Chapter 5 - A broader perspective to Decision Support Systems

5.1 Introduction

This chapter presents a broader background into what DSS are and from where they evolved. It also presents definitions of the terms used in Chapter 2: p6. As stated before, the term Decision Support Systems (DSS) is viewed as a context-free expression. It means different things to different people. There is no universal accepted definition of DSS (Turban 1993). DSS attempt to automate several tasks of the decision-making process (Turban et al 2001). Before viewing DSS, decisions and the process of making decisions are investigated.

5.1.1 What is a decision?

A decision is a reasoned choice amongst alternatives (Mallach 1994; Simon 1960). Decision-making is the process of choosing among alternative courses of action, to attain a goal or goals (Turban 1995). Problem solving and decision-making are not viewed as synonyms in the literature. Problem solving is the overall process of closing the gap between reality and a more desirable situation. Problem solving includes the aspect of making decisions. One view is to consider all four phases or steps of Simon's (1960, 1977) model (See Paragraph 2.2.1: p7) as being part of problem solving, and step three as decision-making. Another view is to consider steps one through to three as decision-making, ending with a recommendation. Problem solving additionally includes implementation of the recommendation (Turban 1995).

5.1.2 Types of decisions

Well-structured problems are repetitive and routine. They are easily solved and may be presented by a standard model. The poorly structured problems are new, novel, non-recurrent and difficult to solve (Shim et al 2002). **Semi-structured** decisions have some structured aspects. Most organisational decisions are of this type (Mallach 1994).

5.1.3 The scope of decision-making

Anthony (1965) categorised managerial activities into strategic planning, management control and operational control. Other authors refer to this as the scope of the decision-making process (Mallach 1994). A **strategic** decision will affect the whole company or a major part of it. It will affect the company's objectives and policies. Strategic decisions are generally made by the upper management level of the company. It affects the company for an extended period of time (Antony 1965; Mallach 1994). Strategic decisions tend to be concerned with the levels of resources needed to achieve organisational goals and involve long-term relationships between the organisation and its environment (Finlay 1994).

A **tactical or managerial control** decision will affect how the organisation works for a limited period. These decisions take place within the context of the previous strategic decisions. Middle management is normally involved in tactical decisions (Mallach 1994). Tactical decisions concern activities that have a longer time-span than operational activities. They are primarily concerned with the most appropriate effective use of the resources already available in the company (Antony 1965; Finlay 1994).

An **operational** decision affects activities taking place in the company right now. The tasks, resources and goals of these activities have already been set by other strategic or tactical decisions. It involves the day-to-day well-established procedures (Finlay 1994) or the execution of specific tasks (Antony 1965). The operational decisions made do not have any impact on the future of the company. Lower management or non-managerial personnel are normally involved in operational decisions. Procedures used in operational decisions are classified as routine and information is unlikely to surprise the decision-maker (Mallach 1994).

5.1.4 The decision-making process

Each decision is characterised by a decision statement, a set of alternatives and a set of decision-making criteria. These always exist, though we are not always aware of them (Mallach 1994). Simon (1960) proposed decision-making as a four-phase model: (1) intelligence, (2) design, (3) choice and (4) implementation (Turban et al 2001: Figure 2-1: p8) also called review (Finlay 1994). Intelligence is comprised of the search for problems; design involves the development of alternatives; and choice consists of analysing the alternatives and choosing one for implementation (Shim et al 2002). There is a continuous flow of activities from intelligence to design to choice, but at any phase there may be returned to a previous phase (See Figure 2-1: p8).

Finlay (1994) suggests a slightly modified and extended model to Simons's (1960) model, called problem tackling, consisting of three phases: structuring, understanding and action in seven stages. His model is shown in Table 2-1 (p8). He recognised a backtracking and iteration between his stages.

♦ The intelligence phase or problem detection and definition

The need for a decision is determined in the intelligence phase. Simon (1960) expresses the intelligence phase as "searching the environment for conditions calling for decision". Finlay (1994) defines it as the searching for problems. He calls this the problem detection stage in his model. The decision-maker decides what to decide or formulates the problem that needs a decision. This formulation is called a decision statement or problem statement (Mallach 1994) or the problem definition stage in Finlay's (1994) model. Finlay (1994) states that the problem will be defined once an objective and the associated obstacle have been defined.

A decision statement states what we are trying to decide. A clear decision statement is important to intelligent decision-making. It keeps the decision-maker's thinking focussed clearly on the main subject and away from irrelevant side issues. Every Decision Support System development project should start by gaining a clear understanding of the decisions to be made with the help of the proposed system (Turban 1993).

The term intelligence in the intelligence phase means the gathering of information without knowing the outcome of the decision (Mallach 1994). The modelling process starts here. Turban et al (2001) defines it as the stage where reality is examined and the problem identified and defined. The intelligence phase may involve activities such as problem classification, problem decomposition and determination of problem ownership (Turban 1993).

- **Problem classification**

Two important factors to keep in mind are the scope of the decision and its degree of structuredness. An important classification is according to the degree of structuredness: **structured** vs. **unstructured** (Mallach 1994) or programmed vs. non-programmed (Simon 1960).

Information is the raw material for intelligence. The manager or decision-maker might need assistance to interpret the information in order to include it in his problem situation or scenario (Finlay 1994). Data, information, intelligence and the process whereby these are formed are all aspects of knowledge. Finlay (1994) presents a knowledge model that build a decision-maker's intelligence in order to place the decision-maker in a better position to plan and control his decisions (See Figure 5-1: p77). The scenario sets the context of the evaluation of a decision outcome e.g. worst case, best case and most likely case. This, to a large degree, sets the evaluation criteria used in the choice (Turban 1993). This model is applicable to any type of cognitive system, not just individual and group planning and decision-making (Finlay 1994).

Managers need information almost continuously. Finlay (1994) claims that different information requirements are necessary for the different levels of problems or decision scope. Figure 5-2 (p77) shows the different requirement characteristics at the different levels of decision scope. Most of the dimensions in Figure 5-2 are self-explanatory. The hardness of the information requirements relates to the objectivity associated with the source. It is often the case that hard data is quantitative and written, while soft data tends to be qualitative and verbal.

- **Problem decomposition and ownership**

Problems may be broken down in simpler sub-problems that could be solved individually. This may help to solve the original more complex problem. It is important to establish the ownership of the problem by establishing if the problem is capable of being solved within the organisation or if it is an uncontrollable factor (Turban 1993). The intelligence phase ends with a problem statement (Mallach 1994).

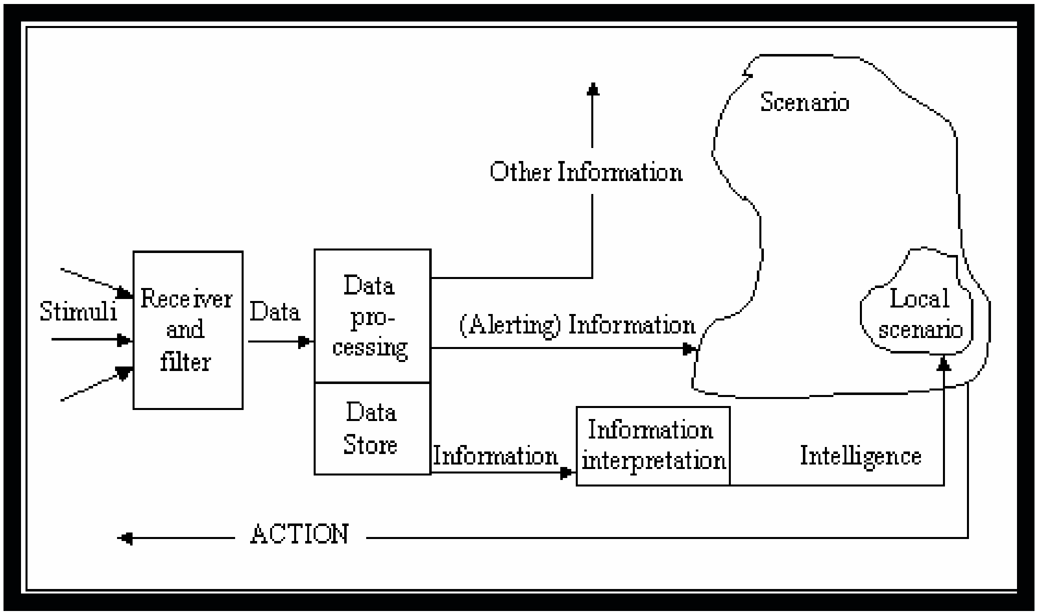

Figure 5-1 A knowledge model of planning and control (Finlay 1994)

Dimension	Operational	Tactical	Strategic
Problem type	Structured	– – – – >	Ill-structured
Time frame	Immediate past	– – – – >	Future
Source	Largely internal	– – – – >	Largely external
Organisation	Tight	– – – – >	Loose
Scope	Detailed	– – – – >	Wide-ranging
Age	Current	– – – – >	Old
Hardness	Hard	– – – – >	Soft
Exactitude	Accurate and precise	– – – – >	Accurate
Expectation	Prescribed	– – – – >	Surprise
Freqency of usage	Often	– – – – >	Infrequent

Figure 5-2 Levels of information Requirements (Finlay 1994)

♦ The design phase

The design phase may involve a great deal of research to determine alternatives or available options that exists (Mallach 1994). Simon (1960) describes this phase as "inventing, developing and analysing possible courses of action". Turban et al (2001) defines this as the stage where a model is constructed and validated and criteria set for the evaluation of potential solutions that are identified. Setting decision-making criteria would assist decision-makers in optimising a decision. Decision-makers can often not define their decision-making criteria precisely. The criteria however exists, even if the user cannot specify them, and should be stated for the decision in question as an outcome of this phase. Creativity should be encouraged in the choice of alternatives (Mallach 1994).

It is in the design phase where models could be built in order to explore alternative solutions (Finlay 1994). Reality is simplified by using models. It involves activities such as understanding the problem. In this phase, a model of the problem situation is constructed, tested and validated. Modelling involves the conceptualisation of the problem and its abstraction to a quantitative and/or qualitative form. In case of a mathematical model, the dependant and independent variables are identified and their relationships established in the form of equations (Turban 1993).

Decision-making includes zones of certainty, risk and uncertainty (Turban 1993). Decision-making under certainty assumes that complete information is available and that the outcome will be deterministic. This occurs most often with structured problems in short time horizons (up to one year). A decision made under risk is also known as a probabilistic or stochastic decision situation. The different types of simulation (See Paragraph 5.4.2: p91) are given, where several possible outcomes may be considered for each alternative, each with a given probability of occurrence (given or estimated). The degree of assumed risk can be calculated. Expected values are calculated and the best alternative chosen. In cases where decisions are made with uncertainty, there are several outcomes for each alternative. The probability of occurrence of the possible outcome is not known and cannot be estimated. This type is more difficult to evaluate. Modelling involves the decision-maker's attitude toward the risk.

♦ The choice phase

In the choice phase all alternatives are searched, evaluated and one chosen as recommended solution (Simon 1960). The solution is tested "on paper" and once the proposed solution seems feasible, the decision can be implemented (Turban et al 2001). The chosen decision is to be carried out. Only if the recommended solution is successfully implemented, the problem is considered solved. The boundary between this phase and the design phase is frequently unclear because of the stating of the alternatives and the evaluation thereof.

The search of an appropriate course of action that will solve the real problem could span several approaches depending on the criteria set. Normative models may use either the analytical (optimal solution) or a complete exhaustive enumeration model. For descriptive models, a limited number of alternatives are used either blindly or by using heuristics. Analytical techniques use mathematical formulas to derive an optimum solution (used for structured problems) or to predict a certain result. Algorithms may be used to assist in increasing the efficiency of the search (Mallach 1994).

When a description of a desired solution is given, a search may be conducted using a goal and search steps. **Blind search** and **heuristic search** may be considered (Turban 1993). **Blind search** is arbitrary and not guided. Two types exist: **complete enumeration**, in which case all alternatives are considered; and **incomplete**, which continues until a good enough solution is found. Blind search is not practical for large problems, because too many nodes must be visited before a solution is found. The limits on the amount of time and computer storage are practical limits to this option. **Heuristics** are decision rules regarding how a problem should be solved (Turban 1993). Rules of thumb are usually developed as a result of trial-and-error. Step-by-step procedures are followed until a satisfactory solution is found. Such a search is much faster and cheaper than a blind search.

Evaluation is the final step that leads to recommendation. Evaluation can be done at the hand of **multiple goals** and **sensitivity analysis** such as **trial-and-error**, **"what-if"-**analysis and **goal seeking** (Turban 1993). In the evaluation of **multiple goals**, it is often necessary to analyse each alternative and its potential impact on several goals. **Computerised models** are used extensively to support multiple goal decision- making (Turban 1993). **Critical Success Factors** (CSF) is a diagnostic technique to identify factors critical to the evaluation of the recommended solution. Selecting an appropriate DSS software package to assist the decision-maker would require these decision-making skills. **Sensitivity analysis** attempts to help decision-makers when they are not certain about the accuracy or relative importance of information. The decision-maker does not know the impact of the input on the model. Sensitivity analysis may provide **standard quantitative models** such as **linear programming**. It is powerful because of its ability to establish ranges and speedily setting of limits. **Trial-and-error** involves the changing of inputs several times to discover better and better solutions. This experimentation appears as **"what-if"** s and **goal seeking** (Turban 1993).

In a **"what-if"** scenario, the results depend on the input data and model the assessment of uncertain futures. Assuming the appropriate user interface, the impact of input data on the model can be analysed. "What-if" analysis can be executed with **Expert Systems**. A revised recommendation is shown that can be compared with the previous one (Turban 1993). In conventional systems, it is difficult to test "what-if" scenarios because of its prewritten routines. When deciding, the "what-if" and **goal seeking** options are easy to execute and provide many opportunities for flexibility and adaptability (Turban 1993). **Goal seeking** analysis checks the inputs necessary to a desired level of a goal (output). It represents the backward solution approach. Some computer packages include a break-even point in their analysis. **Sensitivity analysis** is important, because it can be used to improve confidence in the model (Turban 1993).

♦ The implementation phase

If the proposed solution seems reasonable, it may be implemented. Successful implementation results in solving the original problem. Failure results in returning to the previous phases (Turban et al 2001). The decision-making process is not as easy as it seems. It is often an iterative process (Figure 2-1: p8) where each of the phases is revisited during the decision making process.

5.1.5 Human decision-making processes

Dean (1991), as referenced by Mallach (1994), categorises the many methods by which decision-makers decide along three dimensions:

- Rationality: the ability to collect and analyse information objectively and make a final choice according to the objectives
- Politically: the ability to make decisions in a group within the organisation's goals and power, when different goals exist among the members of the group: It is characterised by compromise and should aim at a win-win outcome. , and
- Flexibility: the ability to make decisions that break the mould of tradition and structure

Table 5-1 Preferred decision-making techniques for personality types: (Dean 1992 in Mallach 1994)

Decision-making style	**Preferred technique**
Left-brain	Analytical and quantitative techniques
Right-brain	Unstructured and spontaneous procedures concerning the whole rather than its parts such as Brain-storming, emergent trend projection
Accommodating	Has dominant styles but adopt to required the alternate decision-making style
Integrated	Combines left- and right brain, taking advantage of their symbiosis filtering the information analytically (left-brain) while intuition helps decision-makers contend with uncertainty and complexity, constantly verifying the appropriateness of the decision.

As stated before, humans are not entirely rational. Different psychological personality types exist influencing the decision-maker's approach to decisions and their preferred support when deciding (Mallach 1994). Another important factor that determines the type of preferred support is whether decisions are to be made by an individual or a group. Psychological types also affect how well people work together in teams. Sauter (1999) further differentiates between four decision-making styles: left-brain, right brain, accommodating and integrated. Table 5-2 shows the preferred technique for each of the decision-making styles.

Table 5-2 Different decision-making styles and their preferred technique to decision-making (Sauter 1999)

Decision-making style	**Preferred technique**
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5.2 Decision-making and models

Modelling simplify reality and help to conceptualise decision alternatives (Mallach 1994).

5.2.1 The benefits of modelling

The benefits or advantages of using modelling are: (Turban et al 2001; Mallach 1994)

- The cost of modelling is much lower that the cost of experimentation conducted with a real system
- Models allow for years of operation to be simulated in seconds of computer time
- Manipulating the model is much easier than manipulating the real system: Experimentation is easier to conduct and does not interfere with the daily operation of the organisation
- The cost of making errors during trial-and-error experimentation is much lower when using models than the real system
- Modelling allows the calculation of risks in specific actions: Experimentation can be done in areas that involve considerable uncertainty.
- Mathematical models allow the analysis of solutions with very large or even an infinite number of alternatives
- Models enhance and reinforce learning and support training
- It is easier to access and manipulate a model when viewing alternatives than applying alternative options to the real world: Several decision options can be evaluated via computer models

- It is easier to collect data from a computer model than from an actual system e.g. production bottlenecks: Data is easily collected as a by-product of a running model. In a real system, the data needs to be specially collected and recorded. , and
- A model compresses time and yields results more quickly than the real world: That which takes years to achieve in the real world can be simulated and made available to decision-makers in minutes

5.2.2 Classifying models

Modelling can be done with various degrees of abstraction and is classified into four groups: **iconic**, **analogue**, **mathematical** and **mental** by Turban et al (2001). **Iconic** (scale) models, the least abstract type, are physical replica of systems. It is usually based on a smaller scale than the original. Examples are models of aeroplanes, cars, bridges or production lines. An **analogue** model does not look like a real system, but behaves like a real system. The shape of the model differs from that of the actual system. Examples include organisational structure charts showing authority or responsibility relationships; maps showing mountains or water using colours; machine or house blueprints; and thermometers.

Mathematical (quantitative) models are the most abstract and may contain four types of variables: result variables, decision variables, uncontrollable variables and intermediate variables. Some systems possess complex behaviour and are best represented as abstract models using mathematics. A **mental** model of a situation provides a description of how a person thinks about a situation. This model includes beliefs, assumptions, relationships and workflow as perceived by an individual. Mental models are important in environmental scanning where it is necessary to determine which information is important. Mental models are subjective and frequently change, so it is difficult to document them. They are not only important for decision making, but also for computer-human interaction.

Mallach (1994) classifies models into **graphical**, **narrative**, **physical** or **symbolic**. A data flow diagram is an example of a **graphical** model. A **narrative** model describes a system in a natural language such as English. A **physical** model is a smaller or idealised representation of the real system. These three models are generally not part of a Decision Support System. The fourth type of model: **symbolic** or mathematical is usually used by Decision Support Systems. It is also called a mathematical model or information-based model.

Table 5-3 (p83) lists some structured management science problems and modelling tools available to solve these problems (Turban et al 2001). Standard models cannot solve managerial problems that are not structured. Such problems are usually classified as tactical or strategic and require the use of a DSS.

Table 5-3 Representative Structured Management Science Problems and Tools (Turban et al 2001)

Problem	Tool
Allocation of resources	Linear and non-linear programming
Project management	PERT, CPM
Inventory control	Inventory management models, simulation
Forecasting results	Forecasting models, regression analysis
Managing waiting lines	Queuing theory, simulation
Transporting and distributing goods	Transportation models
Matching items to each other	Assignment models
Predicting market share and other dynamically orientated situations	Markov chain analysis, dynamic programming, simulation

5.3 Understanding Decision Support Systems

Decision Support Systems exists to help people make decisions. DSS do not make decisions by themselves (Mallach 1994). As stated before DSS attempt to automate several tasks of the decision-making process. Modelling is the core of DSS (Turban et al 2001).

A system is a group of interacting connected components with a purpose (Mallach 1994). The components may be systems in themselves as they interact in fulfilling a common goal or purpose. A system is a collection of objects such as people, resources, concepts and procedures intended to perform an identifiable function or to serve a goal (Turban 1993). DSS is a type of information system that uses and applies several other types of information systems. A DSS may interact with other systems, having information crossing its boundary inward, outward or in both directions. It integrates databases, networks, and programs with user interfaces. A DSS attempts to deal with systems that are fairly open. An open system is very dependent on its environment and/or other systems (Turban 1995). Systems that are fairly open tend to be more complex in nature because of the impact on and from the environment. During analysis, it is necessary to check these impacts (Turban 1995). Virtually every information system has decision support aspects.

5.3.1 Diversity of Decision Support Systems

The concept of intelligence in DSS is important. Finlay (1994) claims that the biggest difference between types of DSS, is between systems that provide information, and those that provide intelligence. Information enables the formation of a better scenario, simply providing the decision-maker with more information only provides the decision-maker with the raw material for intelligence. The decision-maker may need help in the form of intelligence to interpret his scenario. A knowledge model may include data, information, intelligence as well as the process whereby these are formed.

Some DSS have the capability to explore situations that do not yet exist. Analysing such situations require a model or abstraction of reality rather than reality itself. This modelling capability is an important characteristic of a DSS (Turban 1995) and ensures lower cost of experimentation as well as minimising errors and compression of time amongst other advantages. The modelling component of DSS will be discussed in Paragraph 5.4.2 (p91).

5.3.2 Working definitions of DSS

According to Turban (1995), the above definitions do not provide a consistent focus, but each of them rather tries to narrow the populations of DSS systems in different ways. To narrow the population is indeed a proper function of a definition, but the definitions should not be so converse. Collectively they ignore the central issue in DSS namely the support and improvement of decision-making.

After considering the various conceptual frameworks originating from Management Science, Computer Science, Ergonomics, Decision Analysis and Decision Research, Finlay (1994) concludes that DSS should encompass systems that include both management information (MIS) and provide intelligence termed Management Intelligence Systems (MINTS). He specifies that DSS should not be restricted to systems used in person or interactively or concurrently by the decision-maker. He therefore retains his definition of DSS as being a computer-based system that aids the process of decision-making. He adds that the problem structure would be meaningless unless viewed in context of the perceptions of the decision-maker.

Taylor (1999) states that a DSS differs from a Management Information System (MIS) that the manager or decision-maker typically acts as an internal component in a DSS and as an external component in a MIS. The manager interacts with the CBIS to reach a decision through an iterative dialogue process. The iterative capabilities are expressed via the "what-if"-analysis as the manager or decision-maker experiments with the system. Shim et al (2002) states that DSS are typical computer technology solutions that can be used to support complex decision-making and problem solving.

5.3.3 Classifications of Decision Support Systems

♦ The hierarchy of Decision Support Systems

Alter (1980) compared different types or levels of DSS (See Paragraph 2.2.5: p15). **File drawer** systems allow immediate access to data items. When retrieving a specific desired piece of information the decision-maker is in a position to act. This is the simplest DSS and often of great value. **Data analysis** systems allow the manipulation of data. Almost all data in the file drawer category also have a file analysis capability. It is able to perform operations such as conditional retrieval, and elementary arithmetic summaries of selected data. **Analysis information** systems provide access to a series of databases and small models. Analysis is performed by an information system across various files and even external sources.

Accounting models calculate the consequences of planned actions based on accounting definitions. It is a model with no uncertainty, where the calculations of each period only depend on other data of that period. While the accounting model itself does not incorporate any uncertainty, its inputs may not be known precisely. **Representational** models estimate the consequences of actions based on models that are partially non-definitional. This model reflects uncertainty, often noted in individual or collective human behaviour, or represents the dynamic behaviour of systems over time. These models are widely used to forecast the effect of a decision.

Optimisation systems provide guidelines for action by generating the optimal solution consistent with a set of constraints. Alternatives are enumerated or laid along mathematical axes, and the best alternative chosen. **Suggestion** systems perform mechanical work leading to a specific suggested decision for a fairly structured task. Two models are available: a descriptive system and a prescriptive system. A descriptive system may suggest a decision to the decision-maker. This is practical if the decisions are highly structured. Such a DSS is called a suggestion system. A prescriptive model is used to mimic the reasoning process of a human expert in reaching a decision. Human expertise is codified into a reasonable number of rules.

The first three classifications almost entirely focus on their database. They are referred to as **data-oriented**, also called data retrieval systems. The last four categories concentrate more on the model of the business system and less on the database. The databases in these DSS are often small, self-contained and constructed solely for use by the model. Such a DSS is called **model-oriented**, also called Extrapolatory Systems (Finlay 1994). The last two levels: optimisation and suggestion models are often purely based on **process** models. In such cases, it is preferable to refer to them as process-oriented DSS. This focuses the attention on the fact that the DSS mimics the human decision-making process.

Some DSS are further characterised as being an **institutional** rather than an **ad hoc** DSS. An **institutional** DSS is usually used regularly in the organisation and used by more than one person. An **ad hoc** DSS is developed for one-time use only, often used by a single individual. Finlay (1994) bases his classification of DSS on the degree of difficulty to be experienced by the decision-maker in use of the DSS, which in turn is dependant on the degree of complexity and uncertainty the decision-maker perceives, the last being the major factor for classification (Finlay 1994). Figure 5-3 (p86) and Figure 5-4 (p87) show the relationships between DSS.

Finlay (1994) further states that emphasis within DSS changes depending whether the DSS deals with information (using MIS) or with intelligence (employing MINTS). MIS is generally context independent opposed 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). A comparison between MIS and MINTS with respect to emphasis is given in Table 5-4. (p87) Most of the items are self-exploratory.

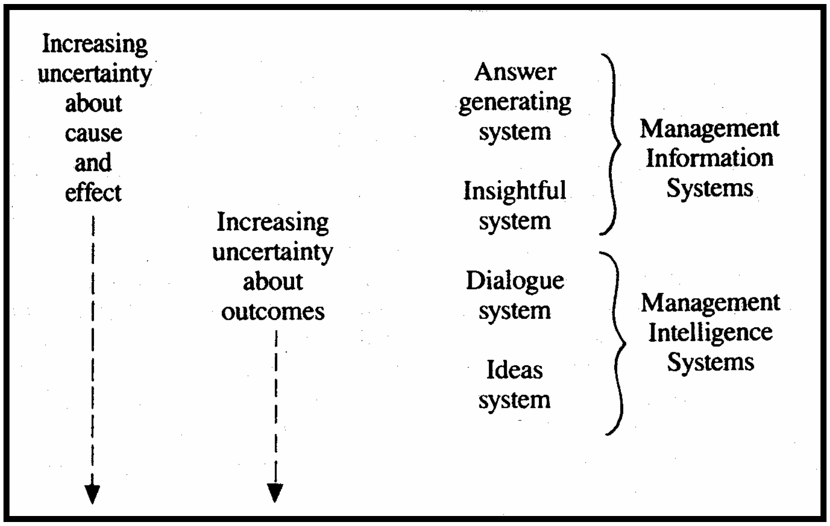

Figure 5-3 Relationships between Decision Support Systems (Finlay 1994)

MIS may be viewed as two broad types: providing information about the past: facts also termed data retrieval systems and those providing information about the future using extrapolation or relationships based on past data also termed Extrapolatory systems. MINTS may also be viewed as two broad types: the first termed preference determination systems where decision-makers choose between options without formally considering cause and effect and a second type called Scenario development systems. Scenario development systems pose great uncertainty in both the preferred outcomes as well as in the perceived cause and effect relations. In this case, the decision-maker uses the DSS to build his overall view of the world: his scenario. Figure 5-4 (p87) shows the extended relationships between DSS.

♦ Types of management information systems

The first broad type of MIS is data retrieval systems. Data retrieval systems can be divided into three subclasses:

- File Drawer systems: providing rapid, ad-hoc access to pre-structured data
- Data Analysis Systems: providing straight forward analysis, reports and graphical output of predefined situations; and
- Executive Information Systems: a recent evolved type of data retrieval systems that provides selected and summarised information and trend forecasts in a suitable form to senior executives

The second broad type of MIS according to Finlay (1994) is Extrapolatory Systems. Many management science techniques are employed by these systems. . Finlay's (1994) practical approach classifies Extrapolatory Systems into three categories:

- Definitional systems that comprise of definitional relations pre-defined between variables such as systems within the accounting arena

- Causal systems that identify cause-and-effect relationships: possibly derived from statistical data from the past and used with assumed future data values to obtain a result. The system builder needs to be a mathematical modelling expert. Models such as linear programming would be required in the system. , and
- Extrapolatory systems distinguish probabilistic systems that include probabilistic features within the system. The data models need to include probabilistic and/or statistical distributions. Examples of this type include simulation and statistical forecasting. These systems require considerable mathematical and statistical expertise from the DSS builder.

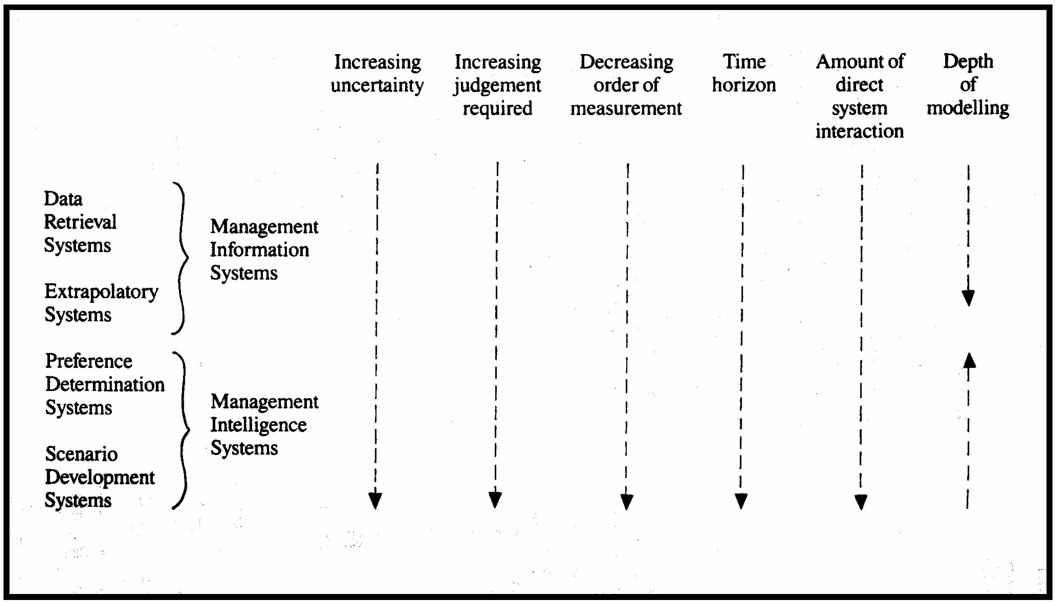

Figure 5-4 Types of DSS (Finlay 1994)

The second type of DSS, MINTS also includes two broad types:

- Preference determination systems, and
- Scenario development systems

The first type requires an exhaustive list of feasible options and associated criteria, and can be categorised based on the predominant decision making technology employed: types based on decision trees and types based on multi-attributed criteria. Decision trees graphically illustrate a series of decisions in a clear and convenient way. It combines probabilistic features with an exhaustive list of possible options and outcomes. Multi-attribute DSS requires several criteria to be specified. The interaction with this criteria and options open to the problem owners will produce a matrix using judgement. Preference methodology exposes the structure of the problem situation. Subjective input from the users and dimensions of uncertainty can be incorporated. The available tools in this DSS type support group decision-making.

Table 5-4 The emphasis associated with types of DSS (Finlay 1994)

	Management Information System	Management Intelligence System
Type of system	Internal control/budgeting	Planning
Focus	On efficient, structured information flows and data structures Efficiency	On effective decisions, flexibility, adaptability and quick response Effectiveness
Objectives	Prespecified	Ad hoc/contingent
Type of situation	Within fixed policies	Within a given scenario
Created by	IT specialists/business analysts	Users/business analysts
Design perspective	Organisational	Individual/small group
Design methodology used	'Classical' systems approach and prototyping of inputs and outputs	'Breadboarding'
Hardware/software orientation	Hardware and software	Software
Models i) ii) iii) iv) v)	Fixed logic Mainly deterministic relations Mainly arithmetic and mathematical Mainly deterministic data Ratio and interval scales	Evolutionary logic Judgemental relations Mainly logical Probabilistic data Nominal and ordinal scales
Output i) ii) iii) iv)	General format Standardised/interrogative reports An answer Management information	User created Iterative/interactive ill-structured reports Insight, learning, dialogue Intelligence
Time scale	Past, present and future	Present and future
Context	Context independent Structured	Context dependent Ill-structured
Exactitude	Precision and accuracy	Accuracy
Validation	'Classical' systems methodology	Appropriateness
Usage	Largely mandatory	Discretionary

The second broad type of MINTS is scenario development systems. The emphasis here is on tools that enhance human cognitive and interactive processes. Two subtypes are identified: cognitive mapping systems suitable to facilitate the codification of the decision-maker's or group of decision-maker's concepts. Analysis of these types identifies where resolution needs to be sought. The second subtype is an idea generation system that supports sessions such as brainstorming to call for relatively uninhibited responses from the participants.

5.3.4 Characteristics and capabilities of DSS

The more beneficial characteristics and capabilities according to Turban (1995) are summarised on the next page (p 89). Most DSS have some of the listed features. The features are graphically represented in Figure 2-3 (p 13).

The characteristics and capabilities of DSS according to Turban (1995) are:

1. DSS support brings together human judgements and computerised information in a semi-structured or unstructured situation. The problem cannot be solved by using a computerised system only.
2. Support is provided for all levels of management
3. Support is provided to individuals as well as to groups. Less structured problems tend to require involvement of various individuals.
4. DSS provides support to several interdependent and/or sequential decisions
5. A DSS supports all levels of decision-making: intelligence, design, choice and implementation
6. A DSS supports a variety of decision-making processes and styles e.g. the individual's decision style
7. A DSS is adaptive over time. DSS should be able to adapt to changing conditions. Basic elements should be capable of being added, changed, combined, rearranged and adjusted to provide fast responses to unexpected situations.
8. A DSS is easy to use specially focussing on non-computer people. Users must feel 'at home' with the system. Ease of use implies an interactive mode.
9. A DSS attempts to improve effectiveness of decision-making including accuracy, timeliness and quality
10. The decision-maker has complete control over all steps of the decision-making process. The system supports but does not replaces the decision-maker. The computer's recommendations can be overwritten at any time.
11. A DSS leads to learning and so initialises a process of developing and improving the DSS
12. A DSS is relatively easy to construct. End users should be able to construct simple systems by themselves.
13. A DSS usually utilises models. The modelling capabilities enable experimenting with different strategies under different configurations to provide new insights and learning. , and
14. An advanced DSS is equipped with a knowledge component to solve difficult problems.

Turban et al (2001) adds another characteristic:

- A DSS allows the easy execution of sensitivity analysis. Sensitivity analysis is the study of the impact changes that one part of the model has on other parts of the model, also called "what-if" analysis. Sensitivity analysis also promotes the discovery of necessary inputs to obtain a desired level of output also called goal seeking.

5.3.5 The benefits of a DSS

In Paragraph 5.2.1 (p81), the benefits of modelling were discussed. Modelling is only one of the components of a DSS (Turban 1993). Most companies use DSS to improve an aspect of their decision-making operation. A DSS assists decision-makers to decide faster with less chance of error, thus improving the decision-maker's efficiency. The benefits most DSS provide are (Turban 1995; Mallach 1994):

- DSS have the ability to support the solutions of complex problems
- DSS can expedite problem solving by providing information to decision-makers about similar decisions made in the past, thus providing increased consistency of similar decisions in the future. The technology of ES can contribute to the consistency of DSS by recommending decisions in an unemotional way. This is one of the many close relationships between Expert Systems and Decision Support Systems.
- DSS provide fast responses to unexpected situations
- DSS have the ability to try several different strategies under different configurations
- DSS provide new insight in learning or training. The ES component can be designed to provide this type of benefit. Most ES offer an interface that allows users to ask why the system made a particular recommendation and receive an answer in non-technical terms. Expert System users, after seeing many of these explanations, will understand the reasoning of experts in reaching the recommendation. Learning has then taken place, because these users would be able to make better decisions without the system.
- DSS facilitate communication: "What-if" analysis can be used to satisfy sceptics and improve teamwork
- DSS facilitate interpersonal communication: One such way is as a tool of persuasion, using to illustrate a particular action to be taken in future, called *offensive* use, or using it to illustrate that a particular action was taken properly in the past, called *defensive* use. When viewed in a broader organisational context, these decisions could influence the group. *GroupWare* is a new form of DSS designed to accommodate the way a group reaches decisions, for instance using electronic mail or bulletin boards. There are also various other ways of electronic conferencing.
- Using DSS as a routine application can eliminate the cost of wrong decisions
- DSS facilitate objective decisions by improving managerial effectiveness and allowing managers to perform a task in less time and/or with less effort. This results in more time for analysis, planning and implementation. , and
- DSS increase organisational control: The DSS can constrain the individual's decision to conform to organisational norms, guidelines or requirements. A level of consistency can be ensured across organisational units. An individual's decisions could also be reported to his manager and then used to assess the productivity of the individual. This aspect has to be used very cautiously, because this might encourage the individual to make "safe" decisions not in the organisation's best interest, or at the worst, damage morale. This use of DSS raises legal and ethical privacy issues.

5.4 Architecture of a DSS

5.4.1 Data management subsystem

Data used by a DSS may be acquired from various sources called: **Internal**, **external** and **personal** (Turban 1995) as well as from **commercial** databases and by **collecting raw data** (Turban et al 2001).

Internal data refer to databases inside the company, some of them maintained by other information systems used by the company. **External** data refer to sources outside the company used around the globe that may range from commercial databases to data collected by sensors and satellites. If relevant, this data may interface with the DSS. In many DSS applications, data come from a **data warehouse**. A data warehouse includes DSS-relevant data extracted from different sources and organised as a relational database (Turban et al 2001). **Personal** data refers to the users own expertise. This includes opinions for example what competitors are likely to do.

Some **external** data flow to an organisation on a regular basis through electronic data interchange (EDI) or via other company-to-company data channels. Much data are also accessible via the Internet in the form of home pages of vendors, clients and competitors. Information can be downloaded from these sites. Online publishers sell access to specialised databases, newspapers, magazines, bibliographies and reports in a timely manner and at a reasonable cost. Several thousand of these services are currently available. **Raw data** can be collected manually or by instruments and sensors. Regardless of how this data are collected, data need to be validated. The quality and integrity of the data are critical for a DSS. Therefore, safeguards on data quality are designed to prevent problems (Turban et al 2001).

Problems observed in large DSS include data not correct, data not timely, data not measured or indexed properly, too much data needed, and needed data non-existent. The data issue should be considered in the planning stage of the system life cycle of the DSS. If too many problems are anticipated, the system should not be undertaken.

If the creation of the DSS involves the creation of a separate DSS database, the DSS builder will need to design and prepare the necessary data. Data may be organised using a relational, hierarchical, network or object orientated database model. The databases may be accessed via networks using technologies like client-server. Many companies develop enterprise-wide databases. Relational Database Management Systems (RDBMS) are better suited for DSS because their records do not contain predefined links to associated records in other files. This provides them with greater flexibility retrieving the data. Another advantage is the use of a standard interface called Structured Query Language (SQL). All the major RDBMS vendors use SQL. It provides database connectivity (ODBC). ODBC is a programming interface that enables applications to access data in a DBMS that uses SQL as a data access standard.

5.4.2 Model management subsystem

An important 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. As stated before, a model is a simplified representation or abstraction of reality, 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. It is limiting to take reality to mean that which presently exist. 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).

♦ DSS models

According to Mallach (1994), DSS uses the fourth type of model: a **symbolic** or *mathematical* model also called an *information-based* model (See Paragraph 2.2.6: p15). Reality is represented by data, which can be processed or interpreted as information. The data elements used in this model normally consists of values containing True/False, character strings or numerical values - any type that computers and computer programs can deal with. The symbolic model incorporates procedures and formulas to manipulate the model's data elements. The values of new data elements are derived. The model may use external values received from the database, the user or other information systems.

In DSS, models are used to predict the outcome of decision choices made (Mallach 1994). DSS represent reality by information about reality. A DSS can incorporate several different types of mathematical models. The DSS builder is often faced with the dilemma of which models to include in the DSS and whether to build new models, to use ready-made ones or to modify existing models. Until recently, mathematical modelling formed the core of almost all DSS. Many applications nowadays use logical relationships other than mathematical ones as the basis of their DSS. Mathematical-based DSS however still constitute the majority of applications (Finlay 1994; Turban et al 2001). A tendency exists to complement mathematical modelling using computer graphics in Decision Support Systems. Visual simulation combines iconic, analogue and mathematical modelling.

♦ The model management subsystem of a DSS

The models in the model base can be divided into four categories: **strategic**, **tactical**, **operational** and **model building blocks and subroutines.** **Strategic** models are used to support top management's strategic planning and tend to be broad in scope to support developing corporate objectives, select plant locations and perform environmental impact analysis. The matching of the organisation with its environment is the primary consideration (Finlay 1994). The raw material for production of intelligence is loosely organised information. Inputs are from a variety of sources such as external databases, external rumours, formal internal reports and formal discussions. High precision of data is generally unobtainable and the concern is accuracy. Strategic planning tends to be periodic with intervals seldom less than months. A well-managed organisation has broad contingency plans to put into practice, should the unexpected happen.

Tactical models are mainly used by middle management to assist in the allocation and control of the organisation's resources such as sales promotion planning and plant layout specification and are usually applicable to one subsystem like the accounting department. **Operational** models support the day-to-day activities of the organisation like approving a loan, supplying advice to students and inventory control. The model normally uses internal data that is accurate and precise. Operational models are buffered from direct influences of the organisation's environment.

In addition, the DSS model base may include **building blocks** such as a random number generator, present value computational routine or regression analysis. These routines may be used on their own or as components of larger models. The models in the model base may be classified by functional areas, such as financial models or production control models, or by discipline, such as statistical or management science models. The number of models in a model base may vary from a few to several hundred. Although some models in the model base are standard, it is frequently necessary to write a model. This can either be done with high-level languages such as COBOL or fourth-generation languages (4GL) or special model languages.

Models, similar to data, need to be managed. Such management is done with the aid of **model base management software** (MBMS) (Turban 1993). The MBMS is capable of interrelating models with the appropriate linkages to the database. This software should ensure that the following exists (Turban 1995):

- Control: The DSS user should have various options of control. The system should support both fully automated as well as the manual selection of models applicable to the intended application. This will enable the user to exercise problem-solving skills at a pace most comfortable for the user. It should be possible for the user to enter subjective information. The information necessary need not be complete. Users should be able use sensitivity analysis such as "what-if" and goal seeking in their experimentation.
- Flexibility: The DSS should be able to switch between modelling approaches during a session
- Feedback: The model should provide sufficient feedback to the user to indicate to the user the state of the problem-solving process at any stage
- Interface: The DSS user should feel comfortable with the specific model. Information provided by the user should be kept to the minimum and optional if possible.
- Redundancy reduction: This can be accomplished by the use of shared models, and
- Increased consistency: Multiple users must be able to use the same model or data

To provide the above the MBMS design must allow the user to

- Access and retrieve existing models
- Exercise and manipulate existing models
- Store existing models, and
- Construct new models

The models are catalogued using a model directory that is similar to a database directory. Model management should control activities such as model execution – controlling the actual running of the model, and model integration – combining the operations of several models, when needed. It must be possible to analyse and interpret the results obtained from such a model.

♦ **Different classifications of models in the model base**

Mallach (1994) also classifies models as being either **system** or **process** models. A mathematical model is an information-based representative of an actual system. The **system** model models the system that needs to be studied, and the **process** model models the process humans follow in making a decision about the system. **System** models would include the correct formulas and algorithms used to solve the problem. It would also include many types of mathematical models to suite the different types of decisions to be made by the DSS.

Process models form the basis of most Expert Systems (Mallach 1994). It would include rules of thumb used by experts in a particular field to determine a specific outcome. When applied, a process model reaches the same conclusion in much fewer steps, and is therefore be more efficient. Process models do not include the deep knowledge necessary to adapt it easily to unforeseen circumstances because its rules of thumb assume certain relationships between the present and the new. When any unforeseen circumstances arise, a system model would adapt the formula values to the given situation and provide the correct answer.

Process models can be classified as being **descriptive, prescriptive** or **predictive** depending on the source of their input data. Both types are based on the same model. A **descriptive** model describes what a system did in the past or what the system is doing in the present. A **prescriptive** or predictive model describes what the modeller expects to do in the future using assumed or statistically described future data. **Descriptive** models are being classified as **static** or **dynamic** (Mallach 1994; Turban 1995). Static models show values of a system in balance. Dynamic models show a system's changes, with cause-and-effect relationships, over a period. A series of cause-and-effect connects one period with the next. A static model may model either a static system or a snapshot of a dynamic system. A **static** model describes relationships among data values at any instant of time. Static models take a single time interval, long or short in duration. Any data element remains stable once calculated or processed. The result will not change unless the decision-maker changes the input.

In a **dynamic** model data values change over time. The change is essential in the model and is time dependant. What happens at one instant in time affects the modelled system at future instants in time. It shows trends and patterns over time. A collection of static models can appear to show quantity varying over time. The difference lies in the presentation of the data over time. If more than one time period of results is shown and formulas exist in the model to effect growth or change over the period, the model is a dynamic one. For some decisions the changing of values does not matter and therefore a static model or series of static modelling would suffice. Dynamic models mimic the behaviour of a system over time, allowing the examination of behaviour and thus focussing on the optimising of the system (Mallach 1994). Dynamic models can be further subdivided into **continuous** and **discreet-event** models. Simple continuous models can be studied via calculus and differential equations. Complex systems are solved easier numerically. Continuous models progress smoothly from one value to the next.

Discreet-event models model systems in which the state of the system changes instantaneously from one value to another. A precise instant exists at which a value changes such as an order that arrives or a product that is shipped. Discreet-event models suit most business planning needs and are classified further into **deterministic** and **stochastic** models. A model is classified as **deterministic** if its outputs are fixed for a given set of inputs and **stochastic** if the outputs reflect an element of statistically defined **uncertainty**. The familiar spreadsheet is a useful tool in dealing with **deterministic** models. A **stochastic** model's output, for a given set of inputs, varies randomly over a range of possible outcomes. When this model is applied several times, many different answers will be obtained clustered around a mean. The variance of this mean will depend on the steps taken during the modelling process.

The decision to characterise a model as deterministic or stochastic depends on what is put inside the model and what is put outside the model (Mallach 1994). To manage **uncertainty** in the model, it is necessary to agree on the boundary of the system. **Accounting** models and **representation** models correspond closely to deterministic and stochastic models. **Certainty** models yield optimum solutions. Many financial models are constructed under assumed certainty (Turban 1995). If insufficient information is available a problem can be treated as an **uncertain** problem. If more information is acquired the problem can be treated under calculated or assumed **risk**. Decision-making under risk assumes that the decision-maker has knowledge of some of the probabilities that are involved with the decision variables (Lawrence & Pasternack 2002). Several techniques can be used to deal with risk analysis such as **probabilistic simulation**, **time (in-) dependant simulation** and **visual simulation**.

Probabilistic simulation assigns probabilities to one ore more independent variables. Two subcategories exist: **discrete** distribution where discrete values are assigned a probability and **continuous** distribution where the values are statistically distributed with a mean and a deviation. Probabilistic simulation is conducted with the aid of a technique called Monte Carlo (Turban 1995).

♦ The seven groups of DSS models

Many DSS incorporate models of various types. Models of a given type tend to have many characteristics in common. Mallach (1994) compares DSS models according to the following:

- System versus Process
- Static versus dynamic
- Continuous versus discreet-event, and
- Deterministic versus stochastic

Turban (1995) also assigns the above characteristics to DSS models, but categorised the models further into seven groups:

- Complete enumeration – few alternatives
- Optimisation via algorithm
- Optimisation via analytical formula

- Simulation
- Heuristics
- Other descriptive models, and
- Prescriptive models

Models have procedures and formulas to manipulate their data elements or to derive other data elements. An external database or other external data sources may be used to derive these values. A useful characteristic of these models is the fact that the model remains valid when data changes (Mallach 1994). The following paragraphs provide summarised explanations of the seven groups as given by Turban (1995).

▪ **Complete enumeration**

A finite and small number of alternatives are modelled by decision analysis. Two types are distinguished: **single goal** and **multiple goals**. Decision tables or decision trees are two techniques used in single goal decision analysis. There are quite a few techniques in multiple goals. The objective in both cases is to select the best alternative after listing them and assessing each one's forecasted contribution towards their goal(s). The decision table is a mathematical model. Two factors that can affect the model are uncertainty and risk. In uncertainty the probabilities of each state of nature is unknown. In the case of risk, these probabilities are known. Sufficient information is gathered about the case to assume the risk. An alternative to the decision table is the decision tree. A decision tree shows the relationships of the problem and can deal with situations that are more complex.

▪ **Optimisation via mathematical algorithm**

Mathematical programming provides a relatively unbiased approach in solving the problem. Linear programming is the most known mathematical technique used in optimisation. Other programming and network models that exist are non-linear programming, goal programming and distribution problems. The objective is to find the best solution from a large or infinite number of alternatives. Suitable problems usually display the following characteristics and necessitate some assumptions:

- A limited number of economic resources are available for allocation (for example labour, capital, machines, and water)
- The resources are used in the production of products or services
- Two or more ways exist to user the resources, each called a solution program
- Each product or service yields a return in terms of a stated goal
- Several constraints limit or restrict the allocation
- The returns from the various resources are measured with a comparable common unit
- The return of a specific allocation is independent from other allocations
- The total return is the sum of the return of the different services or products
- All data are known with certainty, and
- The resources are to be used in the most economic manner

▪ **Optimisation using analytical formulas**

Several inventory models exist in this category. The objective here is to find the best solution using a single line formula. The technique: "Optimisation using a mathematical algorithm", may be used too. Several other inventory models exist including statistics, financial analysis, and accounting and management science models.

Statistical and financial functions are built into many DSS generators (See Paragraph 3.1.5: p35). There are several hundred management science packages ranging from inventory to project management. Several DSS generators include optimisation and simulation capabilities. A DSS generator can invoke these models by issuing a single command. A DSS generator can also interface with powerful quantitative methods in stand-alone packages. Pre-programmed quantitative models can be accessed via templates. Some of these models can be building blocks for other models e.g. the regression model can be part of the forecasting model that supports the financial planning model. SQRT calculates the square root and can be part of the inventory model.

▪ **Simulation**

Simulation is a technique for conducting experiments. Simulation usually imitates reality opposed to models that represent reality (Turban 1995). This means there are fewer simplifications of reality in simulation models than in other models. Output values of the decision given specific input variables are observed. Simulation is a descriptive rather than a normative tool. There is no automatic search for an optimal solution. Simulation predicts or describes a system under certain circumstances. The best one amongst the alternatives can be selected. The process often exists of many repetitions of an experiment. Simulation is usually called for if the problem to be solved is too complex for numerical optimisation techniques. An accurate simulation model requires an intimate knowledge of the problem. The model is built from the decision-maker's perspective and in his decision structure. The simulation model is built for one particular problem and will, typically, not solve any other problem.

The decision-maker can experiment with different input variables to determine which are important. He can experiment with different alternatives to determine which variable set is the best. It allows the decision-maker to ask "what-if" type of questions. Decision-makers that employ a trial-and-error approach to problem solving, can do it faster and cheaper with less risk. A great amount of time compression can be attained, giving the decision-maker an idea of the long-term effects of various policies in a matter of minutes.

Some disadvantages of simulation are:

- An optimal solution cannot be guaranteed
- Constructing a simulation model is frequently a slow and costly process
- Solutions and inferences from a simulation study are often not transferable to other problems, and
- Simulation is sometimes chosen instead of analytical solutions that can yield optimal results

The methodology of simulation consists of a number of steps using a real world problem as the input:

- Problem definition: The real-world problem is examined and classified. Reasons why simulation is necessary should be specified. The system's boundaries are specified.
- Construction of a simulation model: Gather the necessary data, and optionally use a flowchart to describe the process. Write the computer program.
- Testing and validating the model: The model must imitate the system
- Design the experiments: If the model has been proven valid, the experiment is designed. Accuracy and cost is two important contradictory objectives.
- Conducting the experiment: The rules may be terminated and the results presented where applicable
- Evaluation of the results: The final step is the evaluation and analysis of the results. Statistical tools and sensitivity analysis may be used, and
- Implementation: The implementation of simulation results involves the same issues as any other implementation

There are several types of simulation. They include:

- Probabilistic simulation: One or more independent variables are probabilistic. Two sub-categories exist: discrete distributions and continuous distributions. Discrete distributions involve a limited number of events or variables that can take on a finite number of values. Continuous distributions have an unlimited number of possible events that follow density functions such as the normal distribution.
- Time dependent and time independent simulation: Time independent refers to a situation where it is not important to know when the event occurred. Other problems may require that the precise time of arrival is known e.g. waiting line problems. , and
- Visual simulation: It represents the results in a graphical way and is one of the more successful new developments in problem solving

▪ **Heuristic programming**

The simulation process may be lengthy, complex and even inaccurate. In such situations it is sometimes possible to arrive at a satisfactory solution rapidly and less expensive by using heuristics. Heuristics is the finding of a "good enough" solution of a complex problem using rules. Techniques include heuristic programming and Expert Systems. Heuristics are most often used for solving ill-structured problems, but they can also be useful in providing satisfactory solutions to well-structured complex problems. Alternatives can be generated using heuristics. Generating alternatives is done manually in most DSS; however, this activity can be automated. It is necessary to predict the future outcome of each alternative (Turban 1993). The main difficulty in using heuristics is that they are not as general as algorithms. Therefore, they can only be used for the specific situation for which they were intended. The result may still be a poor solution.

It is better to employ a heuristic model when:

- The input data are inexact or limited
- Reality is so complex that the optimisation model is oversimplified
- A reliable exact model is not available
- The computation time of optimisation is too excessive
- It is possible to improve the efficiency of the optimisation process by using heuristics
- Problems are being solved frequently and use up a lot of computer time
- Complex problems that are not economical for optimisation, and
- When symbolic rather than numerical processing is involved

Some advantages of heuristic models are that they are easier to understand and therefore easier to implement. They can produce multiple solutions that can help in the training of people to be creative and set up rules for complex problems, save formulation time and save computer execution time.

▪ **Other descriptive models**

Other descriptive models involve non-quantitative models expressed in terms of rules or formulas. These models may be done separately or in combination with quantitative models such as financial models and waiting lines to find solutions to "what-if" scenarios by the use of a formula.

▪ **Prescriptive models**

The main objective of this type of model is to predict the future for a given scenario. Representative techniques include Markov-analysis and forecasting models. Forecasting predicts the values of model variables at some time in the future. Two types of forecasts are distinguished by Turban (1995): **short run** (up to one year), where forecasts are used in deterministic models and **long run** where forecasts are used in both deterministic and probabilistic models.

Often multiple factors, most of which are uncontrollable, are involved in the difficult task of forecasting. Formal forecasting methods can be divided into four categories:

- **Judgement** models, based on subjective estimates and expert opinion rather than hard data used where historical data are limited or non-existent
- **Counting** methods, involving a kind of experimentation or surveys of the market based on hard historical data commonly divided between time-series and causal methods
- **Time-series analysis** in which historical data are used to predict future events, and
- **Association or causal methods**, that includes more variables than time-series methods and use sophisticated statistical methods in presenting the alternatives

5.4.3 Dialogue subsystem or user interface

This subsystem is the key to successful use of the DSS. Various interface modes exist which determine how information is displayed and used. Dialogue styles, dialogue modes and conversation formats all contribute to the ease of use of the DSS. Styles such as menu interaction, command language, question and answer, form interaction, natural language and object manipulation are techniques used to assist the dialogue subsystem of a DSS. Graphics are especially important for problem solving, because it helps decision-makers visualise data, relationships and summaries.

Graphical User Interfaces (GUIs) are direct manipulation systems in which the user has direct control of the visible objects such as icons or buttons to replace complex command syntax. A wide variety of graphics such as: text - in the form of titles and descriptions, time-series charts, bar and pie charts, scatter diagrams - showing the relationship between two variables, two- or three-dimensional maps, room layouts, hierarchy charts, sequence charts, motion graphics and desktop publishing are all viable options when designing user interfaces. A subset of the above options can be used to enhance the specific DSS, whether the DSS produces reports or just visualise problems and potential solutions.

User interfaces can be enriched by the use of interactive multimedia. One new class of multimedia is called hypermedia and includes several types of media such as text, graphics, audio and video elements as tools to navigate knowledge and data and capture results. Associated knowledge can be linked with hypertext allowing the user to control navigation to various components. Virtual reality, presenting a 3-D user interface, offers rich opportunities for powerful interactions. The implementation of 3-D is difficult and expensive. In virtual reality, a person "believes that what he or she is doing is real", even though it is artificially created (Turban et al 2001).

Several problems could be minimised or even eliminated if the user could communicate to the computer using the user's own native language. The computer should be smart enough to interpret this input regardless of its format. Natural Language Processing (NLP) is part of Artificial Intelligence (AI). Two techniques are used in NLP: key work search (pattern matching) and complex language processing (syntactical and semantic analysis). Keyword analysis search for selected words or phrases. Once found, the program responds with the associated set of responses. Language processing is still an emerging technology. Because communication involves language in context, it is difficult for the computer to understand what is exactly meant when free-format commands are issued.

Heterogeneity exists among users and usage patterns of DSS (Turban et al 2001). Different users have different cognitive preferences and abilities, different ways of arriving at a decision and therefore need different types of support in making a final decision (Paragraphs 2.2.1: p7 and 5.1.5: p80). Some users are skilled in using DSS and need a different user interface than other users that are less experienced.

5.4.4 Knowledge management support for decision making

C.W. Holsapple (2001) in his editorial summary observes the following with respect to knowledge management support for decision-making:

- Decision-making is a knowledge-intensive activity with knowledge as its raw materials, and work-in-progress, by-products and finished goods

- Computer-based DSS employ various KM techniques to represent and process knowledge of interest to decision-makers, including descriptive knowledge (e.g. data, information), procedural knowledge (e.g. algorithms), and reasoning knowledge (e.g. rules)
- Knowledge management is concerned with the representation and processing of knowledge by humans, machines, organisations and societies
- An aim of knowledge management is to ensure that the right knowledge is available on the right forms to the right entities at the right times for the right costs, and
- Proficiency in knowledge management is increasingly important to the competitiveness of decision-makers as we rapidly move into the global knowledge society

ES form the basis of the knowledge component and are discussed in detail in Paragraphs 2.2.6 (p15), 2.3 (p19) and Chapter 6 (p107).

5.5 Integrating the DSS in the organisation

The degree of user involvement, the general implementation strategies and the organisational politics may differ among organisations and DSS. A plan that guides the integration process should be developed that consists of education, installation and evaluation (Sprague & Carlson 1982). The purpose of the integration process is to reduce the risk of failure. Alter (1980) identified eight risk factors. When present, these factors increase the probability of DSS failure (See Table 5-5: p101). The integration processes can help reduce each risk. Evolving prototypes can be installed on the Intranet for the use of the company. Constant evaluation to determine the value of the DSS should determine the life span of the DSS.

User education involves training on how to operate the DSS. It involves training the user to:

- Solve problems using the DSS
- Adapt the DSS to new problems, and
- Use special features of the DSS

Table 5-5 DSS risk factors and integration process (Sprague & Carlson 1982)

Risk Factor	**Integration Process to help reduce risk**
Nonexistent or unwilling user	Education, evaluation
Multiple users or implementers	Education, installation
Disappearing users, implementers or maintainers	Education, installation, evaluation
Inability to specify purpose or usage pattern	Education, evaluation
Inability to predict and cushion impact	Evaluation, education
Loss or lack of support	Education, installation, evaluation
Lack of experience with DSS	Education, installation, evaluation
Technical problems and cost effectiveness	Installation, evaluation

5.6 A more comprehensive view of organisational decision-making

With the increasing popularity and use of the Internet and telecommunications technologies, it can be expected that organisations will increasingly become more global, complex and connected. Mitroff & Listone (1993) as referenced by Courtney (2001) state that managers will require radically different reasoning skills facing such an environment. Much broader cultural, organisational, personal, ethical and aesthetic factors need to be considered in decision-making. Decision Support Systems should be capable of handling softer information in a broader context than the mathematical models and knowledge-based systems of the past.

This is an enormous challenge, but imperative if DSS is to remain relevant in the future. Figure 5-5 presents a more comprehensive view of organisational decision-making (Courtney 2001). The perspective of the problem formulation phase need to include multiple and varied perspectives. The problem formulation should include organisational (O), personal (P) and technical (T) perspectives. In addition, ethical and aesthetic factors should be considered too.

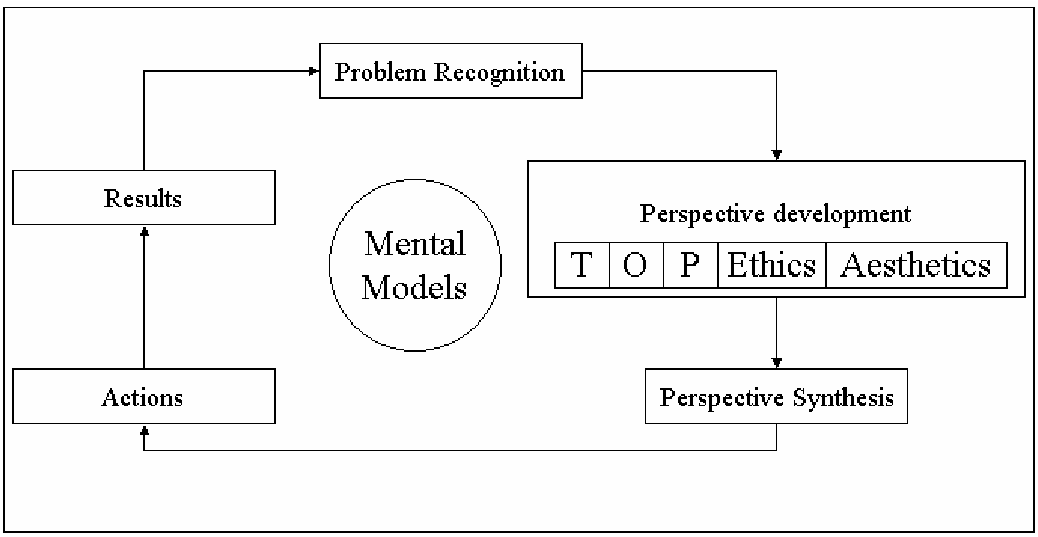

Figure 5-5 A new decision paradigm for DSS (Courtney 2001)

At the heart of defining the problem through to solving the problem, lays the perspective of the problem. The technical perspective has dominated the process in the past and involves the development of the databases and models of the DSS. Individuals are complex and varied in decision-making styles. The organisational and personal perspectives may not be quantifiable, especially the ethical and aesthetic concerns. Given the same external information in an unstructured complex situation, no two people may come to the same conclusion (Courtney 2001). The individual's background, training, experience, values and ethics may differ and thus cause the individual to reach a unique decision. Broader forms of analysis such as group sessions may become even more appropriate in the future.

5.7 The future of DSS

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. They add tools such as data warehouses, on-line analytical processing, data mining and web-based DSS as tool developments for future DSS. These tools together with collaborative support systems, virtual teams, and knowledge management optimisation-based DSS and active decision support are important topics in the development of the DSS concept for the next millennium.

5.7.1 Data warehouses

A data warehouse is a subject-orientated, integrated, time-variant, non-volatile collection of data used in support of management decision-making processes (Inmon & Hackathorn 1994). Barquin (1996) states: "Data warehousing is the process whereby organisations extract meaning from their informational assets through the use of data warehouses".

5.7.2 On-line analytical processing (OLAP)

OLAP is a set of tools that is been developed to provide users with multi-dimensional views of their data and to easily analyse the data using a graphical interface. Multi-dimensional analysis is often used as a synonym for OLAP (Hoffer, Prescott & McFadden 2002). OLAP tools help analyse the historical data in a data warehouse. OLAP tools enables analysts, managers and executives to gain insight into data through fast, consistent, interactive access to a variety of possible views of information that has been transformed from raw data to reflect the real dimensionality of the enterprise as understood by the user.

5.7.3 Data mining

Data mining is knowledge discovery or database exploration using a sophisticated blend of techniques from traditional statistics, artificial intelligence and computer graphics (Weldon 1996). Data mining tools find patterns in data and infer rules from them. Given databases of sufficient size and quality, data mining technology can generate new business opportunities by providing automated prediction of trends and behaviours and provide automated discovery of previously unknown patterns in the data of the database (Turban et al 2000).

Data miners use several tools and techniques such as neural computing, intelligent agents and association analysis (Turban et al 2000). **Neural computing** is a machine learning approach by which historical data can be examined for patterns. Agents sense the environment and act autonomously without human intervention ranging from those with no intelligence (software agents) to learning agents that exhibit some intelligent behaviour. **Intelligent and software agents** (Turban et al 2000) are computer programs that help the user save significant time when they

- Conduct routine tasks
- Search and retrieve information (Search, match and filter using search engines)

- Support decision making, and
- Act as domain experts

Association analysis is an approach that uses a specialised set of algorithms to sort through large data sets and expresses statistical rules among items (Turban et al 2000).

5.7.4 Web-based DSS

Web-based DSS are computerised systems that deliver decision support information or decision support tools to a manager or business analyst using a web browser such as Netscape or Internet Explorer.

♦ Decision support using the Intranet

The Internet is a public and global communication network that provides direct connectivity to anyone over a Local Area Network (LAN) or Internet Service Provider (ISP). Users need effective and efficient search engines to navigate the vast scope of public and advertising information provided in the Internet (Turban et al 2000). The Intranet is a corporate LAN that uses Internet technology and is secure behind a company's firewalls. A firewall is a network node consisting of both hardware and software that isolates a private network from a public network.

Sridhar (1998) views the capability of the Intranet to facilitate access to distributed information as one of the strengths of decision support using this mechanism. The technology underlying the Intranet is fast evolving as new web browsers, supporting collaborative multimedia applications, are developed. Intranets are becoming more popular. He presents illustrative examples and gives classifications of Intranet-based decision support types in order to understand the role of the Intranet in decision support. A major concern, using the Intranet, is the possibility of compromising security, and this needs to be addressed. In his taxonomy, Sridhar (1998) considers the various dimensions of the major decision support components: data, modelling and the user interface.

The dimensions Sridhar (1998) considers for the component are as follows:

- Data
  - Data source: Data may be obtained from internal or external to the organisation
  - Nature of data: Data may be structured or unstructured , and
  - Type of access: Data may be accessed locally or remotely
- Modelling
  - Model source: Models may be obtained internal or external from the organisation
  - Type of access: Models may be accessed locally or remotely, and
  - Type of execution: Models may be executed locally or remotely from the user's computer, and
- User Interface
  - Number of users: Single or multiple users may be involved in the decision process

- Type of use: Multiple users involved in an synchronous or asynchronous use, and
- Place of use: Multiple users involved in different locations (distributed) or in the same location (non-distributed).

The browser may access data and execute models remotely or locally using a remote or local interface at a remote or local place. Sridhar (1998) states the benefits of using an Intranet DSS are greater in terms of facilitating remote access rather than local access. The use of intelligent agents may further facilitate quick retrieval of desired information or models. When using a distributed environment, the communication links between the components of the DSS may experience delays depending on network traffic and bandwidth availability. He expects that these delays, because of the rapid advances in computer and network technology, would decrease and this is therefore unlikely to be perceived as a concern.

♦ Customer Decision Support Systems (CDSS)

The Customer Decision Support System is a Web-based, marketing model that establishes a link between a firm and its customers and provides assistance to the decision-making process (O'Keefe & McEachern 1998). They classify CDSS as a second-generation, web-based, marketing system that includes electronic publishing (first generation marketing systems), but also takes advantage of interfaces and gateways to databases and models to provide richer systems. Decision support is provided for a part of the customer decision process such as information search, product evaluation, purchasing of products and after-purchase evaluation. The service is provided for existing and potential customers using electronic agents to generate needs such as notifications of new publications or price changes such as used by online bookstores.

♦ Open interchange of decision models

A need exists for customers or users to share models and data. In order to achieve this, a modelling tool or environment has to know about other tools and environments in the market and build bridges to them in order for customers to share models and data. In many cases, bridges may not exist or models may not scale well (Kim 2001).

Using an exchange standard in open architecture could be designed to improve the shortcomings of a closed architecture. Each vendor need only implement the standard to leverage access to the other tools. A standard syntax creating data and exchanging data structures is important for this type of integration. XML (Extensible Mark-up Language) provides such a framework and allows the participation of sharing in a web-enabled collaborative environment. XML is a subset of the standard generalised mark-up language (SGML) (Kim 2001). SGML allows documents to be self-describing, through the specification of tag sets and structured relationships between the tags. This specification is referred to as the Document Type Definition (DTD). XML is simple, extensible, interoperable and open. XML's rigid set of rules assists humans and machines to read XML documents. XML are built on a core set of basic nested structures needing very little implementation effort. XML allows users to create their own DTD and by allowing the addition of standards that adds styles linking and referencing abilities to the core XML set of capabilities. XML can be used on a wide variety of platforms and interpreted with a wide variety of tools. It is freely available on the Web and anyone can parse a well-formed XML document and validate it if the DTD is provided (Kim 2001).

Kim (2001) proposes a structured mark-up language called OOSML (Object-Oriented Structured Mark-up Language) based on a conceptual modelling framework: Object Oriented Structured Modelling (OOSM), an object-orientated extension of Structured Modelling (SM). OOSML can be used for the representation and management of decision support models within the DSS community. OOSML is an XML application that supports object-orientated concepts such as object-oriented modular structure, models as entities and specialisation using structured mark-ups. The structure of the decision models is defined using XML tags and this causes the finding, manipulating and using of models much easier. The structured delivery of data enables open interchange between servers and clients and potentially between servlets themselves. Users can manipulate and analyse OOSML models using the syntax and semantics of OOSML. Models can be downloaded from a web server using a web browser. OOSML-aware agents need to be implemented to integrate the models with environments.

5.7.5 Summary

In future new hardware and software technologies will make DSS both easier to develop and easier to use.