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Chapter 2 - Knowledge-based Decision Support Systems

2.1 Knowledge-based Decision Support Systems, Decision Support Systems and Expert Systems

It is impossible to make good decisions without information. Harbridge House in Boston, MA (Turban et al 2001) conducted a survey to determine the importance of certain management practices and the performance level of management in these practices within a company. They included 6500 managers of more than 100 companies in the survey. "Making clear-cut decisions when needed" was ranked as the most important management practices. Ranked second in managerial importance was "getting to the heart of the problems rather than dealing with less important issues". Most of the remaining eight management practices were related directly or indirectly to decision-making. In the survey, only 10 percent of the managers thought that management performed "very well" at any given practice. The participants accredited this to the difficult decision-making environment and the fact that the trial-and-error method is expensive and ineffective. Using models when making decisions would reduce costs and make the trial-and-error process more effective (Mallach 1994).

Processing information manually while making decisions is becoming increasingly difficult because of the following trends (Turban et al 2001):

- Advances in communication, accessibility to global markets, the use of the Internet and electronic commerce (EC) increase the number of alternatives involved in a decision
- Many decisions need to be made within a time constraint: To process the needed information efficiently and effectively is not possible if done manually
- Information technology (IT) and the sophisticated analysis that it provides becomes a factor in making a good decision, and
- Rapid access to remote information such as consulting experts or providing a group decision meeting is often necessary

On the contrary, conventional computer programs are completely inflexible in responding to unexpected situations and lack the judgement humans possess, to make decisions in situations deficient in information. Modelling is an important feature of Decision Support Systems (DSS) (Turban 1995) (See Figure 2-3, p13). DSS provides the framework that allows decision-makers to view alternatives and make good decisions.

When experiencing a problem in a specific problem domain, a decision-maker normally consults a specific domain expert to assist him in his decision-making process. An expert is a person who has specific knowledge and experience in a problem area, who has acquired his expertise usually over

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several years. Expertise is the extensive, task-specific knowledge acquired from training, reading about and experience in a specific domain (Turban et al 2001). The less structured the problem domain, the more specialised and expensive the advice of the expert becomes. When solving complex problems, expertise enables experts to make better and faster decisions than non-experts.

Intelligent Systems describe the various applications of Artificial Intelligence (AI) (Turban et al 2001). Applications of Intelligent Systems include Expert Systems (ES), natural language processing (NLP), speech understanding, robotics and sensory systems, fuzzy logic, neural computing, computer vision and scene recognition, and intelligent computer-aided instruction. Expert Systems (ES) is one of the sub-disciplines of AI that is used and applied more than any other AI technology (Turban et al 2001). An intelligent decision support system (IDSS) or knowledge-based decision support system (KB-DSS) includes an Expert System (ES) as one of the main components (Klein & Methlie 1995). This component supplies knowledge of special interest using artificial intelligence (AI) (Turban et al 2001) to the decision support system user. The ES component provides us with:

- A system, which can simulate reasoning, and
- A system that can explain its reasoning and conclusions

ES is therefore ideal to assist a decision-maker in an area where expertise is required (Turban 1995). An ES' knowledge is stored in electronic format and called upon whenever the need for information arises. The basic idea behind ES is the transferring of knowledge from an expert to the computer to the user or knowledge worker or decision-maker. Like a human expert, the ES advises non-experts and explains the logic behinds its conclusion (Turban et al 2001).

2.2 Decision Support Systems (DSS) and Knowledge-based Decision Support Systems (KB-DSS)

Decision support is a context-free expression. It means different things to different people. There is no universally accepted definition of DSS (Turban 1993). Decision Support Systems exist to help people make decisions. DSS do not make decisions by themselves (Mallach 1994) but attempt to automate several tasks of the decision-making process of which modelling is the core (Turban et al 2001). At the heart of DSS lie decisions and decision-making. To comprehend DSS a person needs to understand the process of making decisions. In this paragraph, a summary of the most important DSS and decision concepts is presented. The terms used are explained in Chapter 5 (p74).

2.2.1 Decisions

Simon (1960, 1977) first recognised two polar types of decisions and named them programmed and non-programmed decisions. Finlay (1994), Mallach (1994) and Turban (1993, 1995 and 2001) referred to it by using alternative terms: structured, semi-structured and unstructured (See Paragraph 5.1.2: p74).

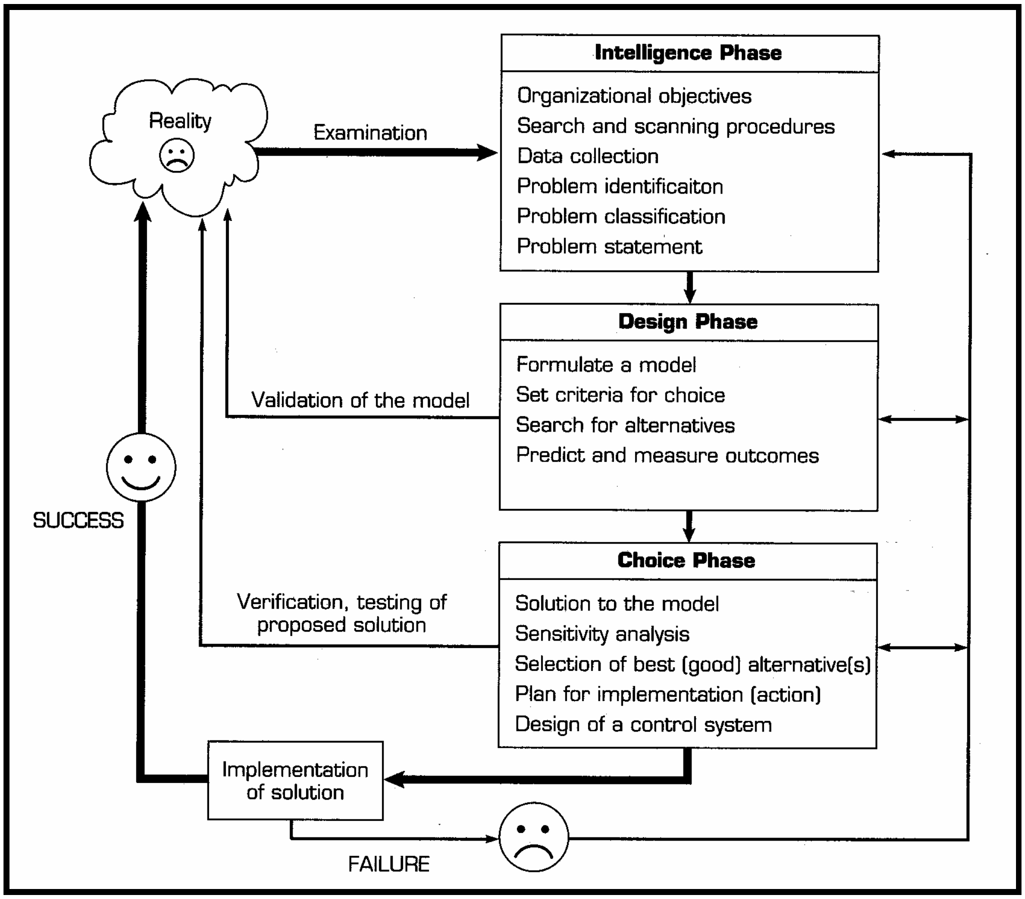

Figure 2-1 The Decision-making/Modelling Process (Turban 1995; Turban et al 2001)

Simon (1960, 1977, and referenced by Turban et al 2001) propose a four-phase model:

1. Intelligence
2. Design
3. Choice, and
4. Implementation

Finlay (1994) refers to the implementation phase as the review phase. Turban (1995) and Finlay (1994) slightly extended and modified the models (See Figure 2-1 and Table 2-1: p9).

In the case study (See Paragraph 4.4: p53), various factors come into play when a student decides his courses for the coming year or semester. These factors include

- Course availability during the semester for registration
- A suitable timetable period match
- Fairly structured prerequisites for the subject
- Other factors such as the student's preferences and talents, and
- Demands of the industry with respect to the knowledge and skills required

Some of these factors are not easily quantifiable and so the decision would be classified as semi-structured.

Table 2-1 Phases and Stages according to Finlay's (1994) model for problem tackling

Phases	Stages
Structuring	Problem detection Problem definition
Understanding	Detailed systems design Exploring courses of action Decision taking
Action	Implementation of change Review

♦ Human decision-making processes

In order to automate assisting humans in decisions, one should keep in mind that people are not entirely rational (Turban 1993). The way that people react to problems, the way they perceive problems, their values and beliefs may cause people to make decisions differently (Turban 1993). Different psychological personality types exist. These personality types play an important role in the decision making process. When presented with all the facts, the ways that people approach decisions are influenced by preference as determined by their personality type. Knowing the personality type of the decision-maker will help design appropriate tools to support that person (Mallach 1994). Huitt (1992), as referenced in Mallach (1994) summarises the preferred decision-making techniques of the eight personality types in Table 5-1 (p80). To be useful, a decision support system should include some of a decision-maker's preferred decision-making techniques.

▪ The Kepner-Tregoe process

When being presented by a multi-attributed problem, it is difficult to choose the best alternative because not all attributes can be optimised simultaneously. Eliminating some of the inferior alternatives by ranking the alternatives in order of importance can simplify the decision-making. Systematic decision-making ensures that all aspects of the decision-making receive consideration. Before using computers, a process aiming to improve the human decision-making was the Kepner-Tregoe process (K-T method). The following stages (Mallach 1994) were proposed as part of the decision-making process:

- State the decision purpose
- Establish objectives
- Classify the objectives by their importance
- Generate alternatives
- Evaluate the alternatives against their objectives
- Make a tentative choice
- Assess its potential adverse consequences, and
- Make a final choice

♦ **Decision-making and models**

Decision-making often involves the exploration of situations that do not yet exist. Analysing such situations requires a model or abstraction of reality rather than reality itself. A model is a simplified representation or abstraction of reality (Mallach 1994; Turban et al 2001). Models are used to portray the important aspects of reality while eliminating other aspects, which cause difficulties in a particular situation. Models make the structure of the problem explicit. Examining a simple model may show general principles of how the system in question behaves and may lead to a deeper understanding of the problem. This behaviour might be hidden behind the mass of details resulting from a more complex model. A simple model can be included in a more complex model and it may be a good starting point even if the objective is to a build a more complex model of the system. Building a simple model may clarify and illustrate the process of modelling the type of system stated as the objective (Mallach 1994).

Turban et al (2001) and Mallach (1994) provide extensive lists of benefits gained when presenting a problem by using a model. These benefits are listed in Paragraph 5.2.1 (p81). Turban et al (2001) further classifies models as being **iconic**, **analogue**, **mathematical** and **mental.** Mallach (1994) classifies models into **graphical**, **narrative, physical** or **symbolic** models (See Paragraph 5.2.2: p82).

2.2.2 Using information technology (IT) to support decision-making

The alternatives amongst which a decision must be made can range from a few to a few thousand. The decision-maker needs to narrow the possibilities down to a reasonable number. Decision support, such as a selective information retrieval system can help with this task. Computers can evaluate alternatives, especially where the alternatives can be put into numerical terms. Even when this is not the case, the computer can assist the decision-maker in presenting the alternatives in a form that facilitates the decision (Mallach 1994). If decision-making involves a group of people, group DSS ensures that the members of the group are trying to decide the same thing. Decision support tools such as electronic mail can help people from different locations to communicate about a joint decision statement.

Many activities are involved with decision-making. To support these activities, systems must be able to include one or more of the following (Finlay 1994):

- Help to detect existing or incipient problems
- Help to model a problem situation in order to clarify it
- Provide the tools so that options can be considered, and
- Help with implementation of change and its review

An important key to the success of Information Technology (IT) is the ability to provide users with the right information at the right time (Turban et al 2001). Decision Support covers all areas of Information Systems (IS) including programming languages, database, networking and systems analysis. DSS brings all these technologies together for a specific type of application. Every information system has decision support aspects.

Four information technologies have been successfully used to support managers or decision-makers (Turban et al 2001):

- DSS that primarily supports analytical and quantitative types of decisions
- Executive information systems (EIS), which supply information and have lately been expanded to include analysis and communication tools to decision-makers
- Group Decision Support Systems (GDSS) or Group Support Systems (GSS) for group decision support, and
- Intelligent support systems that provides expert knowledge via an expert component to optimise a decision

Collectively the above-mentioned systems are known as Management Support Systems (MSS) and can be used independently or combined, each providing a different capability. Computerised aids that can assist a decision-maker are shown in Figure 2-2 (p12). One example of a set of decision aid tools available for managers to be more organised is the Personal Information Manager (PIM). These tools can play an extremely important role in decision support (Manheim 1989, in Turban et al 2001) by providing facilities through which the user can increase his effectiveness.

2.2.3 The initial Decision Support System concept

Making good informed decisions is one of the tasks managers engage in (Turban et al 2001). Anthony (1965) categorised managerial activities into strategic planning, management control and operational control. This is referred to as the scope of decision-making (Mallach 1994; See Paragraph 5.1.3: p74). The type (structured to less structured) and scope of a decision are related. In general, operational decisions tend to be more structured and strategic decisions less structured.

Earlier definitions of DSS classified DSS as systems that support managerial decision-makers in semi-structured decision situations, extending their capabilities but not replacing them. Judgement was required in the decision-making. Pure algorithms could not replace these decisions. Early definitions implied that the system should be computerised, on-line and have some graphic output capabilities (Turban 1993; Shim et al 2002). Turban (1995) summarises the concepts underlying DSS definitions as given by various authors in Table 2-2 (p12). Gorry and Scott-Morton (1971) integrated Simon's (1960, 1977) decision types with Anthony's (1965) levels of management activities to form the original DSS concept or framework (Shim et al 2002).

The concepts in Table 2-2 (p12) are converse and collectively they ignore the central issue in DSS namely the support and improvement of decision-making. Turban (1995) states it is far more beneficial to rather deal with the characteristics and capabilities of a DSS (See Figure 2-3: p13). He formulates his working definition by defining a range of basic DSS to an ideal DSS as

> ”At minimum we can say: A DSS is an interactive, flexible and adaptable CBIS (Computer Based Information System), specially developed for supporting the solution of a particular management problem for improved decision-making. It utilises data, it

provides a user-friendly interface and it allows for the decision-maker's own insights. The most sophisticated DSS definition will add to this: DSS also utilises models (either standard and/or custom-made), it is built by an iterative process (frequently by end-users), it supports all the phases of the decision making, and it includes a knowledge base".

Table 2-2 Concepts underlying DSS definitions (Turban 1995)

Source	DSS defined in Terms of
Gorry and Scott-Morton	Problem type, system function (support)
Little	System function, interface characteristics
Alter	Usage pattern, system objectives
Moore and Chang	Usage pattern, system capabilities
Bonczek et al.	System Components
Keen	Development process

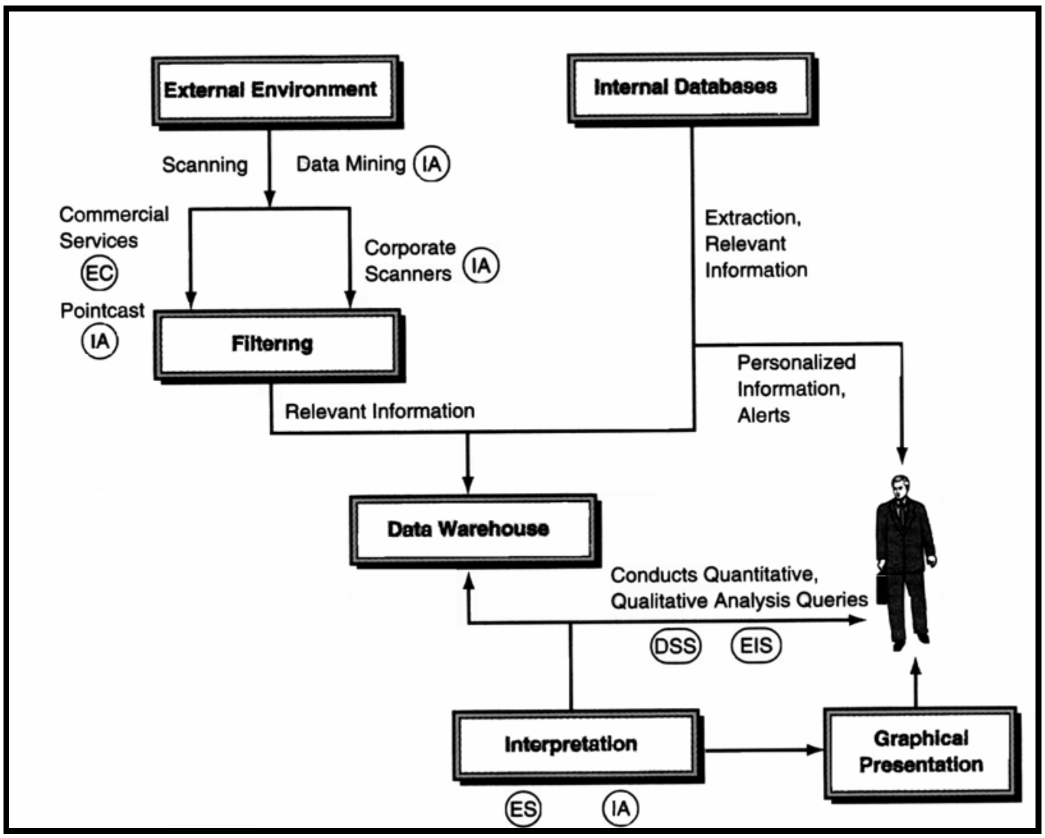

Figure 2-2 Computerised support (MSS) for decision-making. IA - Intelligent Agents, ES= Expert Systems, EC = Electronic Commerce, DSS = Decision Support Systems, EIS = Executive Information Systems (Turban et al 2001)

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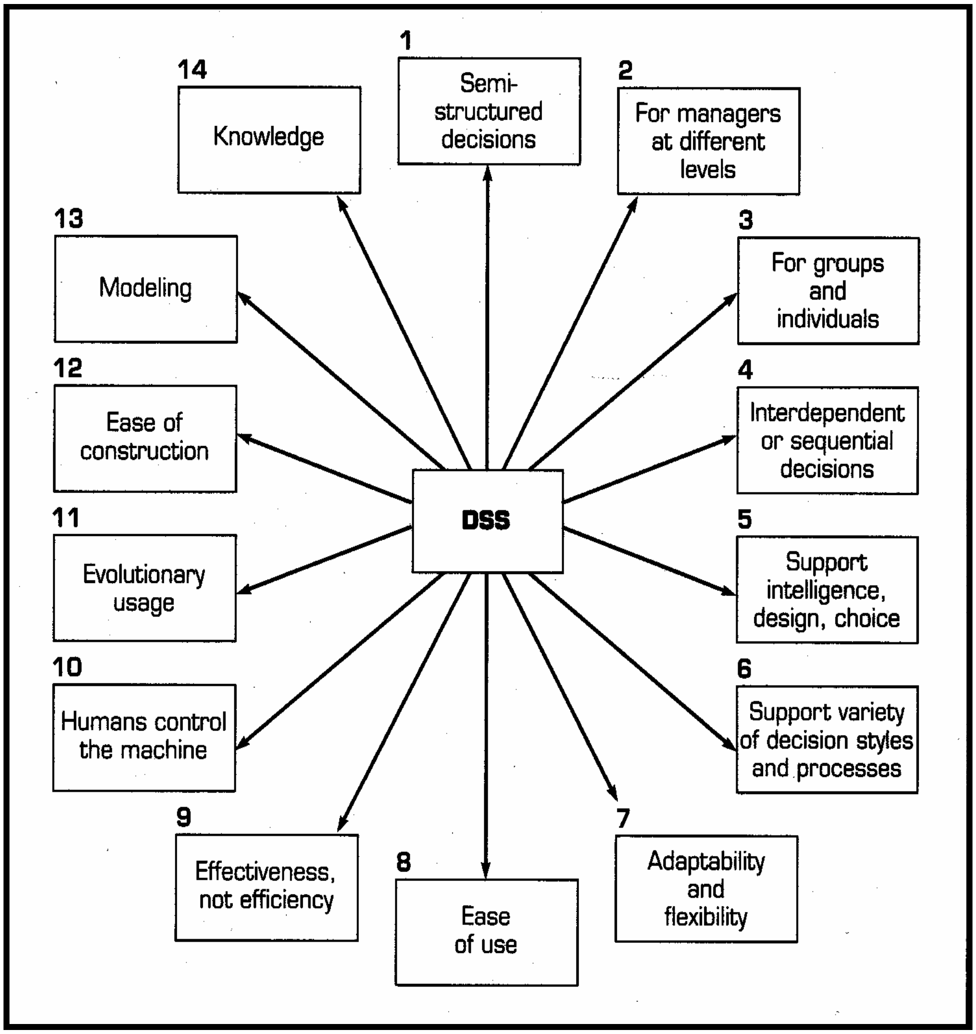

Figure 2-3 The characteristics and capabilities of DSS (Turban 1995)

Turban et al (2001) explores a framework (See Figure 2-4: p14) to determine the decision support needed. This framework was first proposed by Gorry and Scott-Morton (1971) and is based on the combined works of Simon (1960; 1977): the type of decision (programmed to non-programmed or well structured to ill structured), and Anthony (1965): the three broad categories of managerial activities (Strategic, management and operational control). The technologies supporting the various decision types and managerial control are indicated.

2.2.4 The customary decision process in a DSS environment

The process of a more customary-used decision-making model as used in a DSS environment is shown in Figure 2-5. The emphasis of this customary model is on the problem analysis and model development. Once the problem is recognised, it is defined in a way compatible with model creation. Models are used to analyse the various alternatives and the choice made and implemented as described by Simon (1960, 1977). These phases overlap and blend together and have frequent iterations to previous phases as the problem is understood and chosen solutions fail (Shim et al 2002).

	Type of Control			
Type of Decision	Operational Control	Managerial Control	Strategic Planning	Support Needed
Structured	1 Accounts receivable, order entry	2 Budget analysis, short-term forecasting, personnel reports, make-or-buy analysis	3 Financial management (investment), warehouse location, distribution systems	MIS, Management science models, Financial, Statistical
Semistructured	4 Production scheduling, inventory control	5 Credit evaluation, budget preparation, plant layout, project scheduling, reward systems design	6 Building new plant, mergers and acquisitions, new product planning, compensation planning, quality assurance planning	DSS
Unstructured	7 Selecting a cover for a magazine, buying software, approving loans	8 Negotiating, recruiting an executive, buying hardware, lobbying	9 R & D planning, new technology development, social responsibility planning	DSS ES Neural Networks
Support Needed	MIS, Management science	Management science, DSS, EIS, ES	EIS, ES, Neural Networks	

Figure 2-4 Decision support framework showing the technology to be used (Turban et al 2001)

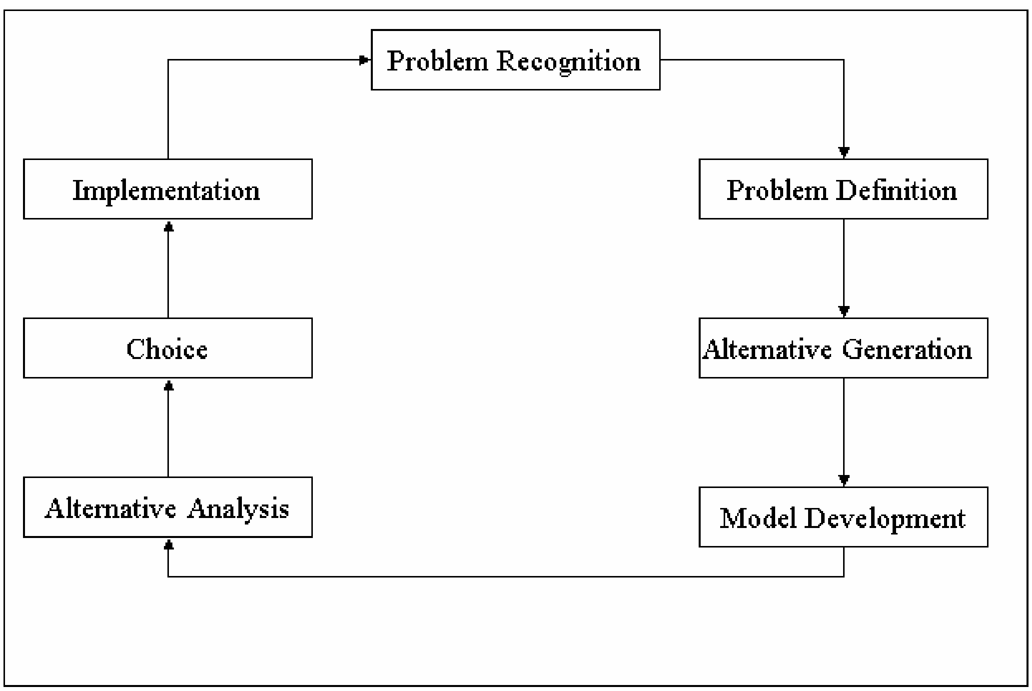

Figure 2-5 The DSS decision-making process (Shim et al 2002)

2.2.5 Classifications of Decision Support Systems

The varieties of DSS are overwhelming. It ranges from a single user spreadsheet to a multi-user database to Internet-based DSS that uses re-usable agents (Bui & Lee 1999). DSS differ in their scope, the decisions they support and the people that use the DSS (Mallach 1994). Finlay (1994) states two important reasons why DSS should be classified into types. The ways in which DSS are developed differ markedly depending on the type of DSS. His second reason states that the classification provides a framework for research. Without this classification or framework, it is impossible to communicate the results and findings about such disparate types effectively and without this communication the understanding of the factors of importance will be inhibited (Mallach 1994). A DSS, which has as major component a logical model, is likely to be developed by people with different skills rather than a DSS where the major component is a data model. The interaction of the user and the developer will be diverse.

Alter (1980) compared different types of DSS and placed all DSS in one of seven categories. He classified the DSS by the type of operation the DSS performs. Mallach (1994) refers to these categories as different levels of DSS. The seven levels of categories (See Paragraph 5.3.3: p84) are:

- File drawer systems
- Data analysis systems
- Analysis information systems
- Accounting models
- Representational models
- Optimisation systems, and
- Suggestion systems

Finlay (1994) classifies these levels into Management Information systems (MIS) or Management Intelligent Systems (MINTS) depending whether the DSS deals with information (MIS) or with intelligence (MINTS). MIS is generally more context independent, compared to the use of MINTS that heavily relies on the context. MIS is concerned with efficiency (doing the thing right) while MINTS is concerned with effectiveness (doing the right thing) (Finlay, 1994; See Paragraph 5.3.3: p84).

2.2.6 Architecture of a DSS

A decision support system is a specific type of information system that consists of many parts (Mallach 1994; Turban 1993; Turban et al 2001):

- **Data management subsystem:** A DSS uses one or more data stores (databases, sets of files and/or data warehouses) to provide relevant information to the Decision Support System. Some of them are maintained by the DSS itself and some are external data sources. Some database primarily used and maintained by another information system with its own database management system (DBMS) and some DSS applications may have no separate DSS database. The data are entered into the DSS as needed.

- **Model management subsystem:** This subsystem is a software package that includes and manages quantitative and qualitative models. Quantitative models provide the system's analytical capabilities.
- **Dialogue subsystem** or **user interface:** The DSS communicates with the decision-maker via this subsystem. The user supplies information to the DSS and commands the DSS using this subsystem. The information supplied determines what data need to be extracted from the data sources. , and
- **Knowledge management subsystem:** This optional subsystem can support any of the other subsystems or act as an independent component. It provides knowledge for the solution of the specific problem.

The above components are considered to constitute the software portion of the DSS, the final part being the decision-maker himself. A conceptual model of DSS as represented by Turban (1995; Turban et al 2001) and is shown in Figure 1-1 (p3). The components are put together by programming them from scratch or by gluing them together from existing components, or by using comprehensive tools called DSS generators (See Paragraph 3.1.3: p32).

♦ Data management subsystem

Data for DSS may be acquired from various **internal**, **external** and **personal** sources (Turban 1995) as well as from **commercial** databases and as **collected raw data** (Turban et al 2001; See Paragraph 5.4.1: p90)

♦ Model management subsystem

A distinguished characteristic of DSS is the inclusion of a modelling capability (Turban 1995). The DSS analysis is executed on a model of reality, rather than reality itself. A model is a simplified representation or abstraction of reality (Turban 1995; Mallach 1994), which has advantages such as lower cost of experimentation, compression of time, manipulation of the model itself, lower cost of error, reinforcement of learning and enhanced training (Turban 1995). To take reality to only mean that which presently exist is limiting. Some DSS tools exist to explore situations that do not yet exist. To include such tools as models, reality should include that which could come about in future (Finlay 1994).

Turban (1995) categorises DSS models further into seven groups (See Paragraph 5.4.2: p91):

- Complete enumeration – few alternatives
- Optimisation via algorithm
- Optimisation via analytical formula
- Simulation
- Heuristics
- Other descriptive models, and
- Prescriptive models

According to Turban (1995), the model management subsystem should include the following elements:

- Model base
- Model base management system
- Modelling language
- Model directory, and
- Model execution, integration and command

The model base contains statistical, financial and other quantitative models that provide analysis capabilities. The ability to invoke, run, change, combine and inspect models is what differentiates a DSS from a computer-based information system (CBIS). Models play a significant role in DSS. Models can be of various types as discussed in Paragraph 5.4.2 (p91). Models need to be managed. Software similar to a DBMS called model base management software manages all the models in DSS. A DSS may include several models as standard or free-standing software interfacing with the DSS. Mathematically based DSS still constitutes the majority of applications.

Modelling in Management Support Systems may involve non-quantitative (qualitative) models. In many cases these models can be presented in terms of rules. Non-quantitative modelling can be done separately or in combination with quantitative modelling. In some cases it is possible to transform, qualitative measures to quantitative ones by assigning values in a certain range for example one to 10 to qualitative values (Turban 1995).

♦ Dialogue subsystem or user interface

This subsystem is the key to successful use of the DSS. Various interface modes exist which determines how information is displayed and used. Graphics are especially important for problem solving, because it helps decision-makers visualise data, relationships and summaries. The User Interface Management System (UIMS) or Dialogue Generation Management Software (DGMS) is a component of the DSS that accommodates the various information representations. It is the DGMS' responsibility to provide and interface between the user and the rest of the DSS.

The important capabilities of a DGMS, as listed by Turban (1993), should include some of the following:

- Interact several different dialogue styles
- Capture, store and analyse dialogue usage (tracking), used to improve the dialogue system
- Accommodate the user with various input devices
- Present data with a variety of formats and output devices
- Give users help capabilities, prompting, diagnostic and suggestion routines, or other flexible support
- Provide user interface with data base and model base
- Create data structures to describe outputs
- Stores input and output data

- Provide colour graphics, three-dimensional graphics and data plotting
- Include different windows to allow multiple functions to be displayed concurrently
- Provide training by examples, and
- Provide flexibility to accommodate different problems and technologies

The main task of the DGMS is to transform the input from the user into languages that can be read by the DBMS and MBMS and to translate output from the DBMS and MBMS and knowledge management subsystems into a form that can be understood by the user (Turban 1993)

♦ Knowledge management

This is an optional subsystem and can support any of the other subsystems or act as an independent component. Complex DSS systems may require an additional component that provides expertise to the decision-maker. Knowledge management software provides a structure to execute and integrate one or more Expert Systems with the operation of DSS components. DSS that includes such a component is called an intelligent DSS, a DSS/ES or a knowledge-based DSS (Turban 1995). It acts as a consultant as it advises and explains to non-experts.

A knowledge subsystem comprising of all the relevant rules governing the possible course combinations of a given degree will be an integral part of the student DSS (See Paragraph 4.4: p53). Holsapple & Joshi (2001) view the knowledge system as well as the problem processing system as key DSS components. The knowledge system holds representations of descriptive, procedural and/ or reasoning knowledge and the problem processing system solves and recognises problems in a decision making process by drawing knowledge from the knowledge representations of the knowledge system. They view decision making as a prime knowledge management application and state that "DSS is a computer-based technology that aims to get the right knowledge in the right form to the right persons at the right time so they can better make decisions and make better decisions".

2.2.7 The future of DSS

Technological developments continually allow for DSS tools that are more effective: disk storage, interactive operating systems, enabled spreadsheets, databases and flexible modelling tools (Courtney 2001). Networks and telecommunications enabled group support and Executive Information Systems (EIS). Expert Systems theory and technology enabled knowledge-based DSS. The Internet and the Web fostered the development of globally connected organisational decision environments and may in future develop technical, organisational, personal and ethical perspective decision support. The web can be used to broaden organisational decision-making and facilitate communication among a variety of stakeholders (See Paragraph 5.7: p103).

Shim et al (2002) expresses that: "In future, mobile tools, mobile e-services and wireless Internet protocols will mark the next set of remarkable developments in Decision Support Systems (DSS), expanding the accessibility of tools to decision-makers where-ever they might be." Mobile tools will play a major role in developing e-commerce as customers will access e-services equally through their cellular phones and their personal computers (Earle & Keen 2000).

Shim et al (2002) calls the database capabilities, the modelling functionality and the interface design components of the DSS, the classic tool design components of DSS. He adds tools such as data warehousing, on-line analytical processing, data mining and web-based DSS as important tool developments for future DSS. These tools together with collaborative support systems, virtual teams, knowledge management optimisation-based DSS and active decision support are important topics in the development of the DSS concept for the this millennium.

DSS will exist in future. It will be more accessible to the global decision-maker because of the popularity of the Web. Instead of using a complete DSS application or DSS generator, the user might seek the integration of DSS tools or models that ate part of different DSS using mobile technologies (Shim et al 2002).

2.2.8 Summary

As stated in Paragraph 2.2.1 (p7) the student DSS (See Paragraph 4.4: p53) is semi-structured and will include a knowledge subsystem (See Paragraph 2.2.6: p15) maintainable by course administration experts.

2.3 Expert Systems (ES)

An expert system's major objective is to provide expert advice in specialised situations. An ES application makes inferences and arrives at conclusions (Turban 1995) while a DSS provides an environment to assist a user to reach conclusions (See Paragraph 2.2: p7; Chapter 5: p74). An ES component is ideal to assist a decision-maker in an area where expertise is required (Turban 1995).

2.3.1 Definitions of Expert Systems

According to Olson and Courtney (1992) ES are computer programs within a specific domain, involving a certain amount of AI to emulate human thinking in order to arrive at the same conclusions as a human expert would. Expert Systems can deal with incomplete and uncertain data in reaching conclusions and incorporates an explanation for its reasoning process. Turban et al (2001) define ES as computer advisory programs that attempt to imitate the reasoning processes of experts in solving difficult problems. ES has the ability to perform at the level of an expert, representing domain specific knowledge, in the way an expert thinks.

The value of ES as a sub-discipline of AI can be appreciated more when compared to natural intelligence. Kaplan (1984) as referenced by Turban et al (2001) gives commercial advantages that AI has over natural intelligence (See Paragraph 6.1: p107). Advantages and disadvantages of using ES are given in Paragraph 6.1.2 (p111).

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ES is appropriate for a limited number of problem domains (Raggad & Gargano 1999; Mallach 1994; Goodall 1985). ES is appropriate when systems:

- Are concerned with judgements
- Have no attempt of mathematical representation, and/or
- Have no traceable paths from inputs to conclusions

2.3.2 Architecture of an ES

The important components (See Paragraph 6.2.2: p113) of an ES (Goodall 1985; Turban et al 2001) are:

- **A dialogue structure**: Access to the ES is obtained via natural language or using a predefined syntax. The knowledge worker provides some information to the ES and receives the ES' conclusion and explanation.
- **A knowledge base**: Obtaining knowledge from experts can be a cumbersome task. Methods include manual, semi-automatic and automated acquisition. Knowledge representation is important and crucially affects the ease and speed with which the inference engine can use it. Deep and surface knowledge are identified (See Paragraphs 6.2.2: p113 and 6.4.1: p123). Knowledge can be formulated using formal theories or normative models. The forms of knowledge representation often used are:
    - Rules
    - Semantic nets
    - Frames, and
    - Cases
- **An inference engine:** The inference engine is activated when the user initiates a consultation session. Three basic techniques are identified when inferring facts or conclusions from the knowledge base:
    - Forward chaining
    - Backward chaining, and
    - Hybrid using both forward and backward chaining
- **A blackboard**: It involves an architecture that allows the independent knowledge sources to communicate. Turban et al (2001) describes the blackboard as a kind of database that an area of working memory set aside for the description of the current problem, the input and the intermediate results.
- **An explanation sub-system**: This is a by-product of the inference engine that provides a trace of the rules fired, and
- **A knowledge refining system**: Having the expert system evaluate and analyse the reasons for failure or success and learning from it will greatly enhance ES. This functionality is currently being developed in experimental ES.

The process of ES is divided into a development process and a consultation process (See Paragraph 6.2.3: p121) and is presented in Figure 2-6.

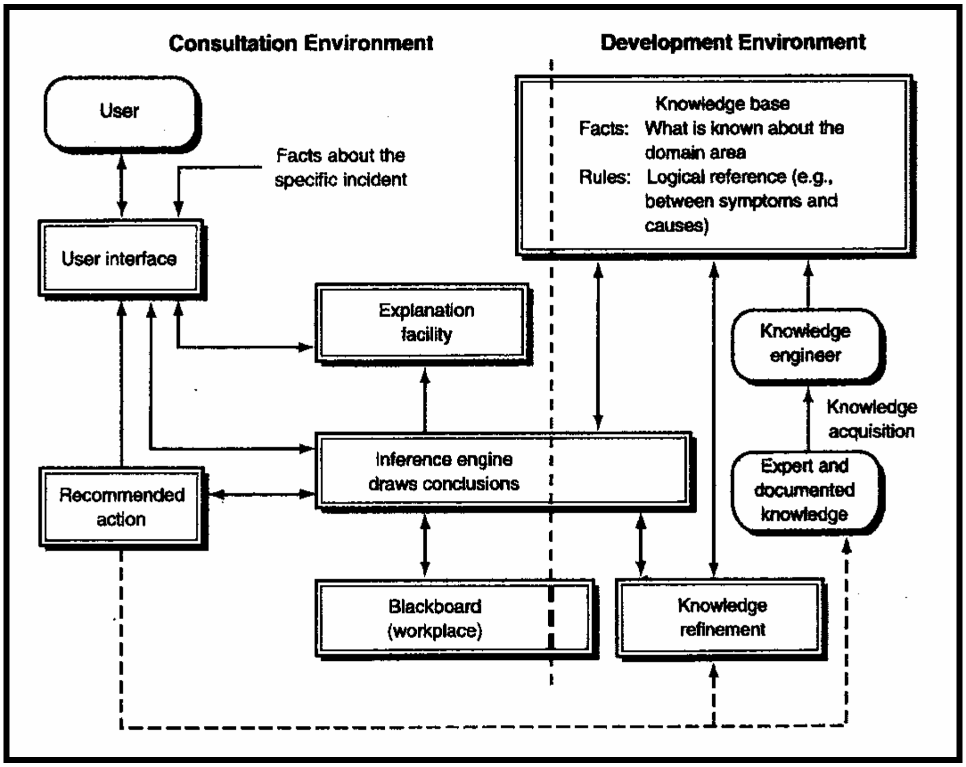

Figure 2-6 Structure and process of an expert system (Turban et al 2001)

2.3.3 ES and ES Shells

Construction time of an ES can be reduced by using an ES shell (Beynon-Davies 1991). A shell is the explanation and inferencing mechanisms of the ES only, stripped from its knowledge (Turban 1995).

The architecture of an ES Shell includes (Beynon-Davies 1991):

- A knowledge base that serves as a repository of rules for domain-specific knowledge
- An inference engine that drives the system in making inferences using the knowledge in the knowledge base
- Development tools that assists in building and testing the knowledge base, mainly used by the knowledge engineers
- A working memory, which is the data area where partial results of the problem being solved are stored, and
- A user interface where the user interacts with and executes the ES: One of the most important parts of the user interface of the ES is the explanation facility

All ES Shells include these five components. Some ES includes one other component such as the knowledge acquisition component to impart the expertise of the domain expert to the system directly

(Beynon-Davies 1991). When using an ES shell, the shell design limits the way the resulting ES operates. Often the problem domain is more complex than what the shell can support. A complex problem need to be built from scratch using programming languages such as PROLOG, LISP or JESS. This option is time consuming, because a complete new ES system and structure needs to be designed. Figure 2-7 illustrates the architecture of an ideal expert system shell.

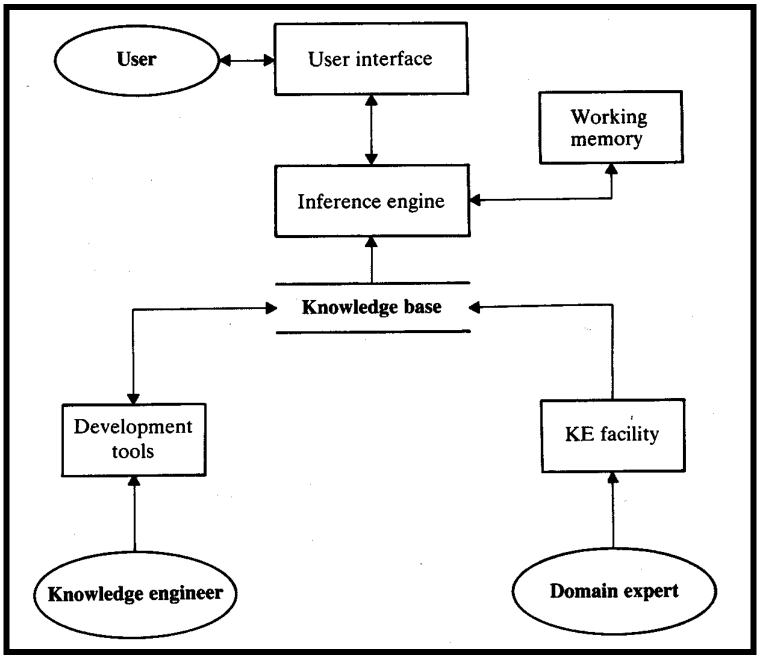

Figure 2-7 Expert shell architecture (Beynon-Davies 1991)

2.3.4 Knowledge acquisition and knowledge base construction

The quality of knowledge contained in the knowledge base determines the effectiveness of the ES. Knowledge engineering is the process of selecting the correct action recommendations and applying the best judgements for a specific situation. High degrees of complexities need to be coped with.

2.3.5 The future of ES

The term Expert Systems has been replaced by Intelligent Systems in publications.

2.3.6 Expert Systems and the Internet/Intranet

One of the justifications of building an ES is to provide expert knowledge to a large number of users. The widespread availability and use of the Internet and Intranets provide the opportunity for ES to be disseminated to mass audiences (Turban et al 2001).

ES can be transferred over the Web not only to human users but also to other computerised systems including DSS, robotics and databases. ES can even be constructed using the Web. Intranet-based GroupWare can facilitate the process of collaboration between builders, experts and knowledge engineers. Knowledge maintenance can also facilitate the use of the Net, which is useful to users

(Turban et al 2001). The Web can support the spread of multimedia-based Expert Systems. These systems also called *Intelimedia systems* support the integration of extensive multimedia applications and ES.

2.4 Knowledge-based Systems or Intelligent Support Systems

The paradigm of DSS is to *support* decision-making as shown in Figure 2-8 (p23). Knowledge-Based DSS (KB-DSS) integrate traditional DSS with the advances of ES. Traditionally DSS constitute data management, modelling, decision methodology and display of numerical data, while the advances of ES embrace symbolic reasoning and explanation capabilities (Klein & Methlie 1995).

The knowledge-based systems development methods in decision support evolved in a new generation of decision support tools known as Intelligent Decision Support Systems (ISS). Decision support systems can assist managers in making strategic decisions by presenting information and interpretations for various alternatives. Three important approaches in the development of current business DSS providing interpretation of knowledge are (Pal & Palmer 2000):

- Rule-based reasoning (RBR)
- Case-based reasoning (CBR), and
- Hybrid (a combination of RBR and CBR)

Each of the above-mentioned approaches focuses on enriching some of the aspects of the traditional knowledge-based business DSS.

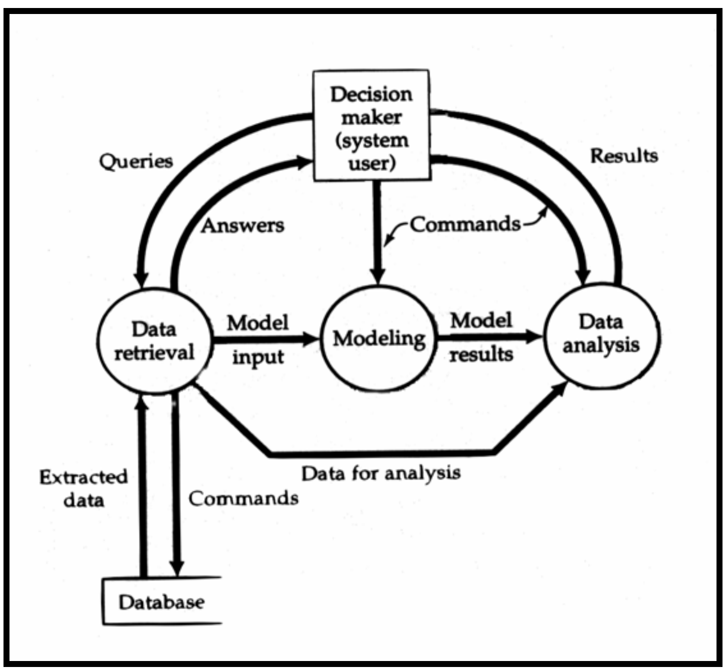

Figure 2-8 Data flow diagram of a generic DSS (Mallach 1994)

Klein & Methlie (1995) describe different directions in extending the DSS framework with ES:

- **Expert advice in a specific problem domain:** When assisting the user to define concepts, compute procedures, run decision models and present reports, a DSS usually does not provide the user with expert advice too. Adding an expert function will provide the DSS user with an expert assistant that could present conclusions or advice that may or may not be followed by the user. This capability requires a knowledge base of domain knowledge and a separate reasoning mechanism that offers expert assistance as part of the DSS.
- **Explanation of the conclusion of the expert:** A good DSS should improve the learning process of the user. The explanation facility of the ES will:
    - Cause the user to have more faith in the result and more confidence in the system.
    - Present the assumptions underlying the system explicitly, and
    - Enable quicker systems development, because the system will be easier to debug
- **Intelligent assistance to support the decision analysis methodology:** Decision analysis is a powerful aid in helping individuals to face difficult decisions. A knowledge base with methodological knowledge can assist the decision-maker to:
    - Define a decision model or an influence diagram
    - Assess a probability distribution, and
    - Assess value functions
- **Explanation of model results and/ or model behaviour:** A complex database may exist for even a simple problem. An expert system can explain the usual logical structure of the models themselves and the causal relationships amongst the variables in the models. Models may be quantitative or qualitative and may perform comparative evaluation of situations. An ES can explain the evaluation algorithm. It can comment on "what-if" scenarios and highlight trends and changes to variables.
- **Assistance when using statistical, optimising or other operations research techniques:** The expert system can:
    - Guide a novice user in using the tools properly
    - Help the user learn good strategies for using the tools, and
    - Discover domain knowledge from large databases
- **Guidance in using the DSS resources: developing intelligent user interfaces**. When a DSS becomes institutionalised in a company or organisation, the number of databases, decision models and reports can increase considerably. When time or money constraints cause difficulties for users to be trained, some kind of expert assistance to select the appropriate resources can be useful. The intelligent user interface can help the user select and use the resources of the system properly.
- **Assistance in formulating certain questions:** An ES can assist a user in formulating his request when the user is confronted with large databases and complex relations, and
- **Intelligence support during the model building process for a specific class of decisions:** An expert system can be used in the process of constructing analytical models. An intelligent component can

- Act as an expert modelling consultant
- Acquire the simulation model specifications
- Automatic document the models in domain terms, and
- Automatically write, compile and solve models

As the decision-making task is performed, expertise in the form of knowledge bases and reasoning and explanation capabilities are applied to specialised problems requiring expertise for their solutions (Klein & Methlie 1995).

2.4.1 The functions of a KB-DSS application

KB-DSS can provide (Klein & Methlie 1995):

- An interface to support man-machine co-operation during the problem-solving task
- Supporting access to relevant information during problem solving
- Support problem recognition
- Support problem structuring
- Support problem formulation and analysis
- An inference engine and knowledge based management systems to provide expert assistance to the user, and
- A reasoning algorithm included in the modelling subsystem

Various knowledge bases can assist the DSS in different domains related to the task to be supported by the application. A functional analysis of KB-DSS is given in Figure 2-9 (p26).
A typical interaction of user and the KB-DSS resources is shown in Figure 2-10 (p26).

2.4.2 KB-DSS architecture

A KB-DSS is a DSS with an ES or intelligent component. When adding this feature to Turban's (1995) DSS architecture (See Figure 1-1: p3), the result would be Figure 1-2 (p3). Figure 2-9 (p26) shows the various components of a KB-DSS. A KB-DSS environment is needed that facilitates communication between the expert module and the traditional modules of the DSS development tool. Full communication and integration is required between the models in the DSS and the knowledge base (KB) (Klein & Methlie 1995). The rules in the database need information from the variable values from the models in order to reach an informed conclusion. The transfer of information between the resources and the application file is given in Figure 2-11 (p27).

Klein & Methlie (1995) claim the KB-DSS environment gave way to new capabilities such as:

- Coupling a causal model's deep knowledge with the expert system's shallow symbolic knowledge, and
- Developing intelligent user interfaces that assist in selecting available resources or interaction with models

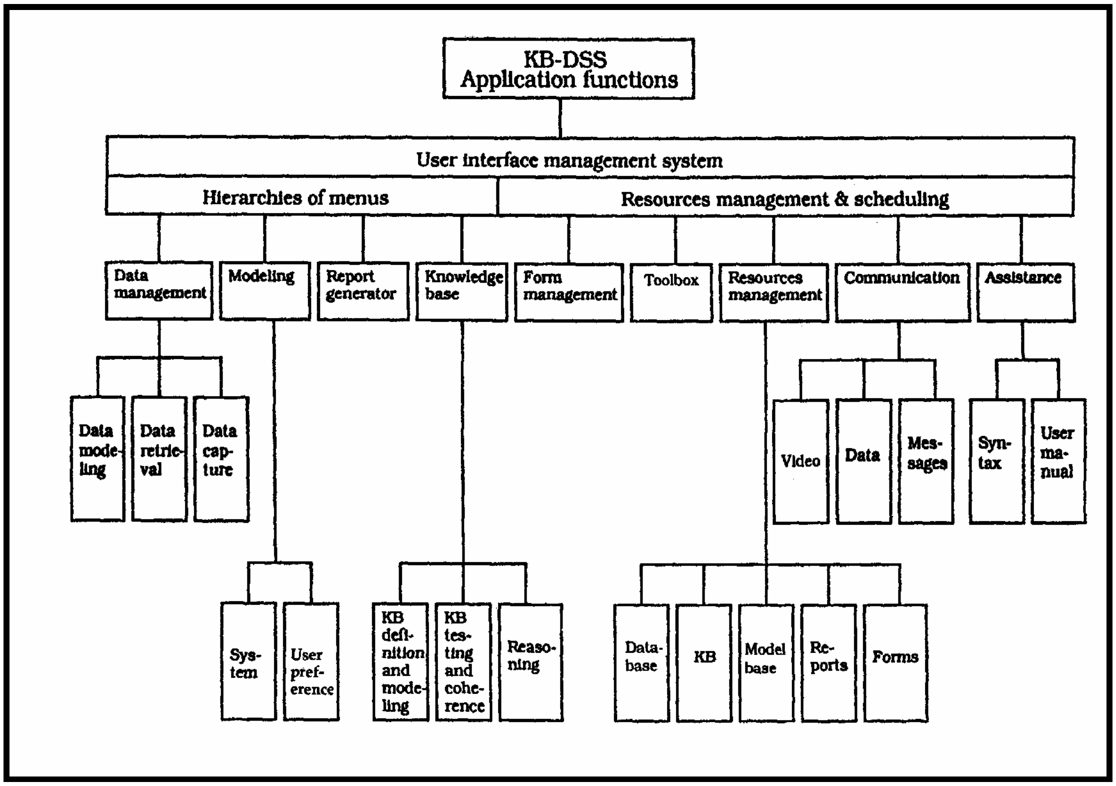

Figure 2-9 Functional analysis of a KB-DSS application (Klein & Methlie 1995)

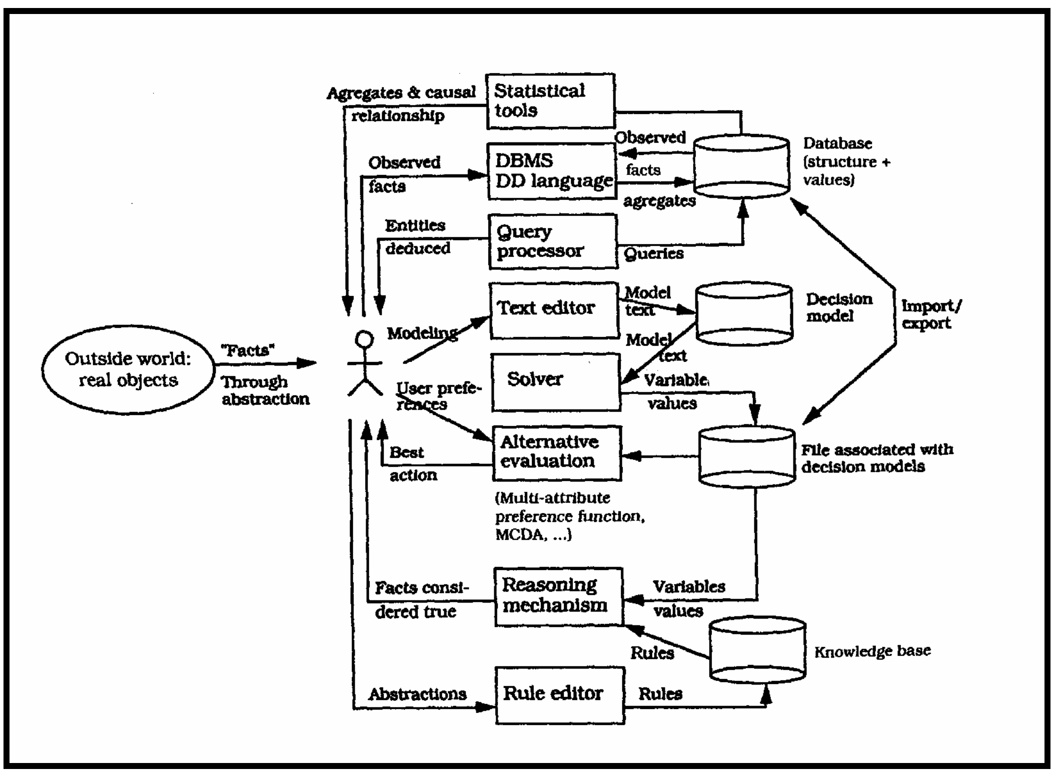

Figure 2-10 Interaction between the user and the KB-DSS resources (Klein & Methlie 1995)

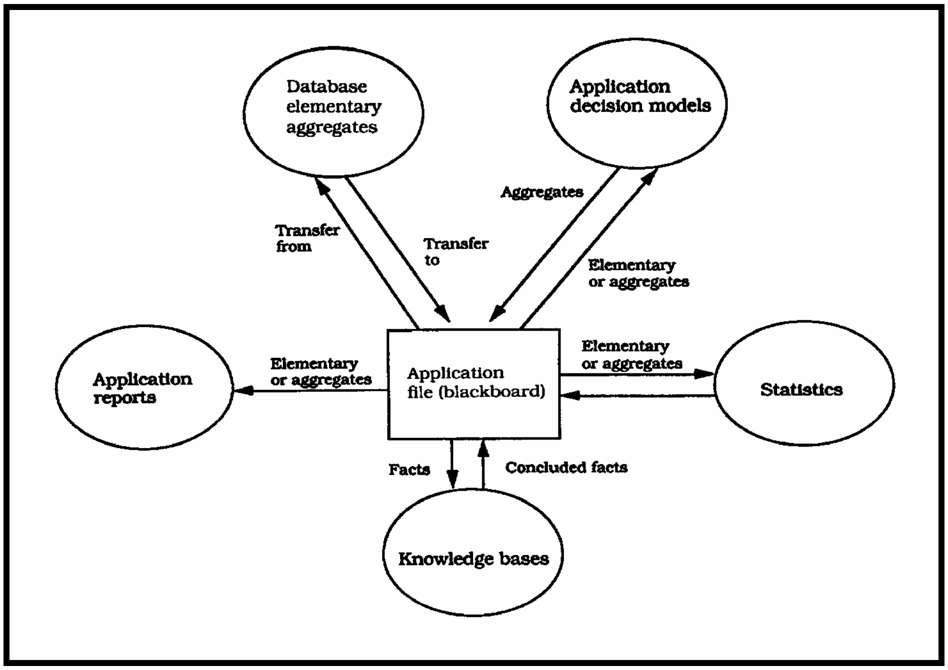

Figure 2-11 Transfer of information between resources and the application file (blackboard) (Klein & Methlie 1995)

2.5 Confirming the Intelligent Systems approach

Bielawski & Lewand (1991) summarise their characteristics of a suitable intelligent system as follows:

- The problem is cognitive (as opposed to computational):
  - It may require reasoning with uncertain or incomplete data, and
  - It does not require common-sense reasoning
- The scope of the problem is manageable:
  - It can be precisely articulated, and
  - Its domain is narrow and specific
- Resources for problem-solving exist:
  - At least one expert in the area exists
  - The expert is willing and able to contribute to the project, and
  - If more than one expert is involved, all must agree on an approach to the problem's solution, and
- The problem is worth solving if it:
  - Results in a saving of time
  - Enhances productivity
  - Reduces physical risk to workers
  - Propagates knowledge
  - Preserves endangered knowledge, and
  - Assures consistence

The advice problem seems to suit a knowledge-based approach, to be modest in scope and has experts willing to co-operate in the process. The completed system will benefit the university by:

- **Increasing productivity**: Departmental personnel will be freed of most of the queries from students regarding their subject choices, leaving them to focus on other aspects of their work
- **Propagating knowledge**: Students and newly appointed staff can obtain the expertise from the system in following certain scenarios
- **Preserving knowledge**: Knowledge attained by experience can be built into the knowledge component, and
- **Assuring consistency**: when advising students the intelligent system has no favouritism of any form or any inconsistencies. The criteria used are included in a knowledge base and the system accesses it to present the most suitable advice.

The advice problem has various components interacting with each other. The necessary information e.g. courses passed by the student may either be entered or obtained from existing information systems. As an integrated system, the advice system aims to provide concrete information and recommendations to the student by supporting him in his decision to choose the correct courses to enrol for in the coming year or semester.

2.5.1 Type specifying the Advice System

Mallach (1994) compares different information systems (IS) in Table 2-3. The characteristics of Transaction Processing Systems (TPS), Information Reporting Systems (IRS) and Decision Support Systems (DSS) are presented.

Table 2-3 Information System Characteristics (Mallach 1994)

Table of Information System Characteristics

System Charcteristic	*Transaction Processing Systems*	*Information Reporting Systems*	*Decision Support Systems*
User community	Clerical and supervisory	Supervisory and middle management	Individual knowledge workers, all management levels
Usage volume	High	Moderate	Moderate to low
Database usage	Some reading, heavy updating	Read-only	Primarily read-only
Typical software base	Third-generation languages	3rd and 4th generation languages	Specialized languages, packages
Emphasis on ease of use	Low	Moderate	High
Emphasis on processing efficiency	High	Moderate	Low
Reason for development	Cost savings, customer service	Reporting requirements, basic information for decision making	Improved decision-making effectiveness

The different components comprising a context-specific DSS have been discussed in Paragraph 2.2.6 (p15). This information system's characteristics at this early stage seem to include the need for information from the university's database to assist the student in his/her decision-making. The aim of the system would be to improve the student's decision-making effectiveness. Because the knowledge workers are students, the emphasis on ease of use should be high. Since this program will only be used a few times by each student, the processing efficiency could be low. The usage volume would be relatively low and the database usage primarily read only. The typical software base would be specialised, probably specially developed. Students as individual knowledge workers would access this package to aid them in their decision of courses.

In a wider perspective, other types of information systems include (definitions by Mallach 1994):

- **Office Information Systems** (OIS), which improves the efficiency and effectiveness of handling information (words, images, schedules and so forth) in an office
- **Executive information syst**ems (EIS), from which the top management of an organisation can obtain information to guide its decisions (This makes them a type of DSS)
- **Personal information systems** developed and used by one individual (often known as end-user computing) to improve his personal productivity and effectiveness. This effectiveness can involve decision-making. A personal information system used for this purpose is a DSS too.
- **Work group information systems**, used to improve communication and co-ordination within members of a group who collaborate on a set of joint tasks
- **Expert Systems**, which follows rules similar to that of a human used to reach a recommendation or conclusion from available data. If the rules are similar and a human being follows it to reach a decision, an expert system can be a DSS also. , and
- **Strategic Information Systems** (SIS), through which an organisation can obtain a competitive advantage over its rivals, or prevent its rivals from obtaining a competitive advantage over it

Based on the above definitions, the advice system could be a DSS with an expert component. Further investigations will be conducted as to what type on information system would best suite the advice application. Mallach (1994) states: "A decision support system is an information system whose primary purpose is to provide knowledge workers with information on which to base informed decisions." He also distinguishes the following themes that are present in all DSS:

- DSS are information systems (IS). All the basic principles of IS apply to DSS
- Knowledge workers use DSS – most definitions call them managers
- DSS are used in making decisions and therefore impacts organisations using them, and
- DSS support does not replace people. Some human review is necessary. If not, the system will not be classified as a DSS.

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Most DSS definitions include the following themes:

- DSS are used in unstructured or semi-structured decisions. The degree of structuredness of a decision was defined in Paragraph 5.1.2 (p74). Most decisions require human judgement.
- DSS incorporate some sort of database (collections of data). Decisions are based on information, often extracted from a database. , and
- DSS incorporate some models. Models represent reality. In DSS, models are used to investigate the impact a decision might have.

DSS may have secondary incidental features or by-products such as reports and other conventional data processing aspects. All types of information systems are related to decision support. A DSS is a system built with decision support as its primary intent. The spectrum of DSS and other information systems are presented in Figure 2-12.

Information systems may be involved in decision support in two ways: as an information system with decision support capabilities or as a decision support system that have decision support as its primary task. The advice system's primary purpose is to provide decision support to students (the knowledge workers).

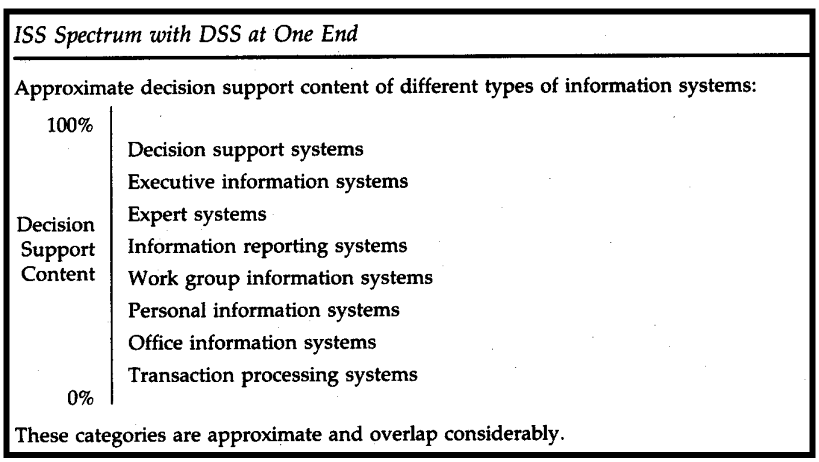

Figure 2-12 IS decision support spectrum (Mallach 1994)

2.6 The future of DSS, ES and KB-DSS

For management to obtain maximum benefit from its investment in information systems, DSS, EIS, group DSS and ES can be combined into an integrated whole called a management support system (Mallach 1994), using new technologies as they emerge.

Including an intelligent agent (IA) component in a DSS can greatly increase its functionality (Turban et al 2001). An intelligent agent is a new technology with the potential to perform a set of operations on behalf of the user or another program with a degree of independence or autonomy. According to Turban et al (2001) an agent can "advise, alert, broadcast, browse, critique, distribute, enlist, empower,

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explain, filter, guide, identify, match, monitor, navigate, negotiate, organise, present, query, report, remind, retrieve, schedule, search, secure, solicit, sort, store, suggest, summarise, teach, translate, and watch”.