

Intelligent Decision Support Systems- A Framework

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Abstract:

Information technology applications that support decision-making processes and problem-solving activities have thrived and evolved over the past few decades. This evolution led to many different types of Decision Support System (DSS) including Intelligent Decision Support System (IDSS). IDSS include domain knowledge, modeling, and analysis systems to provide users the capability of intelligent assistance which significantly improves the quality of decision making. IDSS includes knowledge management component which stores and manages a new class of emerging AI tools such as machine learning and case-based reasoning and learning. These tools can extract knowledge from previous data and decisions which give DSS capability to support repetitive, complex real-time decision making. This paper attempts to assess the role of IDSS in decision making. First, it explores the definitions and understanding of DSS and IDSS. Second, this paper illustrates a framework of IDSS along with various tools and technologies that support it.

Keywords: Decision Support Systems, Data Warehouse, ETL, Data Mining, OLAP, Groupware, KDD, IDSS

1. Introduction

The present world lives in a rapidly changing and dynamic technological environment. The recent advances in technology have had profound impact on all fields of human life. The Decision making process has also undergone tremendous changes. It is a dynamic process which may undergo changes in course of time. The field has evolved from EDP to ESS. Decision Support System (DSS) facilitates the decision making process in making the most effective outcome. DSS is the area of the information systems (IS) discipline that is focused on supporting and improving managerial decision-making. Companies are investing resources in knowledge acquisition, knowledge representation and knowledge processing for making intelligent decisions. Intelligent reasoning techniques can offer great advantages in making optimal decisions (Tonfoni & Jain, 2003).

An effective DSS is primarily meant to aid the efforts of the decision makers and ensure that important details are not overlooked. Irrelevant details must be recognized as such and not allowed to distract and divert the decision making process. DSS do not supervise the decision and never replace human decision makers, but they do support them and help them to make better and consistent decisions.

An effective DSS should:

- (a) Assist decision makers for availability of new and verified data of relevance;
- (b) Provide access to a knowledge repository;
- (c) Provide an infrastructure for interpretation and classification for new knowledge; and
- (d) Be able to discriminate between verified and unverified data.

Various factors that induce organizations to implement DSS are:

- Speed: A computer based system allows a decision maker to perform large number of computations very quickly and at a very low cost.
- Productivity: Using a computerized system avoids assembling a group of people at a place and increases productivity of staff.
- Support: Computers can search, store and transmit data and programs very quickly and economically without the need of a human expert.
- Decision Quality: Computer based systems can improve decision quality by providing several alternatives which can be analyzed and evaluated quickly and expert opinion can be sought quickly and at low cost.
- Competitive Advantage: Research into competitor's activities, customization of products, and customer services can be facilitated by computerized voice systems (Turban, et al., 2007)
- Vast Processing and Storage: According to (Simon, 1977), the human mind is limited in its ability to process and store information but computers are almost limitless in both cases.
- Popular Computer Use: More and more managers and decision makers use ICT with less anxiety. In fact, a study estimated that among 500 companies, about 10 percent of Chief Executive Officers (CEOs) and about 33 percent of high-level managers use computers regularly in their decision making process (Sauter, 1997). As a computer based system, the DSS is becoming popular among the decision makers.

2. Decision Making

A decision is defined as a process of choosing among alternative courses of action for the purpose of attaining a goal or goals.

According to Simon (Simon, 1977) the decision making process consists of four main stages:

1. *Intelligence*: Fact finding, problem and opportunity sensing, data collection, analysis, and exploration
2. *Design*: Formulate a model, Set criteria for choice, Search for alternatives, modeling and simulation
3. *Choice*: Evaluation of alternative, Sensitivity analysis, Selection of best alternative (s) and plan for implementation
4. *Implementation*: Final implementation of the chosen alternative

3. Decision Support System

DSS are a specific class of information system that supports business and organizational decision-making activities. A properly designed DSS helps decision makers to compile useful information from raw data, documents, personal knowledge, and/or business models to identify and solve problems to make decisions.

The early definitions of DSS recognized it as a system intended to support managerial decision makers in semi-structured and unstructured decision situations. In the early 1970s, Scott Morton first articulated the major DSS concepts. He defined DSS as “interactive computer-based systems, which help decision makers utilize data and models to solve unstructured problems.” (Gorry & Morton, 1971)

Another classic definition of DSS, provided by (Keen & Morton, 1978), defines DSS as a system that combines the intellectual resources of individuals with the capabilities of the computer to improve the quality of decisions. It is a computer based support system for management decision makers who deal with semi-structured problems.

Moore & Chang define DSS as extendible systems capable of supporting ad-hoc data analysis and decision modeling, oriented toward future planning, and used at irregular, unplanned intervals (Moore & Chang, 1980).

Bonczek & Whinston define DSS as a computer-based system consisting of three interacting components: a language system (a mechanism to provide communication between the user and other components of the DSS), a knowledge system (a repository of problem domain knowledge embodied in DSS as either data or procedures), and a problem-processing system (a link between the other two components) (Bonczek, et al., 1980).

Keen applies the term DSS “to situation where a ‘final’ system can be developed only through an adaptive process of learning and evolution.” Thus, he defines a DSS as the product of a developmental process in which the DSS user, the DSS builder, and the DSS itself are all capable of influencing one another, resulting in system evolution and patterns of use (Keen, 1980).

In a more precise way, Turban defines it as "an interactive, flexible, and adaptable computer-based information system, especially developed for supporting the solution of a non-structured management problem for improved decision making. It utilizes data, provides an easy-to-use interface, and allows for the decision maker's own insights." (Turban, 1995).

4. Intelligent DSS and Applications

The remarkable advances in intelligent technologies have made an intense impact on most of the technologies including decision support technologies (Jain, 2007).

A regular decision support system helps decision-makers to manipulate data and models. It does not play the role of an intelligent assistant to the decision maker. Recently, many improvements have been noticed in the DSS field, with the inclusion of artificial intelligence techniques and methods, as for example: knowledge bases, fuzzy logic, multi-agent systems, natural language, genetic algorithms, neural networks and so forth. The new common denomination is: Intelligent Decision Support Systems – IDSS (Ribeiro, 2006).

Intelligent decision support systems are interactive computer-based systems that use data, expert knowledge and models for supporting decision-makers in organizations to solve complex, imprecise and ill-structured problems by incorporating artificial intelligence techniques (Ribeiro, 2006).

The inclusion of Artificial Intelligence (AI) technologies in DSS is an effort to develop computer based systems that mimic human qualities, such as approximation, reasoning, intuition, and just plain common sense. The use of IDSS is intended to improve the ability of operators and decision-makers to better perform their duties and work together.

An increasing number of DSS include domain knowledge, modeling, and analysis systems to provide users the capability of intelligent assistance. Knowledge base subsystems are being used to formulate and model the problems, analyze and interpret the results. The knowledge-based Intelligent DSS include a knowledge management component which stores and manages a new class of emerging AI tools such as machine learning and case-based reasoning and learning (Klein & Methlie, 1995). These tools can extract knowledge from previous data and decisions which give DSS capability to support repetitive, complex real-time decision making. Machine learning refers to computational methods/tools of a computer system to learn from experience (past

examples), data and observations, and consequently adjust their behavior, prompted by a modification to the stored knowledge. Artificial neural networks and genetic algorithms are the most widely used techniques for machine learning. Thus an Intelligent DSS has the capability to capture, refine, store and apply the knowledge to support effective decision making.

Many of the models, algorithms and knowledge-based reasoning capabilities that have been generated through artificial intelligence (Firebaugh, 1988) research have led to important contributions to the intelligent systems. Other algorithmic work generated out of systems engineering research, such as data mining, data fusion, decision analysis (Raiffa, 1968), and optimization techniques (Hiller & Liberman, 1986) have also contributed greatly.

5. IDSS : A Framework

There are three fundamental components of a DSS (Andrew, 1991).

- *Database Management Subsystem*: It includes a database which contains data that are relevant to the class of problems for which the DSS has been designed and Database Management System (DBMS) which is a software that manages the database. A DBMS can be interconnected with data warehouse and/or data marts of the organisation. A DBMS separates the users from the physical aspects of the database structure and processing. It should also be capable of informing the user of the types of data that are available and how to gain access to them.
- *Model Management Subsystem*: The role of MBMS is analogous to that of a DBMS. It includes a modelbase which contains financial, statistical, management science and other models that provide DSS with analytical capabilities. It also includes Modelbase Management System (MBMS) that manages the modelbase. The purpose of an MBMS is to convert the data from the DBMS into information by applying models to it. Since many problems that the user of a DSS will cope with may be unstructured, the MBMS should also be capable of assisting the user in model building.
- *User Interface Subsystem*: It covers all aspects of communication between a user and different components of DSS. As their users are often managers who are not computer-trained, DSSs need to be equipped with intuitive and easy-to-use interfaces. These interfaces aid in model building as well as interaction with the model, such as gaining insight and recommendations from it. The primary responsibility of a user interface is to enhance the ability of the system user to utilize and benefit from the DSS.

Besides the above mentioned components, an Intelligent DSS has a Knowledge Management Subsystem.

- *Knowledge Management Subsystem*: Once the information is identified, collected, and managed, it must be transformed into knowledge. This requires classification, analysis, and synthesis which require human intervention. Knowledge cannot be created by technology. Only a human being can render information into a format that causes it to be easily transformed into knowledge by another human being upon retrieval. Hibbard & Carrillo warn against harvesting all existing information or knowledge without knowing whether it will pay off (Hibbard & Carillo, 1998). Since all knowledge is not relevant to the business ventures at hand, some mechanism must exist to filter the unnecessary and non-relevant knowledge (Lubit, 2001). Various tools and technologies that transform and filter the information/ knowledge for this phase of the knowledge management process include Data Mining, OLAP, Machine Learning, and Artificial Intelligence.

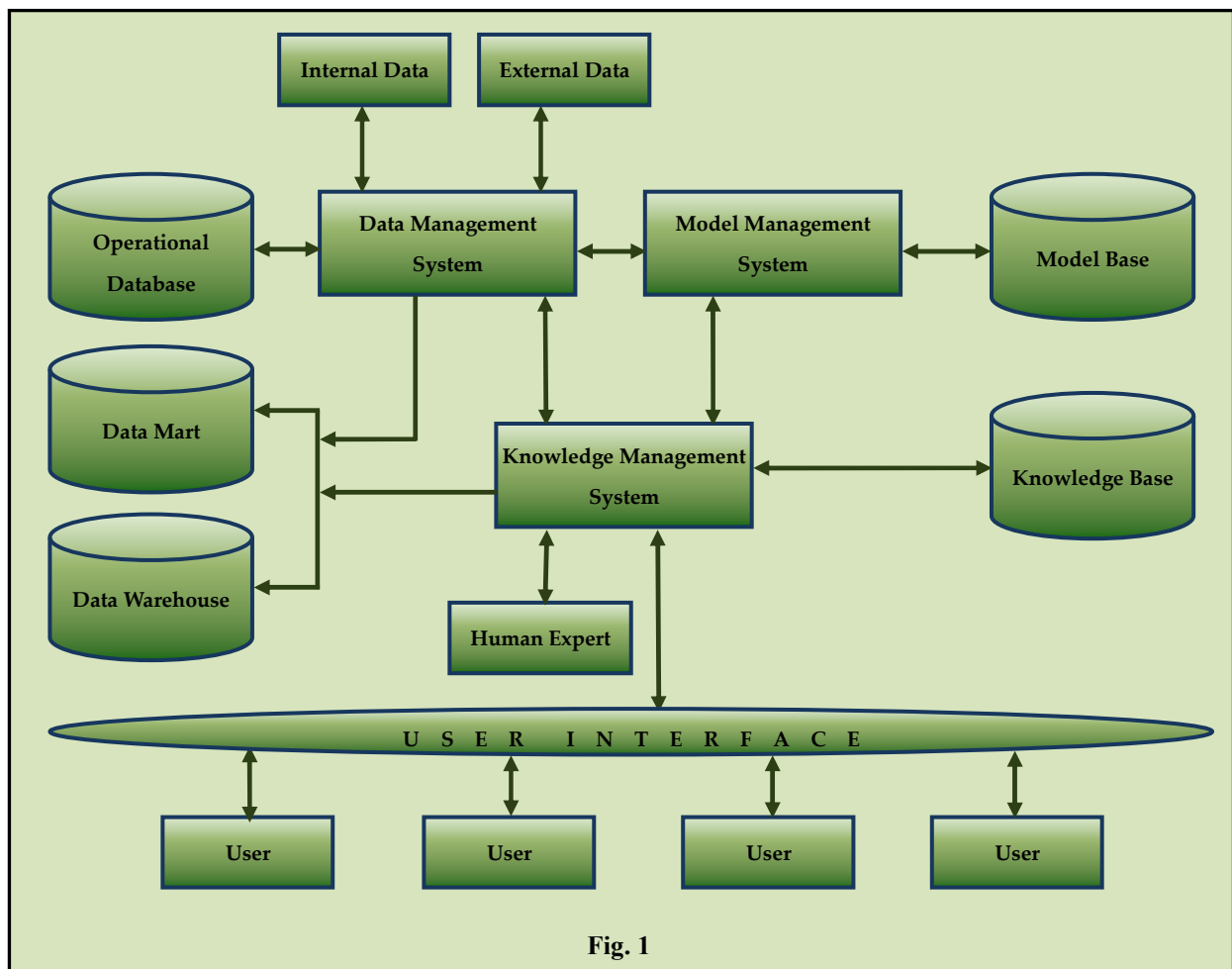


Fig. 1

As shown in fig.1, there are different sources of information/knowledge which can be broadly classified as internal and external. Internal sources include operational database, data warehouse, data marts and humans working in an organization. While as external sources include suppliers, customers, competitors, government agencies, internet etc.

6. Tools and Technologies

Various tools and technologies that can help in capture, transformation, storage and dissemination of information/knowledge are discussed below.

Document Management System: Documents are vital part of any organization. It has been estimated that 94 percent of all business information is stored on paper (Ziming & Stork, 2000). Tidd suggests that successful knowledge management is critically dependent on successful document management, since a significant amount of the information captured and shared is in some form of text-based document (Tidd, 2000). Locating and updating information in that format is a great source of organizational inefficiency.

Internet: As on today, it is estimated that there are over 8 billion indexed web pages, and thousands of newsgroups and forums, on the Internet - covering virtually every topic. To take advantage of the potential opportunities of the Internet, both Web site developers and users need to be aware of the tools and techniques for managing and retrieving online knowledge.

This has driven the development of improved search and information retrieval systems. However, we now need sophisticated information extraction capabilities to present the user only with the information they need, rather than a large set of documents to read.

A popular method for finding Internet resources is through directories, search engines and web mining. Directories allow a user to manually browse a hierarchy of categories to find appropriate Web sites. Search engines take a user's query and automatically search their database to return matching results. Web mining is the application of data mining techniques to discover patterns from the Web. Web mining can be divided into three different types, which are Web usage mining, Web content mining and Web structure mining.

Operational Database: Operational database is main source of data/information. Database is collection of

related files. Data Base Management System (DBMS) is software that manages data in a database.

Data Warehouse: Due to globalization and rapid technological advancement, competition among companies is becoming more intensified. The key to success in this competitive environment is quick and effective decision making. This fast growing demand to analyze business information has quickly led to the emergence of data warehousing (Finnegan, et al., 1999). Data warehouse is a copy of transaction data specifically structured for query and analysis and is informational, analysis and decision support oriented, not operational or transaction processing oriented (Kimball, 1996). The data warehousing technologies, if implemented properly can assist organizations in reducing business complexity, discovering ways to leverage information for new sources of competitive advantage, realizing business opportunities, and providing a high level of information readiness to respond quickly and decisively under conditions of uncertainty (Love, 1996) (Park, 1997).

Data in a data warehouse is subject-oriented, integrated, time-variant, and non-volatile. Populating a data warehouse from internal sources like operational database and external sources requires transformations of the data before it can be loaded into the data warehouse. This transformation process is called ETL and performs the following functions:

- **Extraction:** During data extraction data is acquired from multiple sources including the operational systems well as from external sources. The selected data is consolidated and filtered out from non-relevant data.
- **Transform:** It validates and cleans up the extracted data to correct inconsistent, missing, or invalid values. Data transformation integrates data into standard formats and applies business rules that map data to the warehouse schema.
- **Load:** It loads the cleansed data into the data warehouse/data mart.

Data Mart: these are small localized data warehouses, created by different departments or divisions to provide their own decision support activities. To avoid the risk of failure, huge investment, certain companies invest in data marts for a few functional areas like marketing or finance instead of a full-fledged data warehouse. There are some companies that select both data warehouse as well as specialized data marts which significantly reduce the query complexity and query response time.

Tools for extraction/transformation of knowledge from Information include:

Artificial Intelligence (AI): Knowledge management has a natural relationship with artificial intelligence (AI) methods and software. Artificial intelligence (AI) focuses on automating knowledge processes. It encompasses the use of smart systems that apply knowledge to solve problems for and instead of humans. Many efforts are being done in the field of artificial intelligence relating to knowledge engineering, tacit-to-explicit knowledge transfer, knowledge identification, understanding and dissemination. Examples of such knowledge-based systems (KBS) are IDSS and expert systems. These were devised as problem solving systems long before the term KM became popular (Hasan, 2003). Neural networks are major development by AI researchers. The most important feature of neural networks is their ability to learn from noisy, distorted, or incomplete data (Glorfeld & Hardgrave, 1996).

AI techniques (such as neural networks, genetic algorithms, data mining, expert systems, case-based reasoning, fuzzy logic, and intelligent agents) have different purposes. Data mining and neural networks focus on discovering knowledge while as expert systems and fuzzy logic focus on knowledge in the form of rules. Genetic algorithms main objective is to discover optimal solutions for problems.

Knowledge Discovery in Databases (KDD): KDD can be defined as the non-trivial extraction of implicit, previously unknown, and potentially useful information from databases. Knowledge discovery is an area of research that amalgamates several disciplines, including statistics, databases, artificial intelligence, visualization and parallel computing (Wu, 2004). Since knowledge is the end product of a data-driven discovery (Piatetsky-Shapiro & Frawley, 1991), a well-accepted approach of the KDD process consists of several steps (Fayyad, 1996), (Roiger & Geatz, 2003). Data Mining constitutes one step in the KDD process. It is in data mining step that the actual search for patterns of interest is performed. It is important at this stage to choose the appropriate data mining algorithm (neural networks, linear/logistic regression, association rules, etc.) for the data mining task. The data mining task itself can be a classification task, linear regression analysis, rule formation, or cluster analysis (Imberman & Susan, Dec 2001). Data mining searches for relationships and global patterns that exist in large databases but are 'hidden' among the vast amount of data, such as a relationship between temperature of a room and the productivity of an employee. These relationships represent valuable knowledge about the database and the objects in the database relating to an organization or the internal or external environment. The mining process begins with the raw data and terminates with the extracted knowledge.

Multidimensional Data Analysis: Also called *Online Analytical Processing* (OLAP), which is a function of business intelligence software that enables a user to easily and selectively extract and view data from different points of view. OLAP is software for manipulating multidimensional data from a variety of sources stored in data warehouse/data marts. The software can create various views and representations of the data. It also allows

business analysts to rotate that data, changing the relationships to get more detailed understanding of company information.

Knowledge Repository: The created knowledge must be stored for future use and sharing within the organization. They are collection of both internal and external knowledge and seek to capture both tacit and explicit knowledge.

Dissemination/Sharing: It includes the process of accessing data, formatting and delivery of information/knowledge for decision making. By giving employees access to each other, rather than going through vertical channels of upper management, those with the most current knowledge can share it with those who will benefit most from it (DeTienne & Jackson, 2001). This improves the organization's ability to make rapid decisions and execute them effectively.

The preferred type of data visualization is graphical representation. The user can combine different representation of data and different views of the same data set. Although many knowledge and information work applications have been designed for individuals working alone, organizations have an increasing need to support people working in groups. The key technologies that can be used for group coordination and collaboration: e-mail, teleconferencing, data conferencing, videoconferencing, groupware, and intranets. Groupware and intranets are especially valuable for this purpose. A few of these are discussed below as:

Collaboration Technologies: The internet and its derivatives, intranet and extranets, are the platform on which most communications for collaboration occur. The internet or web, a network of computer networks, supports inter-organizational decision making through collaboration tools and access to data, information, and knowledge from inside and outside the organization. Intra-organizational networked decision support can be effectively supported by an *intranet*, basically an internal internet. It allows people within an organization to work with Internet tools and procedures. Specific applications can include important internal documents and procedures, corporate address lists, e-mail, tool access, and software distribution. An intranet operates safely behind a company's *firewall*, which isolates it from inappropriate external access. *Extranet* links members of a work group like an intranet from several different organizations. Several automobile manufacturers have involved their suppliers and dealers in extranets to help them deal with customer complaints about their products. Other extranets are used to link teams together to design products, where several different suppliers must collaborate on design and manufacturing techniques.

Groupware: Many computerized tools have been developed to provide group support when users in workgroups or departments need to communicate and collaborate. Groupware provides a mechanism for teams to share opinions, data, information, knowledge, and other resources. Groupware is an important technology for enhancing the exchange of tacit information and knowledge.

There are thousands of packages that contain some elements of groupware. Some have only rudimentary collaboration capabilities, while others provide support for every aspect of collaboration (full electronic meetings with videoconferencing). Almost all utilize internet technology for the consistent Web browser-style user interface and communication protocols.

Groupware typically supports at least one of the following: electronic brainstorming, electronic conferencing or meeting, group scheduling, calendaring, planning, conflict resolution, model building, videoconferencing, electronic document sharing (e.g., screen sharing, white boards, or live boards), voting, and so on.

An Electronic Meeting System (EMS) is a form of groupware that supports anytime/anyplace meetings. Group tasks include, but are not limited to, communication, planning, idea generation, problem solving, issue discussion, negotiation, conflict resolution, system analysis and design, and collaborative group activities such as document preparation and sharing.

Web Portal: Sharing information/knowledge on the Web through a portal is gaining considerable momentum. Web-based portals are becoming commonplace as a single personalized point of access for key business information. Various data visualization tools are integrated into web portal for ease of access including:

Balanced Scorecards: The balanced scorecard help the users to put the strategy into practice by providing and measuring performance as compared to the organization's objectives, giving feedback and serving as an indicator of overall organizational efficacy. The balanced scorecard typically includes four different performance classifications: financial perspective, customer perspective, internal business processes, and learning and growth, or the development perspective (Anon., 2008); (Garrison, et al., 2008).

Dashboards: Dashboard system applications have been known in organizations for several years. A dashboard is a visual display of the most vital information needed to achieve one or more objectives, combined and organized on a single screen so that information can be monitored at a glance. Research indicates that dashboards are now about to become more widespread, not only in numbers but also in terms of application areas e.g., (Eckerson, 2006)(Few, 2006) (Malik, 2005).

Dashboards are aimed at helping to visualize large amounts of data in a condensed representation in a user

interface which puts together and shows information in an easy and intuitive manner. They provide a quick overview of organizational processes and supports managers in their decision-making tasks.

7. Conclusion

Decision making tasks are subject to certain limitations as they depend on human knowledge, experiences, judgments and preferences. Intelligent DSS can be used to deliver realistic and reliable decisions, besides to improve the effectiveness of decision making processes. IDSS use a number of approaches and techniques from simple data reporting tools, to sophisticated AI systems using Bayesian statistics or genetic algorithms for decision support tasks. They assist decision makers in high level phases of decision making by integrating human knowledge with modeling tools. These systems remain a tool that can provide companies with a sustainable competitive advantage. This paper discusses DSS, Intelligent DSS, framework of IDSS and related tools and technologies of IDSS.

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