Decision support systems

Overview

Decision support systems (DSS) are a subset of computer-based information systems (CBIS). The general term 'computer-based information systems' is a constellation of a variety of information systems such as office automation systems, transaction processing systems, management information systems and management support systems. Management support systems consist of DSS, expert systems and executive information systems. In the early 1970s, scholars in the CBIS area began to recognize the important roles information systems play in supporting managers in their semi-structured or unstructured decision-making activities. It was argued that information systems should exist only to support decisions, and that the focus of the information systems development efforts should be shifted away from structured operational control to unstructured critical decisions in organizations. Decisions are irreversible and have far-reaching consequences for the rest of organizational life. The importance of effective decision making can never be overemphasized. Decision making is, in effect, synonymous with management.

1 Evolution of decision support systems

Since the first electronic general-purpose computer was put into full operation in the early 1940s, data-processing techniques have been continuously advancing. It was in the late 1950s that many organizations began to utilize transaction processing systems (TPS) or electronic data processing (EDP) systems to automate routine clerical tasks such as payroll, inventory and billing. In the 1960s, we witnessed the emergence of management information systems (MIS) with the development of database management systems for collecting, organizing, storing and retrieving data (see MANAGEMENT INFORMATION SYSTEMS (MIS)). MIS were developed to extract valuable management information by aggregating and summarizing massive amounts of transaction data and allowing user-interactive managerial queries. The inclusion of simple modelling and statistical methods as a component of MIS permits computer systems to make routine (structured) decisions.

It was not until 1970 that scholars began to recognize the important roles computer-based information systems (CBIS) play in supporting managers in their semi-structured or unstructured decision-making activities (see DECISION MAKING AND IT/S). Since the 1970s, study of DSS has become an essential part of CBIS. In the 1980s, we witnessed another wave of information technologies, the artificial intelligence-based expert systems (ES), which are to replace and mimic human decision makers in making repetitive decisions in a narrow domain (see ARTIFICIAL INTELLIGENCE (AI); KNOWLEDGE-BASED SYSTEMS). During the mid 1980s, executive information systems (EIS) emerged as an important tool to serve the information needs of executives (see EXECUTIVE INFORMATION SYSTEMS). EIS provides timely and critical information which has been filtered and compressed for tracking and control purposes. The latest addition to CBIS is artificial neural networks (ANN). Neural network computing involves building intelligent systems to mimic human brain functions. ANN attempt to achieve knowledge processing based on the parallel processing method of human brains, pattern recognition based on experience, and fast retrieval of massive amounts of data (see NEURAL NETWORKS). Fuzzy logic, genetic algorithm, and intelligent agents are some of other intelligent techniques that can be used along with neural networks to improve the effectiveness of personal, group, and organizational decision making.

Table 1 summarizes an evolutionary pattern of CBIS and shows the focus of a CBIS from data and information to knowledge and wisdom. The critical information provided by EIS can be used to identify various symptoms of malfunctioning organizational activities in each functional department (see ORGANIZATIONAL INFORMATION AND KNOWLEDGE). These symptoms can be the basis of diagnosing managerial problems. Decision support systems (DSS) are human–computer decision-making systems to support managerial judgements, and intuitions to solve managerial problems by providing necessary information, generating, evaluating and suggesting decision alternatives. Most organizational problems need a combination of quantitative and qualitative data processing. EIS are to deal with those organizational problems that can be better solved by qualitative data processing. Other subsets of CBIS such as TPS and MIS provide data into DSS to be processed by DSS models and managerial judgements.

Table 1 Taxonomy of knowledge

		Technology analogy	*Management*	*Metaphor*
Data	EDP	Elements: H_2O, yeast bacteria, starch molecules	Muddling through	KNOW - NOTHING
Information	MIS	Ingredients: Flour, sugar, spices, fixed recipe for bread only (OR/MS) type	Efficiency (Measurement + search)	KNOW - HOW
Knowledge	DSS, ESS, AI	Choose among different recipes for bread	Effectiveness (decision making)	KNOW - WHAT
Wisdom	HSM, MSS	Why bread and not croissant	Explicability (judgment)	KNOW - WHY

Source: Zeleny (1987: 60)

Definition of decision support systems

Drawing on various definitions that have been suggested (Alter 1980; Bonczek *et al.* 1981; Keen and Scott-Morton 1978; Sprague and Carlson 1982) a DSS can be described as a computer-based interactive human–computer decision-making system that:

1 supports decision makers rather than replaces them;
2 utilizes data and models;
3 solves problems with varying degrees of structure: (a) non-structured (unstructured or ill-structured) (Bonczek *et al.* 1981); (b) semi-structured (Keen and Scott-Morton 1978); (c) semi-structured and unstructured (Sprague and Carlson 1982);
4 focuses on effectiveness rather than efficiency in decision processes (facilitating decision processes).

2 Architecture of decision support systems

As shown in Figure 1, a DSS consists of two major sub-systems – human decision makers and computer systems. Interpreting a DSS as only a computer hardware and software system is a common misconception. An unstructured (or semi-structured) decision by definition cannot be programmed because its precise nature and structure are elusive and complex (Simon 1960). The function of a human decision maker as a component of DSS is not to enter data to build a database, but to exercise judgment or intuition throughout the entire decision-making process (see DECISION MAKING AND IT/S).

Imagine a manager who has to make a five-year production planning decision. The first step of the decision-making process begins with the creation of a decision support model, using an integrated DSS program (DSS generator) such as Microsoft Excel, Lotus 1-2-3, Interactive Financial Planning Systems (IFPS)/Personal or Express/PC. The user interface sub-system (or dialogue generation and management systems) is the gateway to both database management systems (DBMS) and model-based management systems (MBMS). DBMS are a set of computer programs that create and manage the database, as well as control access to the data stored within it. the DBMS can be either an independent program or embedded within a DSS generator to allow users to create a database file that is to be used as an input to the DSS. MBMS is a set of computer programs embedded within a DSS generator that allows users to create, edit, update, and/or delete a model. Users create models and associated database files to make specific decisions. The created models and databases are stored in the model base and database in the direct access storage devices such as hard disks. From a user's viewpoint, the user interface sub-system is the only part of DSS components with which they have to deal. Therefore, providing an effective user interface must take several important issues into consideration, including choice of input and output devices, screen design, use of colours, data and information presentation format, use of different interface styles, etc. Today's decision support system generator provide the user with a wide variety of interface modes (styles): menu based interaction mode, command language style, questions and answers, form interaction, natural language processing based dialogue, and graphical user interface (GUI). GUIs use icons, buttons, pull-down menus, bars, and boxes extensively and have become the most widely implemented and versatile type. The interface system allows users access to:

(1) The data sub-system: (a) database (b) database management software; and (2) The model sub-system: (a) model base (b) model base management software.

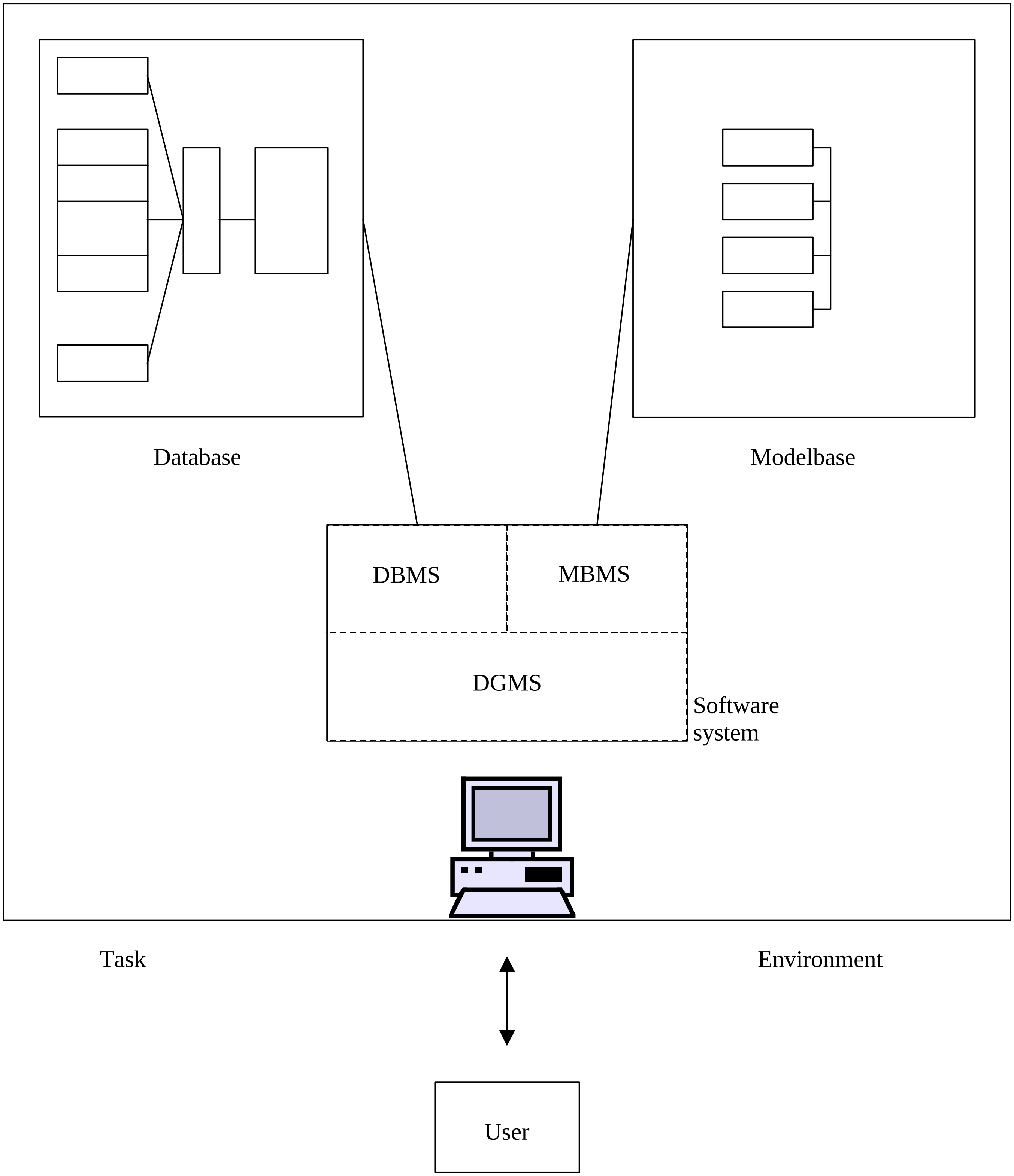

Figure 1 Components of decision support system
Source: Sprague and Carlson (1982: 29)

Decision-making processes and functions

DSS is distinguished from MIS in terms of focusing on effectiveness, rather than efficiency in decision processes (facilitating decision processes). An important performance objective of DSS is to support all phases of the decision-making process (Sprague and Carlson 1982). Simon's model of decision making describes human decision making as having three major steps: intelligence, design and choice. The term 'support' implies many different activities and tasks in each stage of the decision-making process (see DECISION MAKING AND IT/S).

In the intelligence stage, human decision makers play an important role in defining problems to be solved, based on the raw data obtained and information processed by transaction processing systems (TPS)/management information systems (MIS). Alter (1980: 73) suggests seven different types of DSS, based on the 'degree of action implication of DSS outputs' (that is, the degree to which the DSS's output could directly determine the decision). Among them, the following three DSS types are especially useful in the intelligence stage: (1) file drawer systems which allow online access only to particular data items; (2) data analysis systems which permit user(s) to retrieve, manipulate and display current and historical data; and (3) analysis information systems which manipulate the internal data from TPS and augment the internal data with external data using statistical packages and other small models to generate management information.

The majority of DSS in use today are developed to generate and evaluate decision alternatives via 'what-if' analysis and 'goal-seeking' analysis in the design and choice stages. *Accounting* models facilitate planning by calculating the consequences of planned actions on estimate-of-income statements, balance sheets and other financial statements. *Representational* models estimate the future consequences of actions on the basis of partially non-definitional models, including all simulation models. *Optimization* models generate the optimal solutions. *Suggestion* models lead to a specific suggested decision for a fairly structured task. Such systems perform mechanical calculations and leave little role for managerial judgement.

3 Decision support system sub-specialities

As Figure 2 shows, the study of DSS consists of the following three important groups of research areas:

1. Developing a specific DSS (labelled 'A' in Figure 2). Over the past three decades (1970-2000), about 500 specific functional DSS applications have been developed and published in English language journals (labelled 'B').
2. Developing DSS theory:
   (a) developing theory on decision makers, data, model and interface (dialogue) (labelled 'F'–'I');
   (b) developing theory on design, implementation and evaluation (labelled 'C', 'D' and 'E').
3. Study of contributing disciplines (labelled 'J').

The first group of research areas, labelled 'F'–'I', is based on the architecture of DSS heavily influenced by Sprague and Carlson while the second group of research areas, labelled as 'C'–'E', is influenced by the organizational perspectives of Keen and Scott-Morton (1978). The third group of research is DSS application development, labelled 'A' and 'B'.

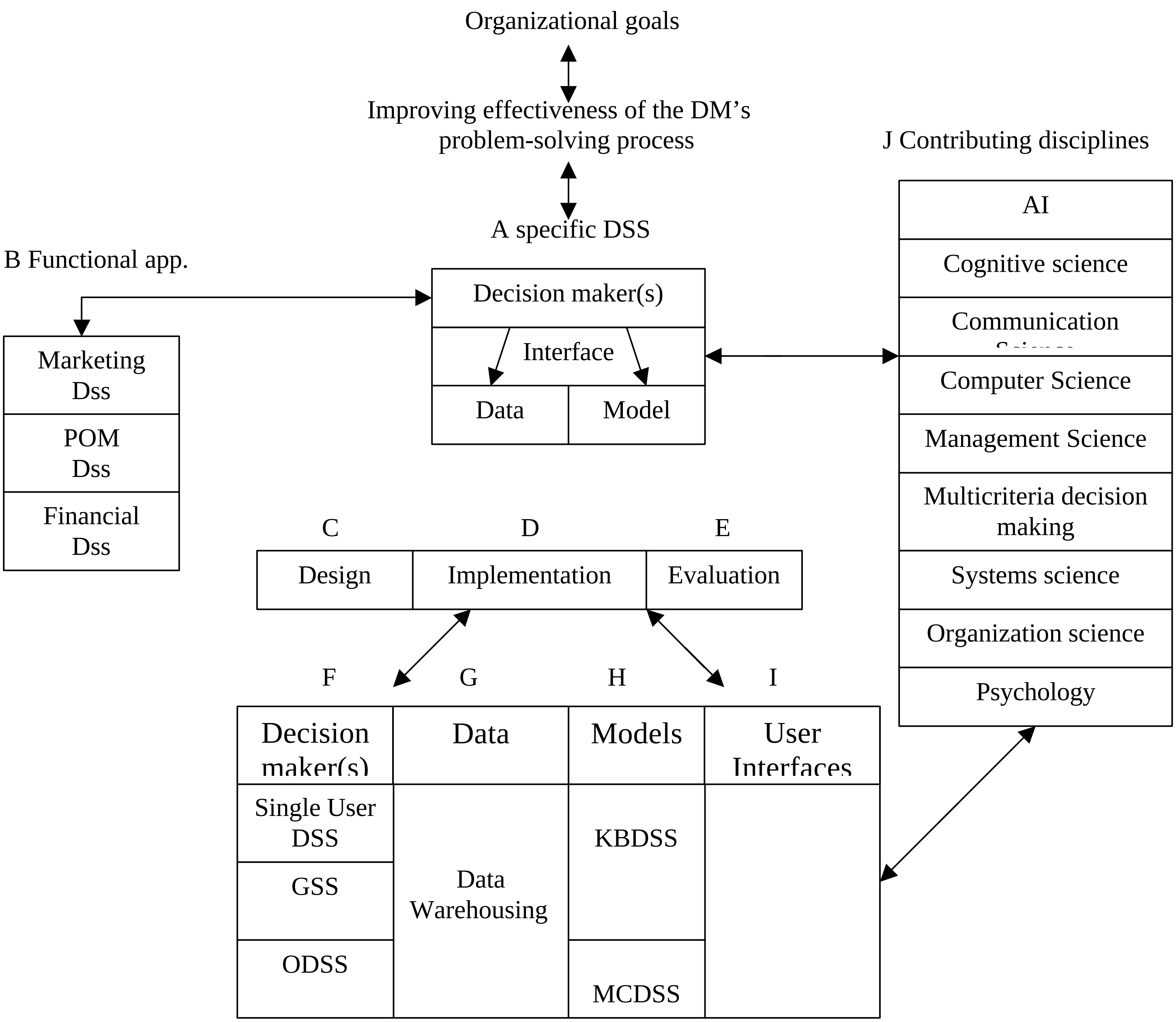

Figure 2 Theory applications and contributing disciplines of decision support system

Data/model management

Since model and data management in DSS are inseparable subjects, many DSS researchers continue to focus on both fields of data and model management. Data are facts which result from the observation of physical phenomena such as daily production quantity, daily sales quantity and inventory level of product A. A database is a collection of interrelated files. Database management systems are computer programs which are primarily concerned with managing a large amount of data in a physical storage such as hard disks and creating, updating and querying databases in an optimal way.

Data management in DSS is a necessary function primarily useful in the intelligence stage of the decision-making process, but not sufficient to support design and choice stages of decision-making processes. To adequately support these stages, DSS should be able to include the following activities: projection, deduction, analysis, creation of alternatives, comparison of alternatives, optimization and simulation (Sprague and Carlson

1982). In performing these essential tasks, DSS utilizes many types of management science/operations research (MS/OR) models. They include linear programming, integer programming, network models, goal programming, simulation and statistical models and spreadsheet modelling. (For a complete list of models used in DSS, see Eom *et al*. 1998.) All these models are stored in the model base. Model-based management systems are computer programs used as a part of a DSS generator to build models, restructure models and update models. In association with model management, multiple criteria decision making (MCDM) model embedded DSS and knowledge-based DSS have emerged recently as important DSS research sub-specialities (Eom and Min 1992; Eom 1996).

User interface sub-systems

The functions of the user interface (dialogue generation and management) sub-system is to:

1 allow the user to create, update, delete database files and decision models via database management systems and model-based management systems;
2 provide a variety of input and output formats. The formats include multi-dimensional colour graphics, tables and multiple windows in a screen;
3 provide different styles of dialogues (such as graphical user interfaces, menus, direct command languages, form interaction, natural language interaction, and questions and answers).

Research in user interface sub-systems has investigated several important issues in the designing, building, and implementing of a user interface. They include data /information display formats (for example, tabular versus graphics), cognitive and psychological factors, use of multimedia (multiple media combined in one application) and hypermedia (documents that contain several types of media linked by association), 3-dimemensional user interfaces, virtual reality and its impact on decision making, geographical information systems, and natural language processing.

Knowledge-based decision support systems

Another important emerging DSS sub-speciality is the study of knowledge-based decision support systems (KBDSS), which are hybrid systems of DSS and ES that help solve a broad range of organizational problems. In integrating DSS and ES, two basic approaches are discernible and labelled expert support systems (ESS) and intelligent support systems (ISS) (King 1993). The key differences between these two systems are as follows. ESS are to replace human expertise with machine expertise, while ISS are to amplify the memory and intelligence of humans and groups (King 1993). A broad range of real-world managerial problems can be better solved by using the analysis of both quantitative and qualitative data. Few would disagree with the notion that there are considerable benefits from integrating DSS and ES. The new integrated system (ESS or ISS) can support decision makers by harnessing the expertise of key organizational members. A bottleneck in the development of knowledge-based systems such as ESS is knowledge acquisition, which is a part of knowledge engineering – the process includes representation, validation, inferencing, explanation and maintenance.

Group DSS/Group support systems/Electronic meeting systems

Single user DSS and group DSS can be distinguished in many different ways in terms of purpose and components (hardware, software, people, procedures). First, group DSS and single user DSS have distinguishable purposes. DeSanctis and Gallupe (1985: 3) define a group DSS as 'an interactive computer-based system which facilitates solution of unstructured problems by a set of decision makers working together as a group'. A single user DSS can be simply defined by replacing 'a set of decision makers working together as a group' with 'a decision maker' (see TEAMS AND TEAMWORK).

Second, to support a set of decision makers working together as a group, group DSS have special technological requirements of hardware, software, people and procedures. Each member of the group usually has a personal computer which is linked to the personal computers of other group members and to one or more large public viewing screens, so that each member can see the inputs of other members or let other members see their work. Group DSS software also need special functional capabilities, in addition to the capabilities of single user DSS software, such as anonymous input of the user's ideas, listing group members' ideas, voting and ranking decision alternatives. The people component of group DSS should include a group facilitator, who leads the session by serving as the interface between the group and the computer systems.

Computer based information systems to support group activities have been conducted under the titles of group decision support systems (GDSS), computer-supported cooperative work (CSCW), group support systems

(GSS), collaboration support systems (CSS), and electronic meeting systems (EMS). GDSS have focused on decision making/ solving problems, while CSCW provide primarily a means to communicate more efficiently. However, these two types of systems, decision making focused systems and communication-focused systems, are becoming indistinguishable. There seems to be a consensus that GSS are a broad umbrella term referring to the collective of computer assisted technologies used to aid group efforts directed at identifying and addressing problems, opportunities, and the issues (Jessup and Valacich 1993).

Organizational decision support systems

An organizational decision support system is defined as 'a DSS that is used by individuals or groups at several work stations in more than one organizational unit who make varied (interrelated but autonomous) decisions using a common set of tools' (Carter *et al*. 1992: 19). According to the same source, an important goal of organizational DSS is to provide 'the glue that holds a large organization together and keeps its parts marching to the beat of the same drummer toward common goals'. The two key factors to achieving these outcomes are: (1) transmittal of consistent, timely information up and down the organizational hierarchy in forms that are appropriate to each decision maker; and (2) a set of decision-aiding models that use this information and that are appropriate for the decisions being made by each decision maker.

4 Sub-specialities based on organizational perspectives

Decision support system design

DSS design is the process of identifying the key decisions through decision analysis, specifying requirements of each DSS component to support key decisions identified through decision analysis.

DSS are designed and implemented to support organizational as well as individual decision making. Without a detailed understanding of decision-making behaviour in organizations, 'decision support is close to meaningless as a concept' (Keen and Scott-Morton 1978: 61). Organizational scientists classify organizational decision making in terms of several schools of thought: (1) the rational model which focuses on the selection of the most efficient alternatives, with the assumption of a rational, completely informed single decision maker; (2) the organizational process model which stresses the compartmentalization of the various units in any organization; (3) the satisficing model which reflects 'bounded rationality' to find an acceptable, good enough solution; and (4) other models.

Decision support system implementation

Use of some computer-based information systems such as TPS and MIS are, in most cases, mandatory. But decision support systems are voluntary systems. In regard to voluntary systems, DSS implementation research has been important for ascertaining the influence of success factors of DSS implementations. DSS implementation researchers are investigating the relationship between user-related factors and implementation success. User factors include cognitive style (the characteristic ways individuals process and utilize information to solve problems), personality (the cognitive structures maintained by individuals to facilitate adjustment to events and situations), demographics (age, sex and education), and user-situation variables (training, experiences and user involvement) (Alavi and Joachimsthaler 1992). future implementation research should be directed toward the development of causal models of user-related implementation factors. Furthermore, it is suggested that DSS researchers shift the research focus from user-related factors to the contextual variables. An important assumption on which the DSS implementation research is based is that DSS are voluntary systems. A recent survey of DSS suggests that an increasing number of DSS have become a strategic tool for organizational survival (Eom et al 1998). Thus, these systems are no longer voluntary ones. Future DSS implementation research must take this changing nature of DSS from voluntary systems to mandatory survival tools. Consequently, individual differences, cognitive styles, personality, demographics, and user-situational variables may become less critical success factors. Shifting the focus of implementation research from user-related factors to task-related, organizational, and external environmental factors may be necessary to reflect the changing decision environment in which organization must survive and prosper (Eom 2000).

Decision support system evaluation

Evaluation of DSS is concerned with analysing costs and benefits of DSS before and after DSS development and implementation. The unique nature of DSS evaluation is that although some DSS provide substantial cost saving and profit increases, measurements of benefits of DSS have been problematic as quantification of the positive impacts of improved decision process is difficult. Therefore, DSS evaluation research deals with the following methodologies: decision outputs, changes in the decision process, changes in managers' concepts of the decision situation, procedural changes, cost/benefit analysis, service measures and managers' assessment of the system's value (Keen and Scott Morton 1978).

5 Application development research

DSS application development is the fruit of DSS study. Theories developed from DSS research must be assimilated into the DSS development process. The next section briefly introduces the current status of DSS application development research in corporate functional management areas.

Applications of decision support systems

According to a survey (Eom *et al*. 1998), computer-based DSS are widely applied in both profit making (about 72 per cent) and non-profit organizations (about 28 per cent). In corporate functional management fields, production and operations management contain the largest number of application articles, followed by management information systems, marketing, finance, strategic management and multifunctional areas. Two functional fields are relatively minor fields for DSS application: international business and accounting/auditing. Table 2 lists some of the important application examples from the survey. Refer to http://cstl-hcb.semo.edu/eom/ORINSIHT.HTM for a more detailed classification of 271 DSS articles by application areas.

Table 2. DSS Applications in Corporate Functional Management

1. **Accounting / Auditing**

Auditing health insurance claims
Estimating pencil manufacturing cost
Stochastic cost-volume-profit analysis

2 **Finance**

Asset-liability management
Cash management and debt planning
Capital budgeting
Evaluating financial risks
Financial analysis and diagnosis
Funding strategic product development
Locating banks
Managing portfolio
Planning in mergers and acquisitions
Selecting R&D project
Structuring optimal lease
Real estate appraisal and investment
Setting interest rates for money market deposit accounts
Small business financial planning

3 **Human Resources Management**

Manpower planning
Massive personnel assignment
Resolving labor management dispute
Tracking critical human resources information

.4 **International Business**

Allocating investment funds in MNCs
Analyzing international investment options
Planning global logistics
Planning global marketing / production / distribution

5 **Information Systems**

Data Communication

Evaluating LAN topologies
Designing a fiber optic WAN

DSS Generators

Application (domain)-independent system for supporting

- group decision making
- massive data retrieval and extraction
- MCDM problems
- consensus reaching processes
- generating and exploring alternatives
- decision conferencing
- multicultural / multilingual communication
- small groups decision making under uncertainties
- modeling tasks
- the Japanese style of group decision making

Systems Analysis, Design, Development & Evaluation

Designing online retail banking systems
Evaluating MIS Effectiveness
Joint application development
Optimizing MIS project portfolio mix
Systems analysis and planning
Strategic planning of system development

Information Resources Management

Planning information systems security
Supercomputer acquisition and capacity planning

6 **Marketing**

Allocating retail space in retail outlets
Competitive pricing and market share
Designing freight networks and integrated distribution systems
Distribution planning
Logistics planning and vehicle scheduling
Managing hazardous material shipments
Media-planning for advertising agencies
Measuring direct product profitability in retail merchandising
Selecting telemarketing sites

7 **Production and Operations Management**

A. Planning for Demand

Designing sampling procedures for accurate estimation of electrical demand
Forecasting rotable aircraft parts demand

B. Master Scheduling

Production planning
Production planning and control

C. Operations Scheduling and Control

C1. Manufacturing Industry

Designing electronics test facilities
Managing manufacturing logistics and dispatch
Operations scheduling
Operations control
Process planning
Planning for offshore drilling
Project scheduling and termination

C2. Service Industry

Airline arrival slot allocation system
Integrated management of fleet
Scheduling courier vehicle, flight, and day-off assignment for airlines cockpit crew
Train dispatching

D. Operations Design

Evaluating personal and machine productivity
Gasoline blending and planning refinery operations
Managing quality-control process
Product design
Selecting machines in integrated process planning
TQM consultant

E. Capacity Planning

Automating factory
Capacity planning
FMS configuration

FMS Scheduling and control
Just-in-time production
Line-balancing
Personnel assignment within FMS production cell
Setup reduction investment
Selecting robot

F. Inventory Planning

Inventory planning and control
Material requirement planning

G. Resource Management

Designing materials management processes
Procurement in business volume discount environments
Purchasing and material management of large projects
Selecting suppliers

8 **Strategic Management**

External environment and industry analysis
Strategic analysis of
- mergers and acquisitions
- multi-level (corporate, division, department) and mulitifuntional corporate planning
- product/market position

Grand strategy selection (managing a portfolio of new product development research projects, and terminating projects)
Strategy control and evaluation
Decision conferencing for Strategic planning
Integrated strategic planning process support
Managing organizational crisis

9 **Multifunctional Management**

Multi-refinery, multi-period capital investments
Planning for expanding refining capacity
Budgeting and manpower planning
Strategic production and distribution planning
Manpower and vehicle scheduling
Integrated multifunctional systems for chemical production
Supporting reciprocally interdependent decisions

6 The future of decision support systems

A host of new tools and technologies are adding new capabilities to DSS/ESS and will reshape DSS developments in organizations. They include hardware and mathematical software developments, artificial intelligence techniques, the data warehouse/multidimensional databases (MDDB), data mining, online analytical processing (OLAP), enterprise resource planning (ERP) systems, intelligent agents, telecommunication technologies such as World Wide Web technologies, the Internet, and corporate intranets.

Single user decision support systems

Ever-increasing computing power makes it possible to solve a large-scale mathematical optimization model in a fraction of a second. The size of the problem solvable by commercial software is virtually unlimited, only dependent upon the size of random access memory of computers and the user's patience. Moreover, several solvers are built into the spreadsheet programs such as Microsoft Excel and Borland's Quattro-Pro, along with the capabilities of linking to databases and graphical user interfaces.

With the increasing trend of national and global communication networking, single user DSS will increasingly become a part of organization-wide distributed decision-making (DDM) systems. The DDM system consists of several single user DSS that work together and independently to make a sequential decision such as joint production/marketing decisions (Rathwell and Burns 1985). DDM systems work as a mechanism for integrating a number of separate DSSs that coexist in an organization, facilitating group cooperation between several DSSs in a distributed environment, and meeting the specific needs of group planning and group decision making.

Notable developments that will significantly affect the future development of DSS are the data warehouse, data mining and intelligent agents. The data warehouse is a subject-oriented, integrated, time-variant, and non-volatile (read only) collection of a relational/multidimensional database (MDDB) optimized for decision support, which is separated from operational databases. MDDB organizes data as an n-dimensional cube so that users deal with multidimensional data views such as product, region, sales, time, etc. with a faster query response time. Data mining, also known as Knowledge Data Discovery, refers to discovering hidden patterns/trends/classes/insights/relationships from data, and it attempts to automatically extract knowledge from the in large databases, either in the data warehouse or elsewhere (e.g., spreadsheets, transaction processing system files, etc.) (see DATA WAREHOUSING and DATA MINING).

Intelligent agents (known also as intelligent interfaces, or adaptive interfaces) research is an emerging interdisciplinary research area involving researchers from such fields as expert systems, DSS, cognitive science, psychology, databases, etc. Intelligent agents research has contributed to the emergence of a new generation of active and intelligent DSS and EIS. The active DSS will be equipped with the tools (stimulus agents) that will act as experts, servants, or mentors to decide when and how to provide advice and criticism to the user, while the user formulates and inquires about its problems under the continuous stimulus of electronic agents. The essence of active decision support activities includes monitoring decision making processes and stimulating creative ideas through carrying out insightful conversations with decision makers.

Knowledge-based decision support systems (Intelligent DSS)

An increasing number of systems are incorporating domain knowledge, modelling, and analysis systems to provide users the capability of intelligent assistance. Knowledge base modules are being used to formulate problems and decision models, and analyse and interpret the results. Some systems are adding knowledge-based modules to replace human judgments. Managerial judgements have been used to ascertain (assess) future uncertainty and to select assumptions on which decision models can be based. Some decisions are both knowledge and data intensive. Consequently, a large amount of data usually requires considerable efforts for their interpretation and use.

The knowledge-based DSS include a knowledge management component which stores and manages a new class of emerging AI tools such as machine learning and case-based reasoning and learning. These tools can obtain knowledge from prior data, decisions and examples (cases), and contribute to the creation of DSS to support repetitive, complex real-time decision making. Machine learning refers to computational methods/tools of a computer system to learn from experience (past solutions), data and observations, and consequently alter its behaviour, triggered by a modification to the stored knowledge. Artificial neural networks and genetic algorithms are the most notable approaches to machine learning.

The role of knowledge-based DSS should be to allow experts to broaden and expand their expertise, not to narrow it down. Zeleny suggests the important future direction of knowledge-based DSS development in this way (Zeleny 1987: 65):

> Trends toward narrow specialization of experts did take place in the society. The task of supportive expert systems should be to counteract such expertise-destructive trends, not to amplify them further. … Observe that so-called 'knowledge explosion' (also 'information explosion' or 'information society') are misnomers limited to the structural ('surface') knowledge only. …Even today we can aim for a 'renaissance man', especially with the help of expert systems constructed to move in the direction opposite of specialization, towards reintegration of knowledge, overcoming specialization, negating the 'experts' themselves.

The World Wide Web and Group/Organizational/Global DSS

The World Wide Web is increasingly being used as the client-server platform of many business organizations due to its network and platform-independence and very low software/installation/maintenance costs. More and more groupware will be inextricably tied to Internet technology. Especially, the World Wide Web is becoming an infrastructure for the next generation of decision support systems and groupware applications. Many groupware products, such as Lotus Development's Domino and Microsoft's Exchange, are integrating more Internet protocols into them. Microsoft's next version of Office suite is expected to completely remove the boundaries between the World Wide Web and groupware. Many companies are applying groupware technology to increase business-to-business collaborations (e.g. collaborations among the company, its customers, and its suppliers, a.k.a. superworkgroup software) over intranets and extranets (see COMPUTER-SUPPORTED COOPERATIVE NETWORK). Another development in the information systems area is the growing importance of enterprise resources planning (ERP) systems. ERP systems are a new generation of information systems packages that integrate information and information-based processes within and across functional areas in an organization. ERP has focused primarily on processing of transaction data resulting in the creation of the extensive, organizational databases of an organization that may consist of individual business units across the globe. The extensive databases created by the ERP system provide the platform for decision support, data warehousing, data mining, and executive support systems. integrated solutions provided by the ERP system are attributable to the use of the common database.

As we enter the age of the global village where geographical and temporal boundaries are shrinking rapidly, global DSS are emerging as the new frontiers in management information systems area. Over the next decade, DSS will focus on teams, work groups, and distributed, decentralized organizational structures (King 1993). Consequently, many organizations will increasingly design and implement group/organizational/global DSS. Global management support systems (MSS) will emerge as a key element in management decision making and as an essential weapon against global competitors. Supporting global business activities is becoming a most important and extremely complex task. To effectively cope with multinational managerial problems such as multiple currency management, foreign exchange risk management, global tax management and global consolidated reporting, global DSS are not enough. It is essential to develop an integrated global MSS which integrates EIS, artificial neural networks, ES with knowledge base captured from numerous experts in the same subject area as well as from a variety of specialists in international financial management, international accounting, international tax areas, and so forth.

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Further reading

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See also: ARTIFICIAL INTELLIGENCE; BUSINESS INFORMATION; DECISION MAKING AND IT/S; DECISION MAKING, MULTIPLE-CRITERIA; ENTERPRISE RESOURCES PLANNING (ERP), EXECUTIVE INFORMATION SYSTEMS; INFORMATION TECHNOLOGY; KNOWLEDGE-BASED SYSTEMS; MANAGEMENT INFORMATION SYSTEMS (MIS); NEURAL NETWORKS; ORGANIZATIONAL LEARNING

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