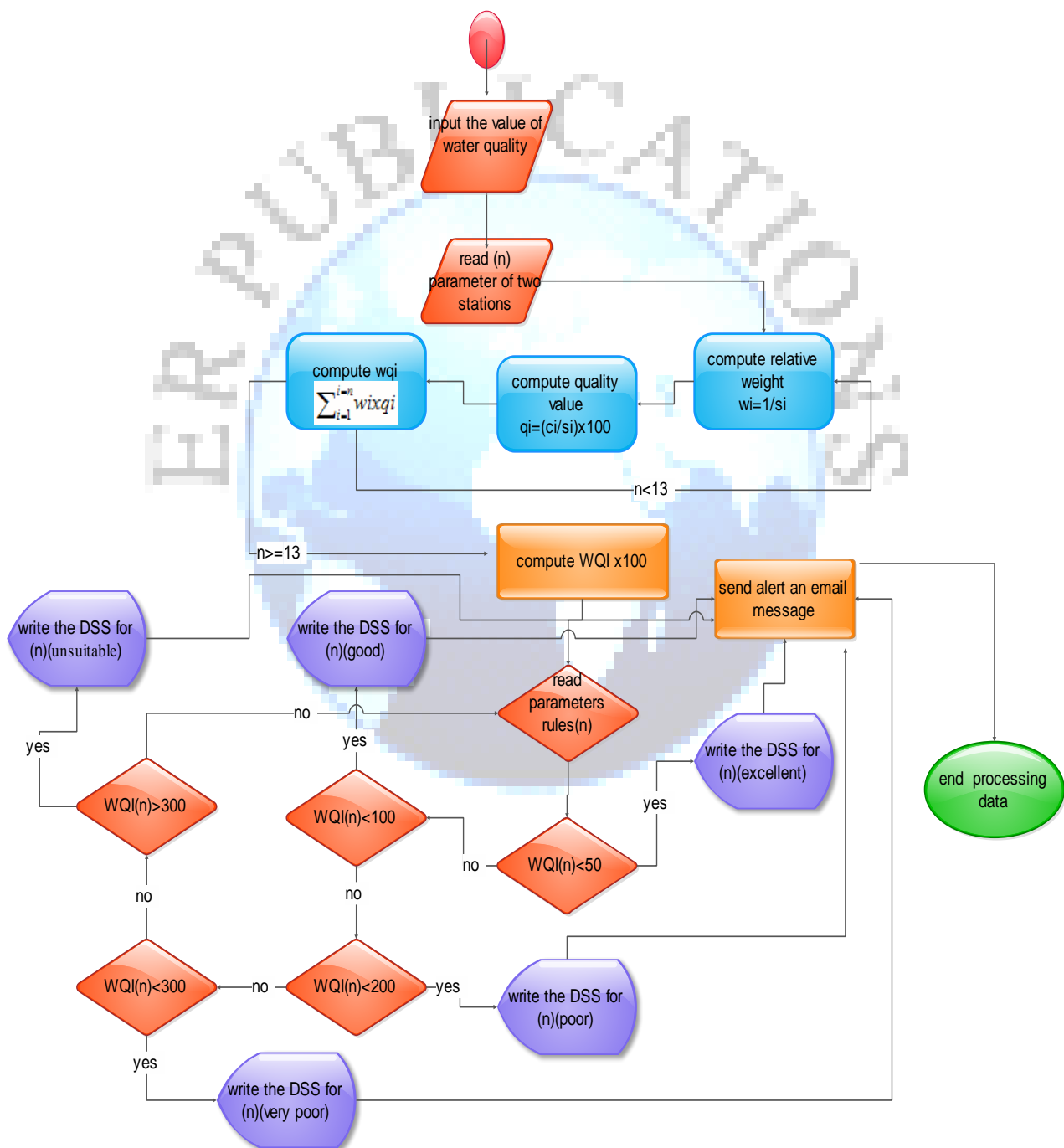

Figure 4the rules base components for WATERDSS to calculate WQI.

3.2 WATERDSS knowledge representation (machine learning (Decision Tree).

Decision Trees are attractive in the utilization of data mining models due to its intuitive representation (easy to understand by humans), its relatively fast construction, compared with other models, and its comparable or superior accuracy to other models. The utilization of a Decision Tree implies an algorithm that guides the construction of nodes and leafs. The nodes of DT depicts the attributes of dataset, and leafs represent the labeled instances.
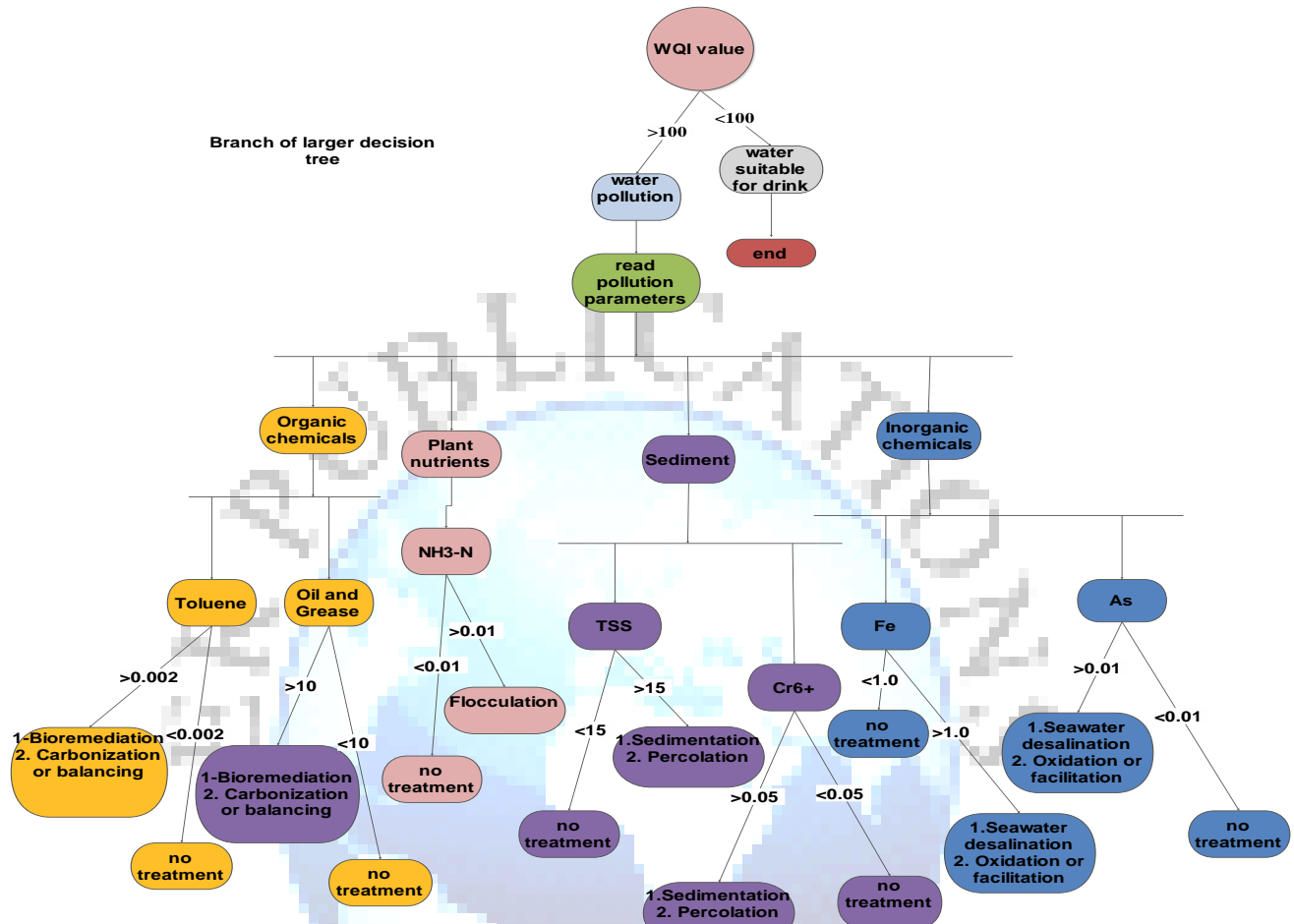
Figure 5 Decision tree of water pollution alerts and treatment decision in WATERDSS domain.

Figure 5 shows decision tree for water pollution management and generate an alert as an email message about the state of water pollution and the suggestion advice to treatment the water quality. The tree declares the conditions of water pollution management which there are many rules to known the state of water. Main windows (figure 10)containing the parameters that causes water pollution which in the first it must determine the parameter ,input the real value of parameter and make process on it to know the kind of water pollution and given decision of the suitable advice to treatment this kind of pollution, which the process its matching the input value of each parameter with a standard value of the same parameter, finally send email of the state of water with treatment methods and the sources of pollution causes to make the water suitable for drink by write sender address email , password sender and recipient e-mail address.

4. WATERDSS Functional Design

In WATERDSS there are Multiple decision methods have been implemented in order to help users think about the decisions and to explore their preferences. The aim of WATERDSS is to support water authorities by solving complex and unstructured decision problems resulting from conflicting water uses. The DSS tool requires an interface which guides users through the decision problems and helps them to make use of the available information and models implemented in the DSS.

4.1 Conceptual Model

The WATER DSS framework conceptual model envisions a four-step decision process of defining context, identifying objectives, formulating alternatives, evaluating and deciding among alternatives, and implementation (Fig. 6). Solicited advice from decision experts and review of literature identified four key overarching ideas that were considered important in developing a successful decision-making model. The aim of WATERDSS is to support water authorities by solving complex and unstructured decision problems resulting from conflicting water uses. The DSS tool requires an interface which guides users through the decision problems and helps them to make use of the available information and models implemented in the DSS.

1. The framework should support a process that follows the concepts of behavioral decision theory and decision analysis to ensure all the necessary elements are considered for making an informed decision.
2. The framework should use analytic-deliberation, which combines rigorous, scientific approaches with an emphasis on communication to facilitate mutual understanding among stakeholders.
3. The framework should encourage adaptive management as a strategy for managing complex environmental systems having uncertainty.
4. The framework should use an accepted conceptual approach for establishing decision context and problem framing.
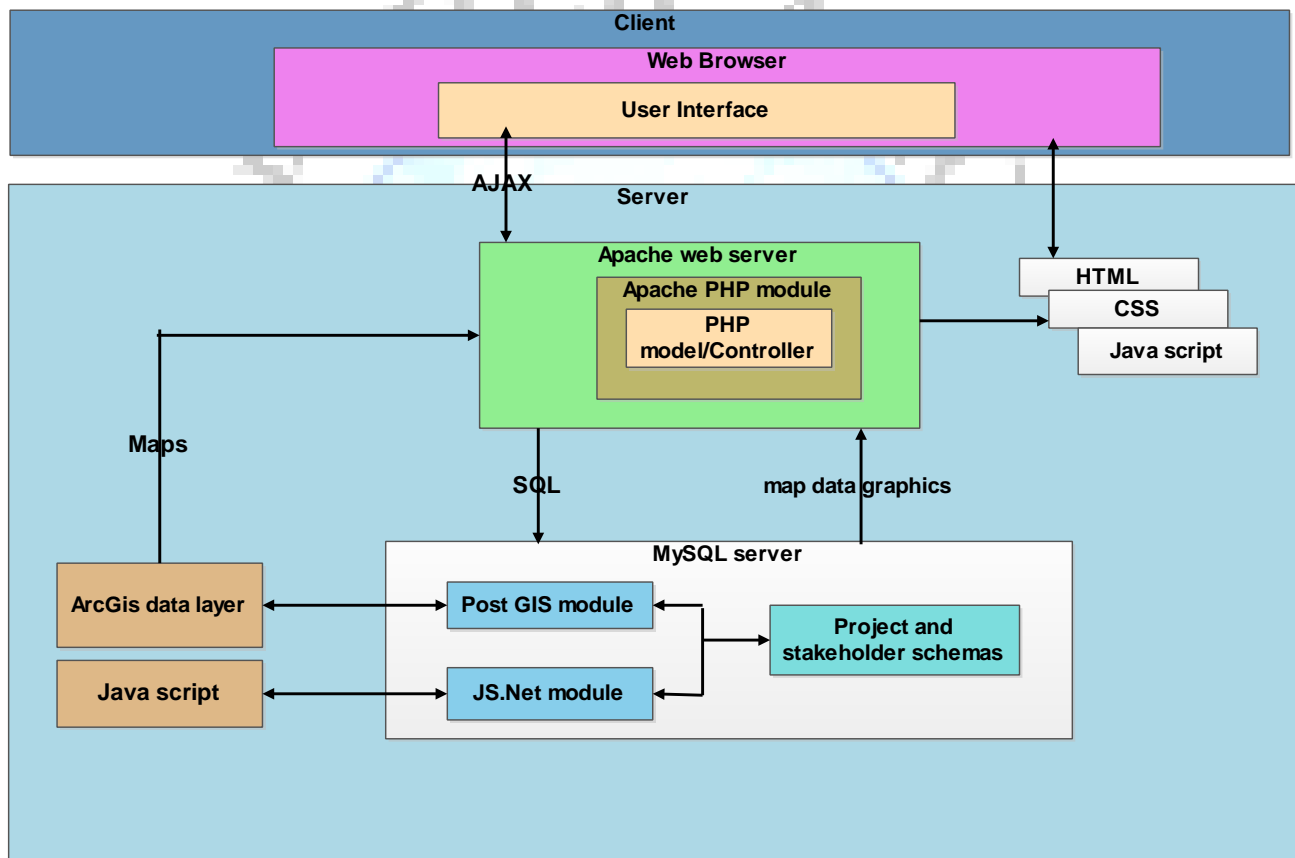
Figure 6   WATERDSS Conceptual Model [27]

At the top level, WATERDSS will consist of a set of guidance and software tools designed both to educate decision-makers in using this conceptual model and to allow them to create their own decision-specific model using interactive tools that allow them to input data and generate graphs, charts, and statistical analyses. By using these tools, different decision options can be quantified and evaluated in the larger context of the conceptual model. In addition, WATERDSS will house case study that demonstrate how the tools and guidance can be applied to specific real-world decisions. The case study will be used as the building blocks for the upper levels of WATERDSS. In terms of site navigation, the structure described above will be implemented as a series of links (Fig 7). Each of these top-level links will contain sub-menu housing tools useful in the decision process. The "WATERDSS steps" will contain an overview links, which will provide an introduction to the individual steps. Each of these sub-menus may contain its own sub-menu, housing guidance or tools.

The interactive mapping interface will be developed in Open Layers (www.universalmap developer.com), and Arc GIS. Open layers provides an API for incorporating and interacting with GIS data layers from several data sources and formats including Google Map base layers, Web Map Service (WMS) requests from a map server, Arc map requests, Google Earth Keyhole Markup Language (KML), Arc GIS, and My SQL requests.

This creates a flexible environment for managing GIS data layers, by taking advantage of data products from external sources (e.g., Google), and allowing for data layers to be dynamically generated, analyzed, and updated. WATERDSS currently is using Arc map, an open source map server application.

4.2 Requirements

4.2.1 Site Navigation
The web site should be organized such that different areas of the site are easy to find and access (with clicks). Different site sections must display promptly in response to mouse clicks. It is important that the organization of the site must reflect the five steps of decision-making that form the basis of the WATERDSS conceptual model.

4.2.2 Content Presentation
Site content should be clearly written and factually accurate. Guidance must be appropriate to the overall conceptual model. Guidance on using the embedded software tools should address all the functionality of the tool in question in language that is understandable by the user without special scientific or technical knowledge.

4.2.3 Graphical Tool User Interface(UI)
Software tools should have interfaces that are dynamic, responsive, and intuitive. Interacting with these tools should not lead to page reloads, require the user to go to a different page on the site or open a new browser window.

4.2.4 Data Management
The user should be able to input data relevant to their decision process and have those data stored in a persistent database. They should be able to modify or delete data after they have been entered. Data input interfaces should be responsive and intuitive.

4.2.5 Data Analysis
WATERDSS should be able to perform technical analysis of user-entered data. This will include performing statistical analysis of the data using Machine Learning (Decision Tree) method and generating plots, charts, and graphs of the data. Images generated by analysis tools must be displayed promptly and without requiring the user to go to a different page on the site or to open a new browser window.

Figure 7   WATERDSS Webpage Design

The components of the WATERDSS approach are many fields as links(see figure 7), 1-Home page: which contained information about the web site of WATERDSS such as the news, stations details, research center and reports to send the water statuses to the authority controller.2-stations: shows the locations of each water stations in Baghdad city.3-report: send the report of water state for decisions to supplying the water or not to the peoples.4-relevant work: includes many researches that relevant with WATERDSS project.5-water descriptions: provided all the parameters of water quality to know the suitability of the water. The propagation of uncertainty at each step of the decision process is the key of WATERDSS components. Data from a wide variety of different sources, as well as stakeholder values and preferences, will be combined as part of the decision analysis process. Highly uncertain information and data are essentially weighted inversely to their uncertainty.
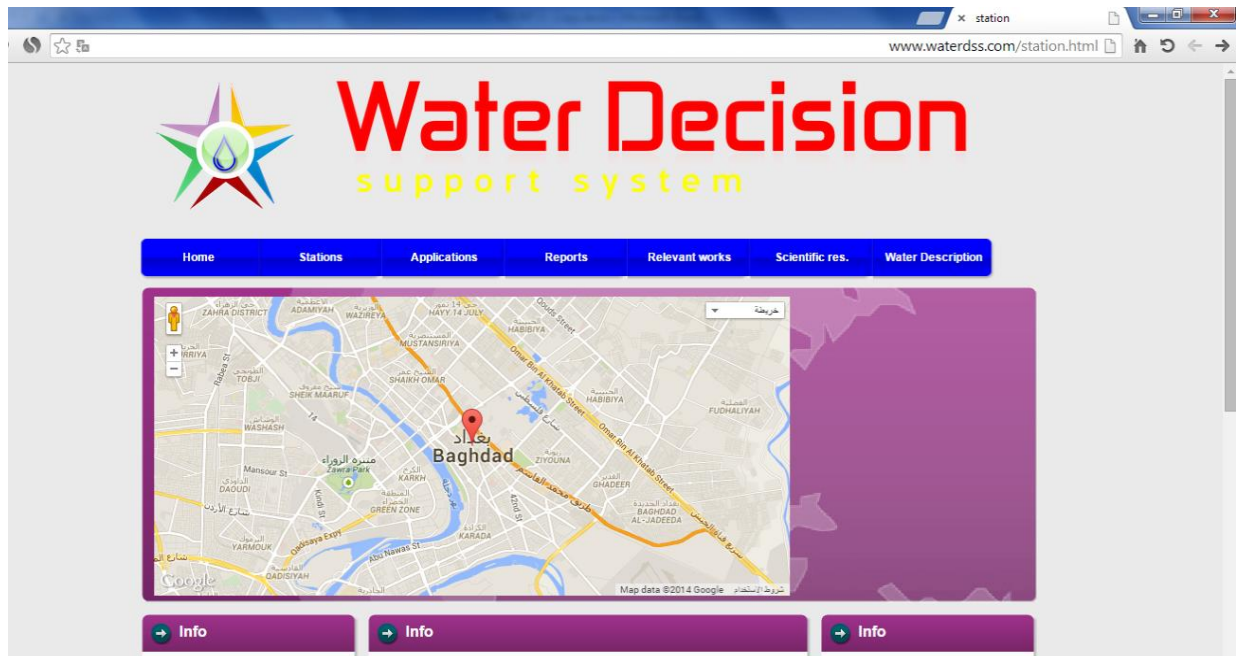
Figure 8 shows the map of Baghdad city which Tigris River is divided it into two sides (east: Russafa and west: Karkh), the case study was focused on these cities where they contains big water stations for supplied the water to the peoples).

Figure 9 water pollution treatment interface

Figure 9 shows Main window containing the parameters that lead to water pollution, shows the standard and the actual acquired value of the parameters (fig. 10). Based on them, the type of water pollution is determined and a decision is taken, that contains a suitable advice to treatment the specific kind of pollution. The application automatically sends an email to an authorized person / group of persons, with information regarding the pollution event.

Figure 10   WATERDSS Webpage Design components (calculating water quality)

Figure 10 shows the main windows to calculate water quality index by using the parameters of water and comparative the real values with the standard values then gives the decision of water states(suitable for drink, poor water, not suitable for drink).

5. Software Development and Implementation

5.1 Development Process

5.1.1Module Skeleton

WATERDSS developers will create an initial navigational, scripting, database, and technical analysis structure that reflects the system design as depicted in Figure 7. The user interface skeleton will be developed in HTML and JavaScript, the Model/Controller skeleton will be developed in PHP, the Database skeleton will be developed using My SQL, and the Technical Analysis skeleton will be developed in JavaScript. These skeleton components will provide containers for implementing specific functionality required by individual tools.

5.1.2Module Interfaces

Interfaces will be developed to allow communication among the modules. The User Interface will communicate with the Model/Controller via AJAX requests; the Model/Controller will communicate with the Database via direct My SQL queries and calls to java script stored procedures; and the Database will communicate with the Technical Analysis module via JavaScript code. These interfaces will be placeholders that will be replaced by task-specific communication mechanisms as individual tools are developed.

5.2 Development

The WATERDSS system is under test. During development phase, each of the new functions and components will be continuously tested as outlined. At the end of the development phase, the new functions and components will be deployed on a test website. In the beta-testing phase, an internal review of the content and function of the new WATERDSS functions and components are conducted. After that review is complete and identified concerns have been addressed, the running system is deployed onto the deployment server and made available at www.waterdss.com

5.3   GIS Layers Management and Web Serving

GIS data layers will be developed and stored natively as ESRI shape files. This will allow static GIS data to be developed under a Windows operating system. ESRI shape files will be imported into Arc GIS. Arc map is used to serve maps that are static, while Arc GIS is used to store spatial information that is being dynamically generated or edited by the user. The advantage of Arc GIS is that open source spatial analysis tools, interact with spatial data, and return results to the database through My SQL requests from the AJAX/PHP/Apache engine. This allows for a responsive interactive web-based spatial analysis environment that can take advantage of the wide array of open source analysis tools.

6. Acknowledgment

7. Conclusion/Results

This article has described the IDSS concepts, applications, potential intelligent techniques and the suggested IDSS framework using machine learning approach. There are many areas, problem domains and intelligent techniques. We conclude that IDSS applications and intelligent techniques applied are developed towards the expertise orientation and IDSS application development is a problem-oriented domain.

Knowledge is a complex phenomenon, and there are many aspects to the process of managing knowledge. Knowledge-based core competencies of firms are key organizational assets. Knowing how to do things effectively and efficiently in ways that other organizations cannot duplicate is a primary source of profit and competitive advantage that cannot be purchased easily by competitors in the marketplace.

This study discusses Web-enabled DSS, related knowledge repositories, and KMS that facilitate the problem solving and learning. The knowledge objects approach to the knowledge representation allows considering contemporary DSS as integrated parts of the corresponding KMS.

Web-based DSS application is a good solution shows complex functions of the system with a convenient web service application. The system allows a decision maker to easily decide or create a new model application on the Intranet/ Internet. The Web-based DSS application implementation has completed successfully using full features of Web-based DSS application for various purposes in water management. In addition, the Web-based DSS application has implemented in a good security on web application standard.

The WATERDSS project aims at developing a DSS which contributes to improve decision making in water management. The developed WATERDSS includes: (1) simulation modeling tools, (2) optimization algorithms of machine learning (decision tree) based on the Evolutionary Computing principles, (3) database tools for data storage and manipulation.

The WATERDSS is tested on a case study of water management distribution network design in Iraq. The solutions obtained demonstrate the feasibility of developing a WATERDSS Workbench and its useful implementation for water management network modeling and optimization.

WATERDSS is designed to help policy makers in the field of water management in defining long term strategies to avoid water pollution accidents, as well as take quick actions in case of pollution events. A decision support system is a collection of software tools (such as models, documents, databases, and data management software) that are integrated together with an easy-to-use interface. The decision support system is well suited for solving types of problems that do not have a clearly defined structure, so that conventional structured programming is difficult to apply

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