A REVIEW AND CRITIQUE OF DSS

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1. INTRODUCTION

For some 20 years the ideas underlying the decision support systems (DSS) field have been influential in directing information systems research and development efforts towards a closer union of computing with management decision making. While not always fulfilling the dreams of its founders, DSS has attracted, and continues to attract, considerable academic and practitioner interest. This paper provides a brief overview of the DSS field and places some of its major research issues in critical perspective. From this, we identify some needed directions for future research.

Section 2 contains a brief history of prior DSS research. In the space available, we cannot give a complete overview of the field. Instead, we describe the origins and aspirations of DSS, discuss several significant areas of past and present research and reference some of the key literature. We cover the following: DSS definitions, classification schemes and frameworks, model management systems, artificial intelligence and DSS, development methodologies, user interface research, human information processing and decision aids, executive information systems, group decision support systems, organizational decision support systems, empirical evaluations of DSS performance, and DSS in practice.

Section 3 provides a critique of DSS research to date, and argues that, although DSS has been relatively successful, there is now both the need and the means to broaden its scope and objectives. This need to revisit some of the basic principles that have governed DSS research was the primary motivation for the Information Systems and Decision Processes (ISDP) project[1] out of which this paper was born.

2. OVERVIEW OF RESEARCH IN DECISION SUPPORT SYSTEMS

2.1 Origins of DSS

The concept of Decision Support Systems, DSS, was born in the early 1970s and prospered through the 1970s and 1980s. It developed at the intersection of two trends. First was a growing belief that existing information systems, despite their success in automating operating tasks in organizations, had failed to assist management in many higher level tasks. Second was a continuing improvement in computing hardware and software that made it possible to place

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[1]The ISDP Project involved a concentrated effort to discover fruitful new directions for DSS research. Approximately 40 DSS researchers worked on this project over a period of several years. The ISDP process culminated in a workshop held at the University of Arizona, Tucson in October, 1989, and the subsequent publication of a book (Stohr and Konsynski [1992].) This paper is a slightly modified version of Chapter 1 of that book.

meaningful computing power (powerful, usable, etc.) directly in the hands of managers and executives. DSS systems were meant to be decision focused, supportive of higher levels of management, adaptive, and user initiated and controlled. While not always fulfilling the dreams of their sponsors, DSS applications have burgeoned and the study of DSS has grown into an important and accepted subfield of information systems theory and practice.

Two seminal articles in the early 1970's defined DSS and have had a major influence on the field ever since. The first of the articles, "Models and Managers: The Concept of a Decision Calculus" (Little [1970]), has its roots in management science. It opened with the observation that: "The big problem with management science models is that managers practically never use them." Little pointed out the difficulty of developing effective computer implementations of management science models and stressed the importance of the model interface. Moreover, he argued that the interface requirements had implications for the design of the model itself. He then described the concept of a "decision calculus" as a "model-based set of procedures for processing data and judgements to assist a manager in his decision-making". The requirements for such a system to be successful were that it be (1) simple, (2) robust, (3) easy to control, (4) adaptive, (5) complete on important issues, and (6) easy to communicate with (ibid p.B 470). Each of these requirements have been recurring issues in the DSS field over the last twenty years.

The second of these articles, "A Framework for Management Information Systems" by Gorry and Scott Morton [1971] defined the term "Decision Support System" and has been widely recognized as the foundation paper for the field. Gorry and Scott Morton were motivated by the failure of management information systems (MIS) practitioners to understand the range of possible applications of computers in organizations. In particular, they argued that a greater proportion of MIS resources should be devoted to the development of systems to support "decision processes" in organizations. They felt not only that the technology (time-sharing systems and relatively cheap minicomputers) was available, but that enough was understood about how human beings solve problems and how to build models that capture aspects of the human decision making process. Moreover, the authors felt that much greater payoffs were possible in this area.

Because this paper has had such an influence on the field, it is worth further explanation at this point. The Gorry and Scott Morton framework maps potential computer support for management activities on two dimensions (see Figure 1.)

	Operational Control	Management Control	Strategic Planning
Structured	Decision Making Systems		
Semi-structured	Decision Support Systems		
Unstructured			

Figure 1
Gorry and Scott Morton Framework

Each axis represents a continuum rather than a discrete classification. The horizontal axis consists of Anthony's three levels of managerial activity: operational control, management control and strategic planning (Anthony [1965]). The vertical axis contains three classes of decision situation structured, semi-structured and unstructured.

To understand the latter terms, we need to regress slightly. The structured and unstructured decision situations correspond roughly to Simon's "programmed" and "unprogrammed" decisions, respectively (Simon [1960]). According to Simon, decisions are programmed to the extent that a definite procedure can be worked out beforehand that can be invoked whenever the decision situation occurs. Decisions are unprogrammed to the extent that they are novel and no cut-and-dried method for handling the problem exists, that they are important enough to warrant special treatment, or that the decision structure is elusive and complex. Programmed decision situations can be fully automated; in unprogrammed situations, the system must fall back on "whatever general capacity it has for intelligent, adaptive, problem-oriented action." Simon also proposed three phases of decision making: intelligence, design and choice. Intelligence involves a search of the environment for conditions calling for a decision. Design involves the development and analysis of alternative courses of action. Choice involves a selection from the alternatives generated by the design activity.

Returning to the Gorry and Scott Morton framework, it is significant that they include human decision makers in the loop with the computer system. Decision tasks could be divided between human decision makers and a computer system in any number of ways. According to their definitions, (op, cit. p. 60) in a fully structured situation, all of the above three phases of decision making are structured, and, therefore, potentially automatable - that is we:

> "can specify algorithms, or decision rules, that will allow us to find the problem, design alternative solutions, and select

> the best solution. An example here might be the use of the classical economic order quantity (EOQ) formula on a straightforward inventory control problem. An unstructured problem is one in which none of the three phases is structured. Many job-shop scheduling problems are of this type."

Gorry and Scott Morton further define the semi-structured case as one in which one or more of the design, intelligence and choice stages is unstructured. Furthermore, they asserted that the line between structured and unstructured decision situations moved over time as management scientists and users understood management problems better and were able to bring more structure to them.

Gorry and Scott Morton proposed that their framework be used to guide the allocation of information systems resources - in particular, to the situations shown on the bottom and to the right in Figure 1, which are more unstructured and more strategic and where greater payoffs from systems that support management activities might be obtained. The term Decision Support Systems (DSS) was proposed to describe such computerized systems. The term "support" is key here. These systems were not decision-making systems (after all, the assumed decision situation was at least partially unstructured) nor were they simply to provide higher quality information from the use of models and databases. These systems were meant to improve the quality of the managerial decision process itself. They were to be an adjunct to decision makers - to extend their capabilities but not to replace them.

Following these two articles, there was significant growth in the literature related to DSS during the 1970s and 1980s. A review of DSS research for the period 1975 to 1985 is contained in Elam et al [1987]. A number of books devoted to DSS (including: Scott Morton [1971], Keen and Scott Morton [1978], Alter [1980], Bonczek et al [1981], Sprague and Carlson [1982], Bennett [1983], Turban [1988] and Silver [1991]) have helped formalize and popularize the field. DSS is now accepted as a course within undergraduate and graduate business school programs and as a topic area at academic meetings throughout the world. DSS software is an important and growing component of the software industry. While many developments have taken place both in practice and in theory over the last twenty years, it is remarkable how well the central message of the above two papers has stood the test of time.

2.2 DSS Definitions

A significant amount of soul searching has taken place regarding definitions of the field. Two definitional issues have been especially pertinent. The first concerns the definition of "structuredness". The second issue has been the effort to distinguish DSS systems from other MIS applications or operations research models.

Several authors have defined the structured-unstructured dimension somewhat differently to Gorry and Scott Morton. Rather than considering the unstructuredness of a task as a whole, the detailed decision making activities associated with each of the three stages of decision making associated with the task can be assessed individually on a structured/unstructured dimension (Lerch and Mantei [1984]). A number of authors have defined unstructuredness in terms of a traditional decision theory model. According to this view, a decision situation is unstructured to the extent that objectives are difficult to determine or conflicting, the alternative actions that might be taken are hard to determine, and their affect on outcomes is uncertain (Stabell [1979]). To some, computerized DSS are useful on the "structurable" part of a decision problem, while the (truly) unstructured part of a problem is that which, given current modeling and conceptual capabilities, must be left for resolution by the decision-maker, or group of decision makers, using the DSS (Ginzberg and Stohr [1981]). From a psychological viewpoint it is supposed that the human memory contains strategies that can be brought to bear in such situations, but that these are not understood well enough to be susceptible to automation (Bonczek et al. [1981]).

Turning to the second definitional question (characterizing DSS software), it is useful to consider three classes of software (Sprague [1980]):

. DSS tools: the underlying technical building blocks (graphics packages, data base management systems, and so on) for both the generators and applications (Sprague and Watson [1989]).

. DSS Generator: A combination of hardware/software that facilitates the construction of DSS applications (Lotus 1-2-3 is a popular example).

. Specific DSS: A DSS application is a hardware/software system actually used by a decision maker or group of decision makers.

DSS Generators and tools are relatively easy to recognize. The debate over the definition of DSS software focuses on how DSS applications can be recognized. Various writers have offered a range of attributes as defining necessary characteristics of a DSS application:

. supports decision makers rather than replaces them.

. is used in semi-structured or unstructured decision situations.

. is focused on the effectiveness rather than the efficiency of decision processes.

. supports all phases of decision making.

. is interactive, easy to use.

. is controllable by the user.

. is used by managers and executives.

. uses data and/or models.

. is developed by an evolutionary design process.

. facilitates learning.

In our view, only the first two attributes are required in a basic definition of a DSS; the other eight items may sometimes be characteristics of DSS but are by no means necessary attributes. However, the decision as to whether a particular software system is a DSS is largely a matter of judgement. Overviews of several DSS definition issues are contained in Alter [1980], Ginzberg and Stohr [1981], and Sprague and Watson [1989].

2.3 DSS Classification Schemes and Frameworks

Another aspect of DSS definitions concerns efforts to classify extant DSS applications. Two efforts will be mentioned here. Alter [1977] divides DSS software into seven types depending on the degree to which system outputs could directly determine the decision. Three of these (file drawer, data analysis, and analysis information systems) are data-oriented, while another four (accounting models, representational models, optimization models and suggestion models) are model-oriented.

Bonczek et al [1981] also differentiate DSS systems on the basis of their data handling and modeling capabilities. They focus on the nature of the language provided by the DSS to manipulate data and models and the degree to which these languages are procedural. They define three levels of procedurality: procedural languages require users to specify how the data is to be obtained or how the model is to process information; at an intermediate level, DSS's can provide a means for users to provide parameters to prespecified data retrieval requests or prespecified models; at the highest level of sophistication, non-procedural languages require users to state only the information that is needed. The concept of a non-procedural model manipulation language is, relatively unique to DSS, though a similar notion is common in research on systems development (Konsynski [1986]). The idea is that users should be able to specify whatever they want from a DSS, regardless of whether that information exists in a data bank, must be computed by an existing model, or must be computed by an entirely new model constructed automatically using model components stored in the system. The goal of much research in model management systems (see next section) is to develop this last level of capability.

Along with the basic definitions, the research frameworks of a field provide insights into its world view and aspirations. We now provide brief overviews of several well known and influential frameworks.

An early attempt to extend the concepts of Scott Morton, Keen and others to build a comprehensive framework for DSS is given by Sprague [1980]. The major elements in this framework are technology levels, development approaches, the roles of users and builders of DSS, and performance objectives. An alternative framework based on systems theory is provided by Ariav and Ginzberg [1985]. In their view there are five main components of DSS as outlined in abbreviated form below:

1. Environment:
   Task Characteristics
   (structurability, decision phase, operational level, functional area)
   Access Patterns
   (interaction mode, user community, relation to other systems)

2. Role:
   Levels of support (e.g. retrieve data, run models)
   Decision range (generalized versus particularized)
   Supported process (e.g. cognitive support, learning, coordination, communication)

3. Functional Components:
   System functions: data, model and dialogue management
   Division and specialization of labor

4. Arrangement of system components and links to environmental elements

5. System resources
   Hardware
   Software (DSS tools, generators, generalized DSS)
   People
   Data

A third framework that concentrates on the affects a DSS has on its users is provided by Silver [1988]. The framework consists of three "tiers" corresponding to questions commonly asked by DSS users:

Functionality: What can it do? (It runs an optimization algorithm to support scheduling decisions).

User View: What does it look like? (It has "operators" such as LOAD, SOLVE and DISPLAY and "navigational aids" such as context sensitive help features that supply cognitive support to users).

Holistic Attributes: How will it affect decision making? (e.g. It restricts decision making to a fixed process or guides users in their selection of a decision process).

Several other frameworks that take a systems architecture or systems development viewpoint will be mentioned below.

2.4 Model Management Systems

Data base management systems are software tools that help programmers develop data-oriented applications and support ad hoc requests for information. In addition, they provide security functions, help maintain data integrity, and provide data dictionary and other data administration functions. The basic idea of a model management system is similar, as it performs all of the above functions for models plus other functions that are peculiar to models and the modeling process. Automatic model synthesis has already been mentioned (see also Blanning [1987], Liang [1988a]). In addition, research has been performed for each of the phases of developing and using models: selection of appropriate models (Athey [1989]), formulation (Raghunathan [1987], Murphy and Stohr [1986]), performing sensitivity analyses (Blanning [1979], Konsynski and Sprague [1986]) and interpreting results (Greenberg [1987].)

The term model management has always had a broad connotation in the sense that it is concerned with the total environment in which models are developed and used. This involves managing the data and user interaction as well as managing models per se. Thus, a framework for a model management software architecture that has been widely adopted consists of three subsystems for user interface management, database management, and model management, respectively (Sprague [1980]).

Blanning [1983, 1987] has developed a relational theory for model management. Other recent developments include the use of techniques derived from the field of artificial intelligence (Holsapple et al [1987], Dhar [1989], Dolk and Konsynski [1984], Elam and Konsynski [1987], Krishnan [1990], Liang [1988b]) and attempts to model the user explicitly to aid in the learning and discovery process associated with DSS (Manheim [1989]).

A comprehensive review of the literature on model management is contained in Blanning [1990].

2.5 DSS and Artificial Intelligence

The aspirations of artificial intelligence (AI) stand in an interesting relationship to those of DSS. The guiding objective of AI is to emulate human intelligence. For example, in the subfield of AI known as expert systems, the objective is to understand human expertise in some domain and codify it in a computer program (see Hayes-Roth et al. [1983]). An expert system is most successful if it completely replaces human decision makers. The fact that many expert systems support rather than replace decision makers is an unfortunate fact of life to be explained by the complexity of the problem and our limited capabilities in building such systems. On the other hand, from its inception, DSS has recognized the need to support decision making in unstructured domains. It seeks to provide a helpful environment for exploration of a problem domain but allows its users to draw their own conclusions. Thus, an expert system may use concepts from DSS and a DSS might contain an expert system component; depending on the point-of-view they are both examples of DSS systems or both examples of expert systems. A comprehensive treatment of DSS and expert systems is contained in Turban [1988]. The relationship between DSS and expert systems research is explored in Henderson [1987].

Another important contribution of AI to DSS is that it provides sophisticated tools and concepts for building advanced software systems. AI approaches are extensively used in the field of model management (Blanning and Whinston [1992]). Going one step further, Holsapple et al [ibid] suggest a need to progress from model management to knowledge management in which models in the usual sense are just one of many types of knowledge.

2.6 DSS Development Methodologies

While user involvement is often advocated in other areas of information systems development and implementation, it has been considered of paramount importance to the success of the DSS development process. User involvement is more important in DSS because, by definition, their development involves "structuring" or "normative modeling" (Gerrity [1971]) of the decision process. Further, the use of DSS applications has been elective and, historically, focused on the decision processes of individual users. Generally, some form of prototyping or evolutionary development process has been proposed in which developers and users jointly learn the requirements of the model and develop the DSS (Keen [1980], Moore and Chang [1980], Sprague [1980]).

A detailed DSS development methodology that is based on a model of the decision processes of users was suggested by Carlson [1979] and Sprague and Carlson [1982]. Their approach is intuitively appealing: decision makers use conceptualizations of the problem, different decision making processes, various memory aids, and various conventions for controlling the overall process. Their ROMC methodology (ROMC stands for representations, operations, memory and controls) involves matching each of these four elements with the most appropriate computer representations, processing operations (to support intelligence, design and choice), automated memory aids, and controls for managing the interaction with the computer. An alternative, "decision research approach" to DSS design has been proposed by Stabell [1983]. This involves the development of both a descriptive model (how the decision is currently made) and a normative model (how the decision should be made); the differences between the two models are then resolved during the design process.

A number of important contributions to DSS thought and practice have come from research into the link between individual or organizational objectives and information systems. While much of this research has been aimed at information systems in general (not just DSS) it has close links to DSS, and has had an enormous impact on the field. Important here is the early work by Churchman [1971] on information systems as processes of inquiry and his emphasis on the dialectic approach (evolutionary thesis/counter-thesis argumentation) as a method for determining system objectives. Continuing this work, Mason and Mitroff [1981] developed methods for "stakeholder analysis" and "assumption surfacing" that have had practical applications and influenced research in this area.

One of the most intuitively appealing and popular concepts in DSS design is that of Critical Success Factors (CSF's) (Rockart [1979b]). CSF's are those few factors on which individuals or organizations must concentrate if they are to achieve their objectives. CSF's differ from situation to situation and change over time. The CSF methodology involves determining the critical factors, choosing suitable measures, and developing information systems to report these measures to management.

The development process, and the form of DSS produced by that process, is closely linked to the purpose of the DSS. Some authors have asserted that a DSS must support learning (e.g. Keen [1980]) and to some, this is the major benefit of a DSS. In any case, there is general agreement that DSS cause change in decision processes (the alternative is that they are either not used or their results are ignored). An interesting question arises as to whether designers should try to direct the change in decision processes or should simply provide the DSS as a tool to be used in whatever manner is thought most appropriate by the decision maker (Stabell [1983], Silver [1990]). Most researchers, perhaps taking the middle "S" in DSS literally, seem to have accepted the latter "non-directed" approach; at least this seems to be what is meant by suggesting that DSS interaction should be controlled by the user. Silver [1990] presents the cases for both sides of this issue and describes two design strategies, system restrictiveness and decisional guidance, that allow designers to achieve either goal.

A framework for understanding and choosing between the different design approaches mentioned above is given in Ariav and Ginzberg [1985].

2.7 User Interfaces

Continuing developments in the technology of computer interfaces, such as windowing software, high resolution screens, interactive graphics, voice recognition, multi-media systems, and so on, have a major impact on the acceptance and effectiveness of DSS applications. A subfield of computer science, human factors, is concerned with the effective design of computer interfaces for a broad range of computer systems including DSS (Shneiderman [1987]). While obviously, relevant to DSS, it is, in general, more microscopic and clinical than DSS research in the area of computer interfaces.

A number of DSS researchers have investigated the affect of computer-generated graphics on management decision making. Much of this research concerns the relative effectiveness of graphical and tabular displays of information. In a comprehensive review of this literature, DeSanctis [1984] notes that the research results have been inconclusive with different studies finding advantages for graphical displays (e.g. Benbasat and Schroeder [1977]), tabular displays (e.g. Lucas [1981]), or no significant differences (Dickson et al. [1986]). DeSanctis argues for a more detailed approach that takes account of the task situation, environment, and human information processing strategies (see also Benbasat and Dexter [1985], Remus [1987], and Jarvenpaa [1989]).

While the above results on the effectiveness of computer graphics in improving decision making are equivocal, there is evidence showing that graphics is effective as a presentation medium where the objective is either to inform or to persuade (Ives [1982]). It is also apparent that graphical user interfaces (GUI) are preferred by many people. Finally, mention should be made of the emerging area of visual interactive modeling (VIM) in which users interact with a graphic image of their problem and immediately see the results of their decisions on the computer screen. VIM applications originated in the area of computer simulation but have had wide application in many other areas. Turban and Carlson [1988] provide an overview and give the results of a survey showing that VIM enhances managerial involvement and understanding of the modeling process.

The close relationship between users and models has led a number of authors to enlarge the traditional view of the user interface to include recognition of the conceptual information exchanged between users and models. According to this view, the user interaction should be guided by an explicit model of the user that is maintained and manipulated by the DSS system (Manheim [1989], Lerch and Prietula [1992].)

2.8 Human Information Processing and Decision Aids

Cognitive style research asserts that DSS design should reflect individual differences in the way that decision makers gather and process information (Benbasat and Taylor [1978]). For example, a DSS might provide only summary information to a person with a cognitive style that involves "preceptive" information gathering (looking at the whole picture rather than messing with details). Unfortunately, research seeking to show an advantage in matching DSS features to the cognitive styles of users has not provided strong prescriptions for DSS design (Huber [1983]).

Although DSS is concerned with supporting decision making, there has been relatively little research by DSS researchers on the decision processes of individuals and the social interaction that takes place as groups make decisions. Apart from the foray mentioned above into cognitive style research, DSS researchers have generally accepted the Simon phases of decision making (intelligence, design and choice) as providing an adequate model of decision making. Recently, however, there has been a realization that cognitive science and behavioral decision theory in particular, have important implications for DSS design and use.

Elam et al [1992] explores these relationships in detail and develops a framework for research that borrows from both prior DSS research and the more process-oriented research of behavioral decision theory.

Generic decision aids (sometimes called cognitive aids) are aimed at improving the decision making process itself, independent of any particular decision situation. Such decision aids can:

- move the boundary between what is structured and unstructured by helping users discover and understand various components of their decision problem,
- suggest a sequence of human information processing steps that should be performed,
- help users manipulate intuitive and judgmental relationships,
- extend human memory and computational capabilities.

Multiple criterion decision making techniques are examples of cognitive aids for situations in which the choice phase of decision making is unstructured because choices have to be made on the basis of multiple conflicting criteria (Keeney and Raiffa [1976], Zionts and Wallenius [1978], Saaty [1980]). Cognitive support for groups is discussed in Johansen [1989]. As another example, a relatively recent stream of DSS research is investigating the possibility of using software to enhance human creativity (Weber [1986], Elam and Mead [1990]).

2.9 Executive Information Systems

The idea that top executives would use the computer to assist them in their control and decision-making tasks has been slow to be realized. Nowadays, however, executive information systems (EIS) are being introduced at an accelerating rate. Amongst the earliest papers describing EIS were Rockart [1979a] and Rockart and Treacy [1982]. Currently, approximately one third of the largest firms in the U.S. have installed EIS systems (Rockart and De Long [1988]).

EIS generally obtain status information from the organization's MIS, and external information from a number of information utilities that supply stock market, economic data, and trade information. While EIS is generally considered a part of DSS, EIS systems often serve the same purpose intended for MIS systems. Thus, EIS differ from traditional DSS in that they are primarily used by managers for status reporting whereas traditional DSS are more often used by analysts for modeling and what-if analysis.

There are probably two reasons for the current interest in EIS. First, modern technology makes these systems both more powerful and more palatable than the paper-based MIS of the 1960s and 1970s. Database and communications technology allow a much more comprehensive and immediate snap-shot of the status of the organization and its environment, while the interface technology - pointing devices, high quality graphics, and navigational aids such as hypertext - provide greater ease of use. The second factor influencing EIS use is the accelerating pace of business and the simultaneous need to make organizations more flexible by reducing layers of management (Huber [1984a]). In this environment, information technology may play an important role in increasing management's span of control.

2.10 Group Decision Support Systems (GDSS)

Most DSS's have focused on a single user or group of users facing a single class of decision problem and have supported a single mode of decision making (e.g., interacting with a model). Over the last decade, however, there has been growing activity in the field of group DSS which is concerned with the application of DSS technology to support group decision making activities. Usually, GDSS are designed to be useful in multiple decision situations (no specific model) but in a single mode of decision making (e.g., group meetings or computer conferencing).

The GDSS field builds on almost a half century of work by behavioral theorists who have studied small group dynamics (Cartwright and Zander [1968], Homans [1950]) and more specifically group decision making behavior (Kelly and Thibaut [1969], McGrath and Altman [1966]). As in other areas of DSS, the presence of computer support obviously changes the nature and limits of unaided group work. GDSS researchers are beginning to focus on these issues (Huber [1984b]). While the task of supporting group dynamics is obviously extremely complicated and there have been failures, GDSS systems have also had some success in real world applications.

DeSanctis and Gallupe [1987] provide an overview of the field of group DSS. As discussed in that paper, information technology can support groups in four different situations: (1) meetings at the same time in the same place (e.g. in a decision room with electronic support), (2) simultaneously in time but separated in space (e.g. video conferencing), (3) communicating over time in a single location (e.g. an office using a local area network), and (4) communicating across time and space (e.g. computer conferencing and electronic mail). Most DSS research seems to have concentrated on the first and last of these four areas. Gray et al [1992] provides a comprehensive review of GDSS research aimed at supporting the decision processes of groups located in a single meeting room. In the electronic mail area, Malone and his colleagues at MIT have proposed enhanced systems that use artificial intelligence techniques to filter the information reaching decision makers (Malone et al [1988]). Comprehensive discussions of research and practice in computer conferencing are contained in Turoff and Hiltz [1978] and Sproull and Kiesler [1991].

Computer Support for Collaborative Work (CSCW) is another new label for research that focuses on building tools to help people work together (Olson [1989]). It has its roots in office automation as well as social science. Obviously, CSCW intersects with GDSS. CSCW focuses on the use of computer-based connectivity to support coordination and collaboration of knowledge workers and to enhance the efficiency and effectiveness of knowledge work processes in general. On the other hand, GDSS tends to focus on processes that lead to management decisions.

2.11 Organizational Decision Support Systems (ODSS)

This is a relatively new research field. There are two interpretations of ODSS (see Nunamaker et al [1992].) The first interpretation is that ODSS are a subset of DSS designed to support decisions that are of organization-wide importance. In this view, ODSS consist of a communication infrastructure together with DSS, GDSS, and EIS systems designed to support top management. A broader view, and the one that will be adopted for the most part in this book, is that ODSS is a natural extension of research focus from individuals (traditional DSS), to groups (GDSS) to the organization as a whole. There are, in turn, two aspects of this broader view of ODSS. The first, recognizes the need to provide the technological infrastructure and management control systems to support the development and use of DSS of various types (corporate planning systems, functional area support systems, executive information systems, and GDSS) throughout the organization (Philippakis and Green [1988]). This has the same flavor as current work in End User Computing (EUC), which has as its object the study and support of all forms of computing by end users (Panko [1988]). The second aspect of the broader view of ODSS is more normative in flavor. In this research, the objective is to link DSS and organizational design (Huber and McDaniel [1986], Watson [1990]). Research on intelligent organizations (Huber[1990]) and organizational learning (Argyris and Schon [1978], Shrivasatave [1983], and Elofson and Konsynski [1990]) are also relevant to this view of DSS. Another view that is relevant to this discussion likens the modern organization to an "information refinery" (Clippinger and Konsynski [1989]).

2.12 Empirical Evaluation of DSS Performance

There are two related questions. Does the use of a DSS improve the quality of the decisions produced? Are economic or other benefits attributable to the use of DSS? The first question is important since it addresses the explicit goal of DSS (namely improving decision making) and because in many situations it is difficult to directly observe the economic benefits obtained from DSS use. However, for decision problems that are appropriate for DSS, it is difficult to determine the attributes of quality and probably even more difficult to measure them. (Decision problems that have unequivocal metrics for quality are best considered as structured problems, which, by definition removes them from the domain of DSS).

Early empirical evaluations of DSS emphasized field studies of working DSS (e.g., Alter [1980]). Subsequent research has emphasized controlled experiments in laboratory settings. Experimental approaches to measuring the affect of DSS on decision quality usually involve a controlled experiment with two groups of subjects - one using the DSS and the other not. The effectiveness of the DSS is determined by "output measures" of the quality of the decisions made by the subjects. These measures are generally based either on the judgements of a panel of experts or on quantitative measures of performance in a computer simulation.

Sharda et al. [1988] contains a review of laboratory studies of DSS effectiveness based on computer simulations. Dependent variables included decision quality (e.g., higher profits in a game situation), time to make decisions, number of alternatives considered and confidence in the decisions made. The results of these experiments are mixed but generally support the notion that decision aids can have positive results on performance. Thus, six of the twelve studies reported in Sharda, et al. showed that DSS users had higher profits in the gaming simulation, five studies showed no significant improvements, while only one study showed DSS users having a worse performance. Where reported, the results on other dependent variables were also mixed. Two studies, for example showed that DSS users took longer to make decisions, and two studies showed no increase in confidence in the quality of the decisions as a result of using a DSS.

Benbasat and Nault [1990] review empirical research on managerial support systems (DSS, GDSS, and expert systems) and also report mixed result with regard to DSS effectiveness. They draw attention to the need for theory that provides a better understanding of the relationship between decision support and performance.

Determining the effectiveness of DSS in real world applications is also a difficult matter. Keen [1981] discusses problems with traditional quantitative cost benefit analysis and recommends an approach based on first determining all of the ways in which a DSS can provide value to an organization emphasizing qualitative factors such as improved decision making and learning. Continued research on the determinants of DSS success is obviously much needed (see Ginzberg [1983]).

2.13 DSS in Practice

If the number of applications are any indication, then DSS has been a great success. Initially, most DSS software was targeted at the financial area, particularly for corporate planning operations. These systems usually contained forecasting algorithms that helped to project financial statements. Over time, graphics capabilities and optimization subsystems were added. By 1976, it was reported that 73% of 1,881 corporations were using corporate planning models (Naylor [1979]). While research interest in such systems may have faded in recent years, corporate planning and forecasting systems currently constitute about 50% of all DSS systems (Hogue and Watson [1985]).

Probably the most important events in the history of DSS applications were the advent of the personal computer in the early 1980s and, almost simultaneously, the introduction of VISICALC, a new class of DSS generator based on the spreadsheet metaphor. To a large extent, the ensuing computer revolution was powered by the spreadsheet, especially, LOTUS 1-2-3. For the first time, end users could easily develop their own models and it was surprising to see how diverse and innovative their applications were. By the end of the decade, there were 20 million PC's in daily use and untold numbers of DSS applications.

A survey of DSS applications reported in scholarly journals in the 1971-1988 period is contained in Eom and Lee [1990]. The authors accepted papers as describing DSS applications if they included descriptions of: the semi- or unstructured decision supported, the data-dialogue model system, the human-computer interface, and the nature of the computer-based support for human judgement and intuitions. Using the ABI/INFORM database, they found 203 articles on DSS applications. They report, among other things, that most (past and current) applications are in the marketing, transportation, and logistics area, and that a very wide range of management science and statistical tools are imbedded in DSS. The articles in the survey are probably only representative of "leading edge" DSS (systems interesting enough to be accepted for publication). Nevertheless they clearly demonstrate a very broad range of DSS types and applications.

Finally, as discussed above, over the last couple of years, group decision rooms have come out of the laboratory and are now being built and used successfully by a number of organizations (Gray et al [1992].)

3. REVIEW OF DSS AND THE NEED FOR NEW DIRECTIONS

3.1 Evaluation of the DSS Field

The DSS movement has served to define an important area of research related to organizations and managerial decision making. The information technology revolution implicitly assumes that technology can benefit humans in organizations. DSS with its focus on individual, group, and organizational decision making processes, should play a central role in this regard.

A second benefit has been that DSS research has attracted researchers from other disciplines such as management science, artificial intelligence, human factors, cognitive science, and organization theory. Each of these disciplines have something to say that is important to an understanding of the real and potential role of DSS in the enterprise. Conversely, DSS can serve as a focal point for multi-disciplinary research on how information technology can be used to improve organizational processes.

In our opinion, DSS has and will continue to make, valuable research contributions. In any field, there are false starts as promising ideas turn out to be unimportant and hitherto neglected areas surface in their place. This is naturally true of DSS which has both a difficult mission and is subject to enormous changes - from progress in technology and from changes in the environment of organizations.

Amongst the established DSS research areas outlined in the previous section, probably the most significant, distinctly DSS, contributions have come from work in the following three areas: DSS design methodologies, model management, and group DSS. The first area, design methodologies, has given us new insights on how to align DSS with individual and organizational objectives and how to go about the implementation process. The philosophical debates and methodologies developed here have had a major impact on the broader arena of information systems thought and practice. The second area, model management, gives promise of a new class of software to support work processes in general (not just DSS). The third area, group DSS, involves the development of new technologies, and the study of their impact on social processes within organizations - a direction that may have considerable importance for the future.

3.2 Need for a Fresh Approach to DSS

We began the last section with Little's observation that managers rarely use management science models. This is certainly not true for DSS applications. Indeed, at least in the end user computing area, there are concerns that there may be too much indiscriminate and ill-informed use of decision models. We also believe that past DSS research has made some significant contributions. However, it is time for a new impetus in DSS. Technological advances make ever more sophisticated forms of computer support possible, while, on the demand side, the faster speed of business, internationalization, and competitive pressures are forcing a restructuring of markets and organizations that is entirely dependent on the successful use of computer and communication technologies.

To find new directions, it is often useful to look at the past. To date, DSS research and application have focused primarily on the following:

- The choice phase of decision making. There has been less research on developing systems to help in the intelligence or design phases.

- The DSS system and model rather than on the processes actually used in organizations to make decisions.

- Support for individual decision making. Systems to support groups are a relatively recent phenomenon.

- Modeling and data analysis. The effort has been in trying to structure as much as possible of the decision problem. The unstructurable part has been left unsupported. General problem solving abilities (analogy, intuition, problem redefinition, and so on) have been largely neglected.

- "Hard" quantifiable information rather than "soft" qualitative information.

Running through much of the criticism of DSS in the literature, is the feeling that the "decision focus" of DSS is too limiting. We believe that these researchers are finding fault with the "system is all" focus of much DSS research -the attempt to build a logical entity that, given inputs, will produce correct outputs, and through a process of sensitivity analysis, give valuable advice to managers.

In what ways is this limiting? First, these critics assert the importance of the user in the DSS dialogue. They call for models of the user that take into account intuition, motivation, cognitive limitations and cognitive styles. Second, they point-out the need to look at the DSS in its organizational context, emphasizing political and cultural issues that affect the success of the DSS in changing decision making behavior and influencing the actions taken by the firm. Third, they point-out that many decisions taken by organizations may not be well-explained by a "rational" model in which choices are made to maximize the likelihood of obtaining stated objectives. Rather, the actions taken by organizations can be the result of inertia or of actions that are taken according to fixed patterns of response that do not correspond to a rational analysis of payoffs in the usual sense. Alternatively, the actions taken by organizations can be the result of political processes - of bargaining between individuals and groups who are trying to maximize their own welfare rather than that of the organization as a whole.[2] Finally, as if this list was not already long enough, they point-out that actual decision processes involve many people over long periods of time and that decision making (choice) is only a small part of their total activities. These other activities include information gathering, communicating, coordinating, and the use of "soft" information such as rumors, legal opinions, trade reports and news items. These activities are not well supported by traditional DSS.

The previous work in DSS with its emphasis on models and supporting individual managers and groups is still valid - but too limiting. The problem, we believe, is that this is a bottom-up approach. To respond to the above criticisms, we need a top-down approach so that the performance of the organization as a whole can be improved. To develop this new approach, we must break a mind set that has been pervasive in DSS research and practice and was implicit even in the work of Gorry and Scott Morton, John Little, and other pioneers of the DSS field. This is the focus on single DSS or single modes of decision-making, rather than on multiple systems and multiple modes of decision making.

The single DSS paradigm is as follows:

1. discover an important decision or class of decisions,

2. determine the information needs of the decision makers, and

3. construct a DSS model to support the decision-making process.

There is nothing inherently wrong with this approach; nor should it be abandoned. It is simply myopic. What we advocate is that it be seen as only one part of a much more integrating form of decision analysis. Decision processes in organizations are rarely susceptible to viewing through a single window (i.e. the model). Rather, there may be several organizational processes involved, and many different forms of information needed by different individuals and groups over an extended period of time. There is the need for coordination and learning, for preparing for the decision-making process, for negotiation, and for following through in an

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[2]A fascinating analysis of the Cuban missile crisis from these three points of view (rational, organizational process and political) is contained in Allison [1971].

implementation phase. In general, the single model paradigm is less effective, the more strategic the decision, the more it affects many different people, and the more complex it is. In these situations, many forms of evidence, both "soft" and "hard" are likely to be gathered to help make (or justify) the decision.

Similar statements can be made about the preoccupation of much DSS research with a single mode of decision making. Most existing DSS focus on interaction between a model and one or more users. The implication is that the users will use the model, find a good solution to their problem, and make their decision. Most GDSS research also focuses on a single mode of decision making (a group in a meeting room) as does research in the area of collaborative systems (a group communicating via e-mail, or participating in a computer conference or in a video conference). While these forms of decision making are interesting and useful, there are many decisions that are not made using the above mechanisms, and many decision processes that involve combinations of these mechanisms with other more traditional forms of decision processing.

We do not mean by the above that no decisions are made using single models or single modes of decision making. Our major concern is that there are other things going on in real decision processes that are not captured by this approach to DSS and that there are new opportunities to apply information technology if only we knew what to do and how to go about it.

3.3 Towards a Decision Process View of DSS

We believe that we should, as Elam et al.[1984] assert in their "visions" paper, return to the original objectives of DSS with its focus on support of the decision processes of management. Here the important emphasis should be on the processes involved when decisions are made rather than on the decisions themselves. Thus, rather than exclusively focusing on decision models per se, we should focus on the overall processes by which decisions are made in organizations. Decision processes may encompass multiple kinds of information from soft (rumor and gossip) to hard (economic time series and data processing reports) and may entail processing that information in many different ways ranging from face-to-face meetings to computer models. When we study the portfolio of decision processes extant in a given organization we are at a macro level of analysis consistent with questions of corporate strategy and organizational design. When we look at decision processes singly we are at a more micro level of analysis similar to that of traditional DSS but admitting a greater range of inputs and including human as well as machine processing elements. A more complete discussion of the decision process view of DSS is contained in Konsynski and Stohr [1992].

Effective research on decision processes entails much more than simply covering all the phases of decision making, or taking an inventory of decision making types and tasks and setting in motion streams of research and development aimed at supporting those tasks. It means taking a hard look at where management support needs are greatest - working from an organizational perspective. In our view, this does not mean only looking at important problems that are faced by the organization or organizations in general. It means also working on the infrastructure of organizations to change their ability to make decisions and to take actions. Note the parallel here with the current emphasis on redesigning or "reengineering" business processes (Davenport and Short [1990], Hammer [1990]). We believe that there is a parallel need to reengineer decision processes.

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