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Connecting Small Hydro Power Stations for Decision Support

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Acknowledgment

Abstract

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Chapter 1

Introduction

1.1 Reading Instructions

This thesis may present different interests for different readers. In this chapter, I will provide a guideline explaining what is covered in each chapter in order to facilitate browsing of the thesis and efficiently help every reader find the relevant information for him/her.

The first chapter presents the details and circumstances in which this thesis was created upon. The Problem statement of this thesis will be defined along with the motivation for solving that specific problem. Readers interested in a high level overview of the goal and the approach used for solving the specified problem, along with the original contribution brought to the existing system should refer to the *GoalAndApproach* and *OriginalContribution* sub chapters respectively.

The second chapter will discuss the most relevant concept of this thesis, namely decision support systems. They will be discussed and evaluated in terms of the foundations they are built on, their functionality, the Interfaces used for them, how they are implemented and their evaluation matrices and impact on decisions. This chapter will be most relevant for readers who would like to learn about decision support systems and understand the underlying concepts.

The third chapter will cover the Connect Hydro Project that my thesis aims to support and add to it. Connect Hydro proposes a system to connect small, private and independent hydro power plants through networked intelligent control system. In the chapter, I will also give an overview on the device they developed to collect sensor data from the power plants.

Chapter four will highlight in detail how a decision support system can bring advantage to the connect hydro project. In this chapter, I will also discuss what are the requirements for this proposed decision support system and describe the different inputs along with the expected outputs in addition to what should be the defined rules for such system. This is the chapter that my work will be based on.

The fifth chapter will cover the technical aspects of the implementation done to support this thesis. It will begin with describing the frameworks and technologies used for the implementation while explaining why they were used. Furthermore, each implemented aspect of the project will be explained in detail, namely the database model, the web portal, the data visualization and finally and most importantly the decision support system. This chapter might be of interest also for readers that want to find more details about the design and implementation of this system.

Chapter six will explain how the system implemented was evaluated, what matrices were used in its evaluation and the results. Readers interested in the results only will find this chapter the most informative for them.

The last chapter containing the conclusion and the future research will be most relevant for users interested in extending and improving the proposed system.

1.2 Motivation

Renewable energy is the new trend that all governments are directing research into simply because they are environment friendly and cheap. All researchers predict that the earth natural resources will run out and for the past 20 years have been trying to research new techniques to produce energy.[9]

1.3 Problem Statement

Given data from small, private & independent hydro power plants, we should be able to consolidate the data coming from their sensors and provide the owners with decision support such that the overall energy production is increased and down time is minimized.

1.4 Goal and Approach

1.5 Original Contribution

Currently there exists no system connecting small hydro power plants. Owners of said power plants don't communicate with each other resulting in a need for an early warning system (Decision support system). The main goal of the Decision support system is to receive data from previous power plants along the same river and direct the owner to do some action in response to the data received.

1.6 Outline of the Thesis

Chapter 2

Decision Support Systems

A decision support system (DSS) can be defined as a computer information system that analyzes complex data and solves problems by either supporting decision makers make informed decisions or suggesting decisions/actions for them.[16] DSSs are a sub-collection of information management systems that help planners, analyzers and managers in the decision making process.[6] A decision support system may present information graphically and may include an expert system or artificial intelligence (AI). It may be aimed at business executives or some other group of knowledge workers.

Much research and practical design effort has been conducted in each of the domain that comprise a Classic DSS tool design. These areas are :

- Sophisticated database management capabilities with access to internal and external data, information, and knowledge
- Powerful modeling functions accessed by a model management system
- Powerful yet simple user interface designs that enable interactive queries, reporting, and graphing functions.

2.1 History of Decision support systems

DSS concept was first introduced in the early 1960s.[12] A model-oriented DSS or management decision systems was introduced as a new type of information system.Following that, the concept of decision support evolved into two main areas of research according to the two DSS pioneers, Peter Keen and Charles Stabell, the first being "The Theoretical studies of organizational decision making" done at the Carnegie Institute of Technology during the late 1950s and early '60s and the second is "The Technical work on interactive computer systems", mainly carried out at the Massachusetts Institute of Technology in the 1960s.[12][16]

In 1971, a ground breaking book "Management Decision Systems: Computer-Based Support for Decision Making" written by Michael S. Scott Morton was published. The book discussed how creating analytical models along with computers can help make key decisions. The book also highlighted an experiment where managers used a Management Decision System which was considered the first test of a model-driven decision support system.[12]

By 1975, J. D. C. Little defined the four main criteria for designing and evaluating models and systems to support management decision making which are still considered relevant today. They include: robustness, ease of control, simplicity, and completeness of relevant detail.[12] In the early 1990's, some desktop online analytical processing (OLAP) tools were introduced and DSS technology shifted from mainframe-based DSS to client/server-based DSS and eventually to web-based DSS.[3] As a result of that change, Enterprise data warehouses were completed and data management and decision support companies updated their infrastructure to support the change in DSS technology.

According to Powell [11], DBMS(Database Management systems) vendors "recognized that decision support was different from OLTP(Online transaction processing) and started implementing real OLAP capabilities into their databases". In 1995, Researchers were directed towards the development of Web-Based Group Decision Support Systems(GDSS), Web access to data warehouses in addition to Web-Based and ModelDriven DSS.

According to Power [12], in the early 2000's, portals were introduced that combined information portals, knowledge management, business intelligence, and communications-driven DSS in an integrated Web environment called "Enterprise knowledge portals". This solidified the notion that the Web is the best suited platform for building future DSS.

2.2 Concept of DSS

The original DSS concept was built by combining some categories of management activity and decision problem types according to Gorry and Scott Morton.[5] The management activities were the set of decisions defined by the management to serve a specific purpose which could be strategic planning (decisions that contribute to the overall mission and goals), management control (decisions guiding the organization to achieve the specified goals), or operational control (decisions directing specific everyday tasks). The decision problem types were categorized into structured, semi-structured or unstructured problems. Structured problem types are problems that are repetitive and easily solved, they are usually solved using a computer program. Unstructured problems are problems that are difficult to solve using a computer program and relies on the decision maker's judgment.[16]

According to Gorry and Scott Morton the characteristics of information needs and models differ in a DSS environment. The unstructured nature of information needs in a DSS situations forces us to search for different kinds of database systems than those for operational environments. Flexible query languages and relational databases are needed. Similarly, the need for flexible modeling environments was arisen to handle the problem of unstructured decision process, such as those in spreadsheet packages.[16]

Fig. 2.1 explains a generic model that was used and implemented in a DSS system for a decision making process where the focus is on the analysis of the problem and development of the model. It starts by recognizing a problem, then defining said problem in terms that contribute towards the model creation. Once the problem is defined, a model is designed and some alternatives are developed to find a solutions. Following that a solution is chosen and the DSS system implements it. This Figure explains a the process of a simple structured clear decision process, however, no decision process is that defined which leads to a lot of back and forth between the phases and overlapping to earlier stages as the problem becomes more defined or the solutions fail.[16]

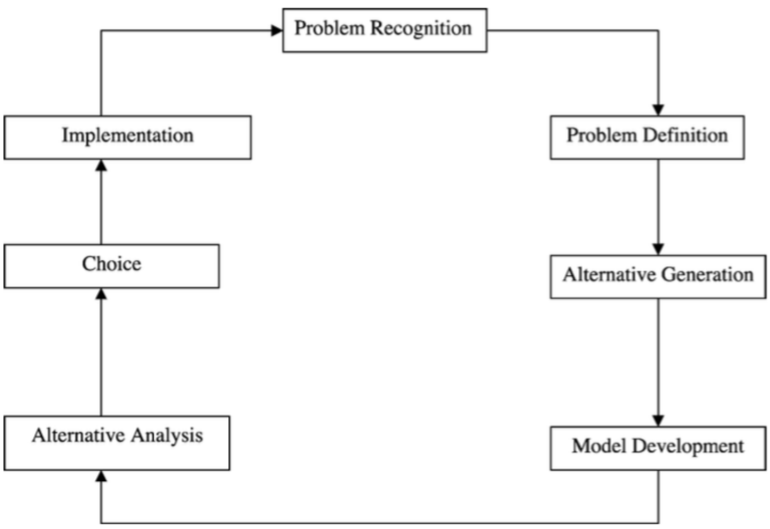

Figure 2.1: The DSS decision-making process [16]

2.3 Types of DSS

There exists a number of Decision Support Systems. These can be categorized into five types:

- Communication-driven DSS
- Data-driven DSS
- Document-driven DSS
- Knowledge-driven DSS
- Model-driven DSS

We will explore each type briefly in the following sections.

2.3.1 Communication-driven DSS

A communication-driven DSS is a type of DSS that focuses on communication as well as help two or more users collaborate, share information, co-ordinate their activities and support shared decision-making.[13]The most common technology used to deploy this type of DSS is a web or client server. A few example of a communication-driven DSS include chats and instant messaging softwares, online collaboration and net-meeting systems or a simple bulletin board or threaded email.

Communications-Driven DSS software should include at least one of the following characteristics:

- Enables communication between groups of people
- Facilitates information sharing
- Supports collaboration and coordination between people
- Supports group decision tasks

Group Decision Support Systems(GDSS) is a hybrid type of DSS. It is based on communication-driven DSS. Using various software tools, multiple users can work collaboratively in groupwork.[13]
Examples of group support tools are:

- Audio Conferencing
- Bulletin boards and web-conferencing
- Document Sharing

- Electronic Mail
- Computer Supported face-to-face meeting software
- Interactive Video

2.3.2 Data-driven DSS

Data-driven DSS is a type of DSS that is able to process huge amounts of data from different sources and store them in a data warehouse system. Data Driven DSS uses on-line analytical processing(OLAP) and Data mining techniques to extract the needed data which will be discussed in the section *ToolsToDevelopDSS*. There exists two special purpose Data-driven DSS, they are: Executive Information Systems (EIS) and Geographic Information Systems (GIS). An example of a data-driven DSS is computer-based databases that have a query system.

Executive Information Systems (EIS) are computerized systems intended to provide current and appropriate information to support executive decision making for managers using a networked workstation. They focus on graphical displays and on offering an easy to use interface that presents information from the corporate database. EIS offer strong reporting and drill-down capabilities.[13]

A Geographic Information System (GIS) or Spatial DSS is a support system that represents data using maps. It helps people access, display and analyze data that have geographic content and meaning.[13]

2.3.3 Document-driven DSS

A relatively new field in Decision Support is Document-Driven DSS. Its focus is on the retrieval and management of unstructured documents. Documents can be Oral, written or video. They help a decision maker by keeping track of knowledge represented as documents that can affect the decisions.[15] Examples of oral documents are conversations that are transcribed; video can be news clips, or television commercials; written documents can be written reports, catalogs, letters from customers, memos, and even e-mail.[13]

2.3.4 Knowledge-driven DSS

Knowledge-Driven DSS can suggest or recommend actions to managers. It contains of specialized problem solving expertise also known as a knowledge base. The knowledge base comprises of rules, facts and procedures about a particular domain. The knowledge base also provides understanding of problems within that domain, and "skill" for solving some of these problems. A related technique used in knowledge-driven DSS is Data Mining, discussed in the section *ToolsToDevelopDSS*. Intelligent Decision Support methods are used to build Knowledge-Driven DSS [15].

2.3.5 Model-driven DSS

Model-Driven DSS (MDS) are a standalone systems that performs modeling of unstructured problems with an easy to use user interface. The most basic modeling functionality; the what-if model ;can be achieved using a simple statistical and analytical tool. There can exist a hybrid DSS system that combines the modeling functionality of the MDS and the complex analysis of data of an OLAP system.[13] In general, model-driven DSS uses complex financial models, simulation models, optimization models or multi-criteria models to provide decision support.[13] Data and parameters are provided by decision makers to the Model-driven DSS to aid decision makers in analyzing a situation. Very large databases are not needed in Model-driven DSS as they are not usually data intensive.[13] Model-Driven DSS can also be called model-oriented or model-based decision support systems.

Model-driven decision support process can be divided into three stages:

- Formulation : A model is generated in a form that can be accepted in the model solver.[16]

- Solution : Finding the solution of the model in an algorithm form.[16]

- Analysis : Analyze and interpret 'what-if' model solution or a set of solutions.[16]

Initially optimization of Model-driven DSS focused on optimizing the solution algorithm, but later the focus shifted to also finding better techniques to formulate and analyze the functions to support the DSS.[16]

Tools used in Model-driven DSS include [8]:

- **Decision Analysis tools** - help decision makers decompose and structure problems. These tools aim to help a user apply models like decision trees, multi-attribute utility models, Bayesian models, Analytical Hierarchy Process (AHP), and related models.[13]

- **Forecasting Support System** - A computer-based system that supports users in making and evaluating forecasts. Users can analyze a time series of data.[13]

- **Linear Programming** - A mathematical model for optimal solution of resource allocation problems.[13]

- **Simulation** - A technique for conducting one or more experiments that test various outcomes resulting from a quantitative model of a system.[13]

2.4 Tools to Develop DSS

As Mentioned in the previous section, there exists a number of tools that are used to support the decision making process. In this section, I will explain briefly each of them.

2.4.1 Data Warehouse Systems

Data warehouse systems are systems that allow the manipulation of data by using either computerized tools customized for a specific task or general tools and operators that provide a certain functionality. A Data Warehouse is basically a database that is designed to support decision making in organizations. Data warehouses are structured to contain large amounts of data and handle rapid online queries and managerial summaries. According to Power[12], Data warehouse is a subject-oriented, integrated, time-variant, nonvolatile collection of data that supports the management's decision making process.

2.4.2 On-line Analytical Processing

On-line Analytical Processing (OLAP) is a technique used to support the decision support functionality especially in Data-driven DSS. It is linked to analysis of large collections of historical data.[13] OLAP software is used for manipulating data from a variety of sources that has been stored in a static data warehouse. The software can create various views and representations of the data.[13] Three main features should be available in a software product for it to be considered an OLAP application. They are:

- Multidimensional views of data

- Complex calculations

- Time oriented processing capabilities

2.4.3 Data Mining

Data Mining helps in extracting useful information by finding patterns or rules from existing data to produce data content relationships. It is based on Artificial Intelligence techniques combined with statistical tools. This information is then used to predict future trends and behaviors which also makes it a very important technique when implementing a data-driven DSS.

2.4.4 Web-based DSS

Web-based DSS can be defined as a computerized system that provides an easier and less costly way to deliver decision support information or decision support tools to a manager, business analyst or a decision maker using a Web browser. As shown in Figure 2.2, any Type of DSS can either be web-based and implemented using web technologies or local based(LAN-Based). However, the web opened a gateway that allowed for the implementation of DSS with larger scopes, access to more users and most importantly rapid access to "best practices" analysis and decision-making frameworks. The result would be well-designed DSS in a company. Using a Web infrastructure for building DSS promotes more consistent decision making on repetitive tasks[14].

	Technology	
DSS Types	LAN-Based	Web-Based
Communications-Driven and GDSS	Narrow scope	Global scope
Data-Driven	Thick-client	Thin-Client
Document-Driven	Limited, .doc,.xls	Also HTML, Search engines
Knowledge-Driven	Stand-alone PC	Shared rules
Model-Driven	Single user	Multiple users

Figure 2.2: Decision Support Systems using Web Technologies [14]

2.5 DSS Design

DSS has components and phases of development, like any other software system. No matter what kind of decision support system is being developed, there should exist four components:

- Input: Input type that will be used in the analysis should be defined.
- User Knowledge/Expertise: will user knowledge be used as part of the input as well?
- Output: The output is specific or generic?
- Decisions: The system should suggest actions, analyze data and different actions or do the action to correspond to the output.

Once these four components are considered and clear enough we can proceed to the next phase in the design and development process which is Analyzing the business decision making process.

2.5.1 Analyzing Business Decision Making Process

A key consideration in designing a decision support system is to understand the context in which the decisions will be made. These considerations include the decision type, nature of problem, people involved and eventually the decision making context.[4] An analyst is responsible for defining all the key components and creating a clear understanding of what will be required of the system.

Decisions can either be Strategic decisions, Operational decisions or Managerial decisions. It is very important to understand which type of decision should the DSS being developed support.

Strategic decisions are non-repetitive and require a lot of time to be arrived at. They involve careful analysis of the situation and consequences. Some examples of strategic decisions: evaluation of an investment proposal, decisions related to mergers and acquisitions, resource allocations, fund raising, etc.[4] Operational decisions can either be long term decisions that impact the business functionality and help the company realize their mission or short term decisions that impact day-to-day activities.[4] Managerial decisions are usually decisions taken by top management. Examples of Managerial decisions include resource allocation, talent management, research and development, new product introduction, withdraw or revamp old products.[4]

After defining the decision types to be supported, the nature of the problem should be defined. Problems can either be repetitive, non-repetitive, structured or unstructured and depending on the nature of the problem we can define what type of analysis will be required by the system and if any human interaction will be needed. Another factor to be taken into consideration is weather decisions are to be taken individually or within a group.

2.5.2 Decision Making Process

After analyzing the Decision making from a business perspective, the following step would be to start the decision making process. The process starts by the following steps:

1. Defining the Problem: It begins with recognizing that a problem exists, sets a base on which assumptions can be built, collect and analyze data and finally evaluate alternatives[4]. A problem exists when:

- The expected output and the delivered output are different
- There's a divergence from the normal expected results
- An action taken is not explainable

2. Identifying Decision Maker: A problem should be sent to the right person depending on its nature.[4]

3. Gathering Information : A DSS can process tons of data in just few seconds thus helping the concerned person with collecting data and identifying the factors influencing the situation.[4]

4. Evaluating Alternatives and Deciding: All possible courses of action are evaluated and the most suitable action is determined, by assessing the pros and cons of each alternative. A DSS helps in justifying a particular choice.[4]

5. Implementation and Follow-up: Once the decision is taken, It's time to implement the decisions. Decisions proposed should be monitored in order to determine weather it was helpful in achieving the objectives or not. If not the entire process must be repeated.

2.6 Decision Support Implementation and Development

Once There is a clear understanding of the system requirements and all the processes are defined and the design phase is complete, the development process begins. It starts with choosing a system development approach, followed by designing the user interface. The System Architecture, networking and security will be addressed in the *DecisionSupportArchitecture* and *DecisionSupportNetworkingAndSecurity* sections.[4]

2.6.1 Choosing a System Development Approach

There are three common development approaches as shown below in Figure 2.3. Each of them will be discussed in detail.

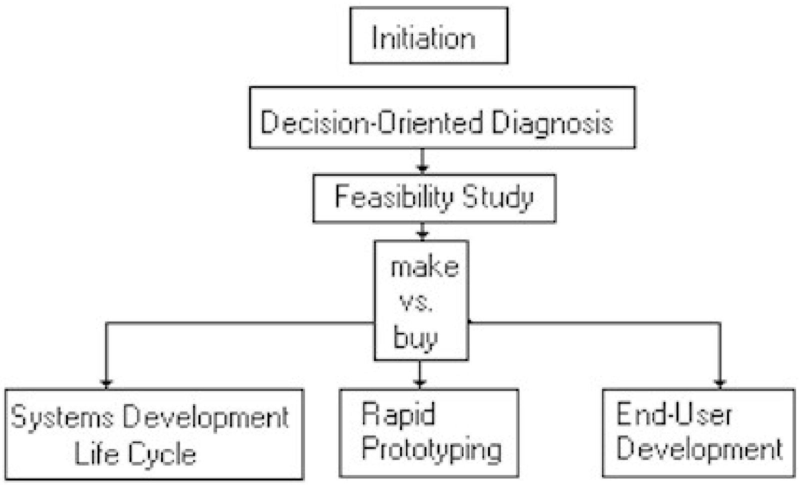

Figure 2.3: DSS Development Approaches [13]

- **SDLC - System Development Life Cycle Approach**
  The SDLC is a sequential, structured and a standardized process for a system development. It starts with identifying the system objectives (needs of end users) and goes through various stages shown in figure 2.4[7], including
  * System analysis (technical components required)
  * System design (architecture)
  * Development (programming)
  * Testing (errors and bug fixing)
  * Implementation & Use(execution in the organization)
  * Evaluation (verification of functions and capabilities)
  * Modification (adjustments required)

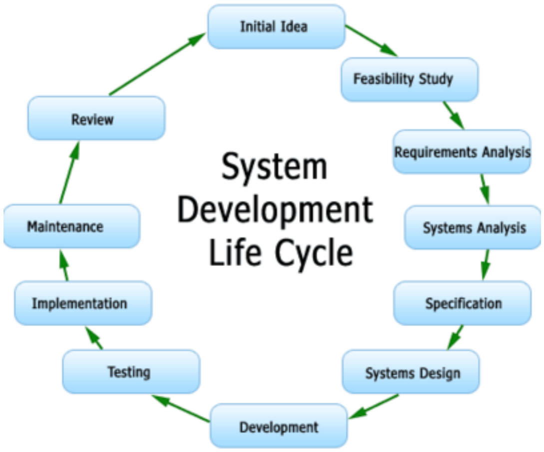

Figure 2.4: System Development Life Cycle Approach [7]

SDLC is the most commonly used and most rigid system development approach. In complex situations, it becomes difficult to use this approach, as the requirements of users are constantly changing. It doesn't promote recurring development and testing.[4]

- **Rapid Prototyping Approach** Rapid Prototyping promotes a faster system development. It combines the effort of the decision makers and the analyst in charting the specific requirements. The decision maker uses general terms, the analyst uses DMS (database management system) to support rapid development of the application.[4]
  Rapid prototyping goes through the following steps also shown in figure 2.5:
  * Identifying objectives/ user requirements
  * Developing the first model
  * Evaluating the first model, identifying adjustments required and modification
  * Testing the developed DSS.
  * Go back to evaluation and modification, if needed
  * Implementing

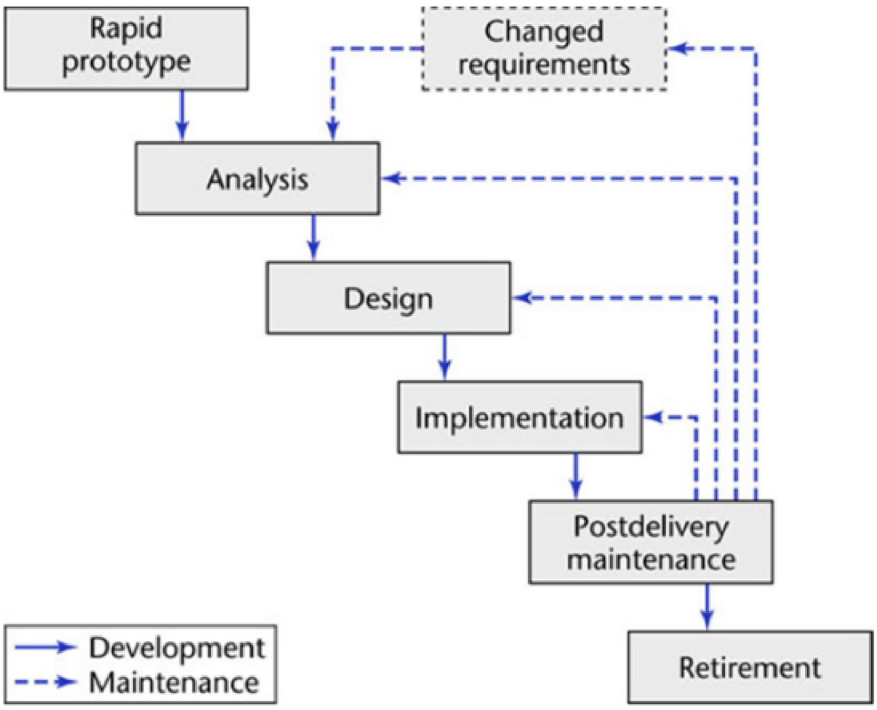

Figure 2.5: Rapid Prototyping Approach [2]

Evaluation and modification at a rapid pace is the core concept behind the Rapid Prototyping Approach as communication lines are always open. This approach is better suited than SDLC in complex situations.

- **End-User DSS Development Approach** Designing and development a software system depending on the specific or individual needs of the decision maker is the basis of the End-User development approach. The Decision maker customizes the system on his own. This approach is rarely used as usually the decision maker lacks technical expertise and chooses inappropriate software.[4]

2.6.2 Designing User Interface

A Decision support system relies heavily on its design. If its user friendly and easy to use then chances are that this DSS will be used. Although the technical expertise of analysts, designers and developers is crucial, needs of DSS users must be evaluated and met at every step of the process. The right user interface design approach is the first step in developing an efficient decision support system.[4]

2.6.2.1 ROMC Design Approach

ROMC is a systematic approach for developing large-scale DSS, especially user interfaces. The approach involves designing Representation, Operations, Memory Aids, and Control mechanisms. It is user-oriented approach for stating system performance requirements. It was originally presented by Sprague and Carlson in 1982.[1]

Representation: It involves presenting information or results, in a structured way. All decision making activities in an organization take place in a certain environment or context. The representation in addition to the decision making context, provide a way to communicate information to the decision maker or user of the system about the situation.[1, 4]. It provides a platform to the decision makers supported by information to help them interpret DSS outputs. It can be in the form of a table, graph, map, chart or a text document and each value on a map or a table communicates decision making context.[1, 4]

Operation: Specific tasks that can be performed by a decision maker with a DSS. Example DSS operations include tracking market trends, carrying analytics or suggesting alternatives or performing all the functions.[4]

Memory Aid: A data warehouse is the memory aid for a DSS. A DSS must give users a link to data warehouse. In addition, links and command shortcuts or sequences can be supplied to help users control a decision support system.[4]

Control Mechanism: Allows users to effectively use representations, operations and memory aids.[4]

2.6.2.2 UI design success Factors

In order to evaluate a UI design success. The following factors are considered:
Execution Time for a command given and action performed should be minimized.
Versatility of a decision support system should be flexible enough to integrate new tasks if needed.
Adaptability of a decision support system needs to remember the user's habits and adapt to them.
Learning Time should be reduced for the system.
Uniformity of Command/theme should be maintained throughout the system
Quality of Help should be available to users. The system should offer self-help manuals both online and offline.
Memory Load; Avoid too many numbers and statistical information on 1 screen. Users don't want to remember numbers

Ease of Recall; The user can remember how to use the system quickly after not using it for some time.
Fatigue; simple designs should be maintained to avoid Mental fatigue.
Errors should be managed for possible error-producing situations that might happen.

2.7 Decision Support Architecture

DSS Architecture requires full understanding of how a user will interact with the system and how the information will flow from one point to another.[4]

There are four fundamental components of DSS architecture:

- User Interface : Discussed in *DesigningUserInterface*
- Database
- Model (context or situation representation)
- Knowledge

Database: A DSS accesses information directly from a database. The system architecture scheme focuses on the type of database required for a particular decision making system model, Who's responsible for different types of databases and how to maintain accuracy and security of database.[4]

Model: This component of the DSS architecture handles 2 components, the DSS model and DSS model management system. A model is a representation of a context, a situation or an event that carries out some type of data analysis needed for the decision making process. A DSS model management system stores and maintains DSS models.[4]

Knowledge: Information about data relationship is represented in the knowledge. This knowledge is managed by the DSS architecture and provides decision makers with alternative solutions to a problem when needed.[4]

2.8 Decision Support Networking and Security

DSS Network needs to define how hardware is organized, how data is distributed throughout the system how DSS components are connected and whether the information is fed/accessed using Internet, Extranet or Intranet.[4] DSS Networking is all about connection between the components – software and hardware.

A network is defined as an assortment or a group of computers that are connected with each other or in a specific way, in order to communicate with each other. This connection facilitates the sharing of information among the connected computer systems.[4]

Resource Sharing
The computer network's main objective is to share information. The most common technology for connection and resource sharing is LAN (Local Area Network). It serves hosts within a restricted geographical area. WAN (Wide Area Network) is another technology for resource sharing. The difference between LAN and Wan is that the latter is much larger and connects a group of LANs.[4]

Resource Connection
TCP/IP (Transmission Control Protocol/ Internet Protocol) is a set of standard networking protocols, to enable computer systems to communicate with each other. It defines the rules and formats for the diffusion and reception of information or resources. The TCP sends data between programs using IP (Internet Protocol). It assigns a unique IP address to each workstation and sends information from one host to another in the form of packets.[4]

Constant presence and cost effectiveness of the Internet make it the best way to send Information or data. One aspect that should always be taken into consideration is that data have to transferred through a secured connection to maintain security. Security related concerns are discussed in the next section.

2.8.1 Security

As a decision support system contains secret or classified information, it needs to be 100% safe and secure. It's also necessary for safeguarding employee and customer data. The Process for Addressing Security Issues begins with:

Identifying security needs: DSS users and analysts must brainstorm to identify security needs and evaluate potential threats.

Determining how important security is for your DSS.

Remedying problems: Fix the problems found that affect the DSS security. The solutions may be in the form of [4]:

* Strengthened password
* User education
* Firewalls
* Enhanced privacy
* Logging and use statistics

Implementing solutions and observing their impact: the decided solutions are im-

plemented and observed.
There may be some security holes at any given point. DSS users and analysts must Keep track of them and change the passwords and strengthen firewalls on regular basis.

2.9 Evaluation and Impact

It is difficult to determine if a DSS is successful. Therefore, some criteria have to be evaluated and decided upon them how successful the system really is. Figure 2.6 shows a few examples of how various features of a DSS can be evaluated.[10] One aspect in evaluation of a DSS can be user satisfaction. However, users may have poor introspection or (if they are not experienced in using a DSS) may not recognize good advice and may dislike being corrected by a computer system, so while it should be taken into consideration, it shouldn't be a deciding factor.[10]

Various features and criteria used for the evaluation of DSS

Subject of validation	Examples of measurements
(DSS) Development process	Involvement of future users in early development phases, appropriately defined system requirements, evolutionary system development, clear definition of beneficiaries
DSS components	Precision of models, quality of data, user interface, reporting system to choice of suitable technology and management of data, complexity of DSS and data inputs
Decision process	Appropriateness of logical process followed when using DSS, number of alternatives explored by DSS, internal communication, correspondence to and appropriateness for decision organisation
Decision output	Quantification profit/loss from DSS usage, consensus achieved among decision-makers, savings of time or other resources through DSS usage, contribution to organisational efficiency, consistency of solution
User satisfaction	Degree of confidence in results derived by DSS, acceptance (willingness to change current management methods), improvement of personal efficiency, correspondence of DSS output with decision-making style, users' understanding of implemented models

Figure 2.6: DSS Process Evaluation [10]

In addition to evaluating various DSS features, there exists some tools that can evaluate a DSS, Some of them include:

1.Cost-Benefit Analysis: Determines if a DSS is a good investment or not. This tool is used to compare the total benefits that a system is expected to produce vs the total cost of development and implementation .[4]

2.Incremental Value Analysis: The process focuses on the value offered by a proposed DSS rather than the cost incurred on it.[4]

3.Qualitative Benefits Scenario Approach: This method aims to determine if the proposed DSS will maintain the same quality and capabilities in future scenarios.[4]

4.Research and Development Options Approach: This approach aims to determine the cost of keeping the DSS flexible for future enhancements or future DSS.[4]

5.Scoring Approach: The approach separates the business and technical validation and considers other benefits of a DSS that were not considered during the analysis phase. It assigns points to each criterion/benefit upon reflecting on how well it satisfies a given factor.

Business validation involves assessment of strategic alignment, management information support, competitive advantage and organizational risk.[4]

Technical justification involves examining technical uncertainty, strategic systems architecture and system infrastructure risk.[4]

Chapter 3

Connect Hydro Project

3.1 Small Hydro Power Plants

Hydropower systems are systems that make use of the energy in flowing water to produce electricity or mechanical energy. The water flows via channel or penstock to a waterwheel or turbine where it strikes the bucket of the wheel, causing the shaft of the waterwheel or turbine to rotate. When generating electricity, the rotating shaft, which is connected to an alternator or generator, converts the motion of the shaft into electrical energy. This electrical energy may be used directly, stored in batteries, or inverted to produce utility-quality electricity. A small scale hydroelectric facility requires that a sizable flow of water and a proper height of fall of water, called head, is obtained without building elaborate and expensive facilities. Small hydroelectric plants can be developed at existing dams and have been constructed in connection with river and lake water-level control and irrigation schemes. By using existing structures, only minor new civil engineering works are required, which reduces the cost of this component of a development.

small scale hydropower systems capture the energy in flowing water and convert it to usable energy. Although the potential for small hydro-electric systems depends on the availablity of suitable water flow, where the resource exists it can provide cheap clean reliable electricity. A well designed small hydropower system can blend with its surroundings and have minimal negative environmental impacts.

Moreover, small hydropower has a huge, as yet untapped potential in most areas of the world and can make a significant contribution to future energy needs. It depends largely on already proven and developed technology, yet there is considerable scope for development and optimization of this technology.

Hydroelectricity is the term referring to electricity generated by hydropower; the production of electrical power through the use of the gravitational force of falling or flowing water. It is the most widely used form of renewable energy, accounting for 16 percent of global electricity generation – 3,427 terawatt-hours of electricity production. The main aspects of hydro power plants: 1) Design and Operation. 2) Generating methods. 3) Advantages and Disadvantages.

3.1.1 Benefits of Small Hydro Power Plants

Hydro electric energy is a continuously renewable electrical energy source. It is non-polluting - no heat or noxious gases are released. It is essentially inflation proof due to its low operating and maintenance cost, it also doesnt have any fuel cost. It is a proven technology that offers reliable and flexible operation along with a long life, many existing stations have been in operation for more than half a century and are still operating efficiently. Hydro power station provide an efficiency of over 90%, it the most efficient of energy conversion technologies. Finally, Hydro power offers a quick means of responding to changes in load demand or due to certain events.

3.1.2 Generating methods

- **Conventional (dams)** – Most hydroelectric power comes from the potential energy of dammed water driving a water turbine and generator. The power extracted from the water depends on the volume and on the difference in height between the source and the water's outflow. This height difference is called the head. The amount of potential energy in water is proportional to the head. A large pipe (the "penstock") delivers water to the turbine.

- **Pumped-storage** – This method produces electricity to supply high peak demands by moving water between reservoirs at different elevations. At times of low electrical demand, excess generation capacity is used to pump water into the higher reservoir. When there is higher demand, water is released back into the lower reservoir through a turbine. Pumpedstorage schemes currently provide the most commercially important means of large-scale grid energy storage and improve the daily capacity factor of the generation system. Pumped storage is not an energy source, and appears as a negative number in listings.

- **Run-of-the-river** – Run-of-the-river hydroelectric stations are those with small or no reservoir capacity, so that the water coming from upstream must be used for generation at that moment, or must be allowed to bypass the dam.

- **Tide** – A tidal power plant makes use of the daily rise and fall of ocean water due to tides; such sources are highly predictable, and if conditions permit construction of reservoirs, can also be dispatchable to generate power during high demand periods.

Less common types of hydro schemes use water's kinetic energy or undammed sources such as undershot waterwheels. Tidal power is viable in a relatively small number of locations around the world.

- **Underground** – An underground power station makes use of a large natural height difference between two waterways, such as a waterfall or mountain lake. An underground tunnel is constructed to take water from the high reservoir to the generating hall built in an underground cavern near the lowest point of the water tunnel and a horizontal tailrace taking water away to the lower outlet waterway.

3.1.3 Problems with Small Hydro Power Plants

3.2 Control Strategies

3.2.1 Local Control Strategy

3.2.2 Cooperative Control Strategy

3.2.3 Centralized Control Strategy

3.3 Connect Hydro Problem

3.3.1 Technical & Financial Aspects

3.3.2 Proposed Concept

3.4 Proposed Implementation

3.4.1 Technical Level

3.4.2 Software Level

Chapter 4

Decision Support in Connect Hydro

Chapter 5

System Architecture and Details

5.1 Frameworks and Technologies

5.1.1 Web Development

5.1.1.1 JSON

5.1.2 Front-End Technologies

5.1.2.1 AJAX

5.1.2.2 Bootstrap

5.1.3 Back-End Technologies

5.1.3.1 Spring

5.1.3.2 MySQL Database

5.2 Database Design and Implementation

5.3 Web Portal

5.4 Data Visualization

5.5 Decision Support

Chapter 6

Evaluation

Chapter 7

Conclusion

7.1 Summary

7.2 Lessons Learned

7.3 Future Research

7.3.1 Machine Learning

7.3.2 No-SQL Database

Abbreviations

DSS Decision Support System

JDBC Java Database Connectivity

DBMS Database Management Systems

OLAP Online Analytical Processing

OLTP Online transaction processing

EIS Executive Information Systems

GIS Geographic Information Systems

GDSS Group Decision Support Systems

MDS Model-Driven DSS

AHP Analytical Hierarchy Process

SDLC System Development Life Cycle Approach

LAN Local Area Network

WAN Wide Area Network

TCP/IP Transmission Control Protocol/ Internet Protocol

IP Internet Protocol

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Work Experience and Internships

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- Participated in Workshops with Customers to determine their needs and propose a solution
- Wrote functional/technical specification and Solution Architecture documents
- Wrote User Guide and Deployment Guides
- Developed applications as per functional specifications document using .NET framework and Amadeus Web Services, followed by testing and delivering the applications
- Provided second level support and training
- Trained new Members and offered them support

July 2010 – Sep 2010: **Database Administration Intern**, *Vodafone Egypt*

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Programming Languages:	C#, Java, VB.NET
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Eidesstattliche Erklärung

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Hagenberg, Juni 2017 Nada Ossama