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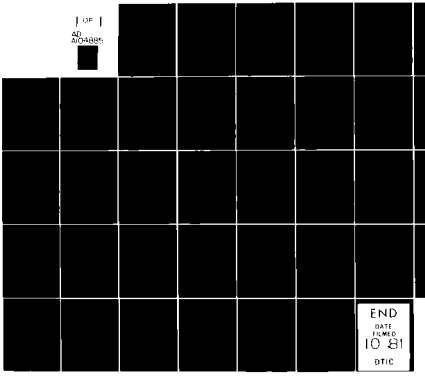

DECISION SUPPORT SYSTEMS: THEORY

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"The views, opinions, and/or findings contained in this report are those of the author and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation."

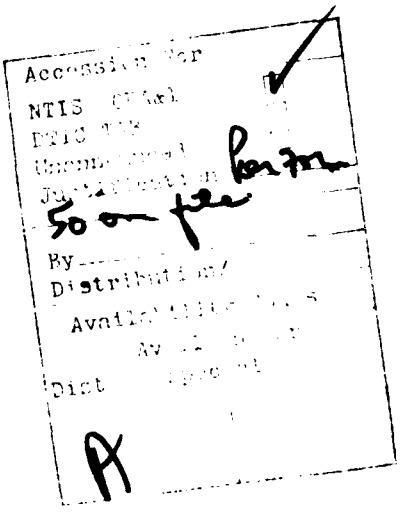
EXECUTIVE SUMMARY

The purpose of this project was to research, collect, and evaluate all available information on Decision Support Systems (DSS) Theory. A biographical search resulted in over 600 articles, books and other documents directly and indirectly related to DSS. This bibliography is included at the end of this report. The report is based on reading and evaluation of between 75 and 85 separate documents from the bibliography.

DSS are interative, conversational computer systems supporting decision makers. DSS rely heavily on human intuition, judgement, and experience as an integral part of the decision process. DSS designers emphasize the interfacing mechanisms between the decision maker and the computer. *Terms characterizing DSS include: computer-based, interactive, conversational, flexible, adaptable, convenient, quick, helpful, and reliable.* Color graphics terminals, light pens, joy sticks, digitizer pads, and similar devices usually replace or augment the typewriter terminal in the design of DSS to enchance the man-machine interface.

DSS design draws on three important methodologies: Operations Research and Management Science (OR/MS), Computer Science, and Behavioral Science. DSS utilizes the modelling and analysis techniques of OR/MS to identify and evaluate alternative courses of action. Computer Science contributes the necessary expertise in information storage, processing, and retrieval. Finally, DSS design accounts for those elements of individual and group behavior to ensure the best utilization of the decision maker in the interactive decision making process and acceptance by the decision maker and the organization of the DSS.

DSS is not a separate science; it is an idea whose time has come. Namely, that by combining the computer's computational power with the decision maker's intuition and judgement in an interactive manner, better decisions will result than by either the computer or human taken separately.



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1. INTRODUCTION

1.1 Purpose

The United States Army Institute for Research in Management Information and Computer Science (AIRMICS) contracted with the School of Industrial and Systems Engineering at the Georgia Institute of Technology to research and collect all available information in Decision Support Systems (DSS). The information was to include all past, current, and proposed research. This report discusses the results of that activity as well as a requested evaluation of the information in relation to the Management Information Systems mission of the U. S. Army Computer Systems Command.

Activities within this contract focused on DSS Theory. A separate contract, with Dr. Lesley G. Callahan as principle investigator, was intended to focus on DSS applications.

1.2 Methods

After extensive meetings with AIRMICS personnel, a comprehensive bibliography search was initiated. This activity continued throughout the contract period. It included a library search, and contact with organizations and individuals involved in DSS activities. The bibliographical search produced over 600 titles, including several books. The complete bibliography appears at the end of this report. While the bibliographical search continued, a companion activity was initiated. This consisted of reading and evaluation of approximately a dozen books and major articles on the subject of DSS. This evaluation produced a second list of 50-60 documents which appeared to be important to the development of DSS. These documents were read and evaluated, and they, in turn, pointed to other documents. In total, between 75 and 85 separate documents were read and evaluated.

A second major activity included visits to U. S. Army installations and agencies. Discussions were held with personnel at (1) Fort Lee, Virginia, (2) Military Personnel Center (MILPERCEN) in Alexandria, Virginia, and (3) USAMSSA in the Pentagon in Washington, D. C. These discussions centered on the nature of DSS and its potential for application within the U. S. Army and their own particular activities.

1.3 Organization of the Report

Chapter II gives several definitions of DSS and some of its distinguishing characteristics. In Chapter III, the concept and structure of a DSS is outlined. Chapter IV presents conclusions and recommendations. An extensive bibliography of DSS literature is presented at the end of this report.

2. DEFINITIONS AND CHARACTERISTICS OF A DECISION SUPPORT SYSTEM

2.1 Evolution of DSS

During the period from the late 1950's through the early 1970's rapid success was achieved in the use of the computer in decision making activities. As computers became larger and more sophisticated, more complex decision making tasks were turned over to them. Often, when the computer could not be programmed to make the decision, it could be utilized to produce large volumes of information which a human could use in reaching his decision.

By the early 1970's a few notions had become apparent. First, the volume of information computers were generating had exceeded the capacity of humans. Decision makers were being presented boxes of printouts, even though it was obvious to all concerned that they wouldn't look at more than a few numbers.

The second observation was slower in crystallizing. Breakthroughs in computerized (as opposed to computer aided) decision making were occurring less frequently. In short, the computer had about reached its saturation point in replacing man's decision making activities. And yet, many decision making activities remained virtually untouched by the computer.

Beginning in the late 1960's computer scientists and users were examining the feasibility of interactively linking the "intuition, judgement and experience" of the human with the computational power of the computer to achieve even greater heights in decision making. Out of this single idea was born the field of *Decision Support Systems*.

2.2 A Problem Class for DSS

Simon (1960) developed a distinction between "programmed" and "non-programmed" decisions. Keen and Morton (1978) modified these terms to "structured" and "unstructured" to free them from an implied computer environment; they also added an intermediate term, "semistructured" decisions.

Structured Decisions "...do not involve a manager. ...the decision is well enough understood to have been given to clerks or ...automated through the computer."

Semistructured Decisions involve some judgement and subjective analysis, but this alone is not adequate, due to problem size or computational complexity.

Unstructured Decisions "...are those that are either not capable of being structured or that have not yet been examined in depth and so appear to the organization as unstructured."

Semistructured decisions provide a natural class for application of DSS. A combination of the human's judgement and the computer's computational power can extend the human's effectiveness in such decision making activities.

Anthony (1965) developed three categories of managerial activities - strategic planning, management control, and operational control. Although, for DSS, this distinction seems much less important, since DSS has applications in each activity so long as the decision is semistructured.

Donovan and Madnick (1976) categorize DSS into two types: *institutional* and *ad hoc*. Institutional DSS, currently the most common, are those supporting repetitive or recurrent decisions. Ad hoc DSS, currently few in number, support decisions which occur infrequently or are not usually anticipated.

2.3 Some Definitions of a DSS

Much of the initial focus and direction in DSS was provided by Professor Peter G. W. Keen, Michael S. Scott Morton and their students; as well as Eric D. Carlson and his colleagues. Figure 2.1 presents some of the definitions which have evolved from this early work.

By examining the words separately, one might accept the erroneous conclusion that DSS consists of any system which supports decision making activities. This definition is far too broad and, as can be seen from examination of Figure 2.1, is not intended by researchers and practitioners in the field.

DSS Involves Computers

Virtually all the definitions include the term computer in them. Even McCosh and Morton limit their focus to computer systems. The computer is there for its computational power - including data searching and reduction, modelling and analysis, and informational display. In may ways, in a DSS, the computer can be viewed as a powerful calculator.

DSS Involves Humans

Such terms as *support, assist, meet with, extend, aid, and help* imply the use of the human component (Manager, Decision Maker) as a part of the DSS. Current state-of-the-art computers still cannot model human intuition, judgement and experience. However, careful design of a DSS, involving both the human and the computer, which accounts for the abilities of the human and the computer, can extend the capabilities of both.

The Linkage is Important

DSS is serious in its attempt at integration of the human and computer components into a single system, and thus the linkage is important. Such terms as *flexible, interactive, conversational, and relevent information* become significant.

Emphasis is placed on the human ability to transmit, receive and process information. Computer transmissions employ charts and graphs instead of tables, limited amounts of information, color coded and spatial displays, etc. Human transmissions occur in english-like commands, or through flexible control devices such as light pens or joy sticks, etc.

By far and away, the greatest concern in the design of a DSS is the linkage

1. "A COMPUTERIZED SYSTEM WHICH IS DESIGNED SPECIFICALLY TO HELP MANAGERS MAKE DECISIONS". (ALTER, 1975)

2. "INTERACTIVE, COMPUTER-BASED SYSTEMS WHICH ARE DESIGNED TO AID PROFESSIONAL DECISION MAKERS IN SOLVING UNSTRUCTURED PROBLEMS". (GRACE, 1976)

3. "THE FLEXIBLE SUPPORT OF DECISION MAKERS WITH COMPUTER-BASED INFORMATION". (CARLSON & MORTON, introduction to Carlson, 1977)

4. "COMPUTER SYSTEMS DESIGNED TO MEET WITH MANAGER'S EXISTING ACTIVITIES AND NEEDS WHILE EXTENDING THEIR CAPABILITIES". (KEEN & STABELL, introduction to Keen & Morton, 1978)

5. "THE USE OF COMPUTERS TO:

    1. ASSIST MANAGERS IN THEIR DECISION PROCESS IN SEMISTRUCTURED TASKS.

    2. SUPPORT, RATHER THAN REPLACE, MANAGERIAL JUDGEMENT

    3. IMPROVE THE EFFECTIVENESS OF DECISION MAKING RATHER THAN ITS EFFICIENCY". (KEEN & MORTON, 1978)

6. "SUPPORTING THE DECISION PROCESSES OF MANAGERS WITH FLEXIBLE ACCESS TO MODELS AND RELEVANT INFORMATION". (MCCOSH & MORTON, 1978)

7. "INTERACTIVE, CONVERSATIONAL COMPUTER SYSTEMS SUPPORTING DECISION MAKERS". (JARVIS, 1978)

FIGURE 2.1 SOME DEFINITIONS OF A DECISION SUPPORT SYSTEM

between the human and the computer.

2.4 Some Characteristics of a DSS

Examining the definitions in Figure 2.1 and the variety of applications typified by the bibliography, we are able to identify a set of basic characteristics possessed by most DSS's. One such list of characteristics is presented in Figure 2.2. WE shall discuss each characteristic in turn, and indicate how it relates to DSS.

Computer-Based - As already indicated, DSS implies the use of a computer.

Interactive - The human is involved in the system. Further, the human role is active (guiding, controlling) rather than passive (observing).

Conversational - The human uses english-like commands to operate the DSS.

Flexible - The DSS is able to operate under different control sequences. That is, the human is able to combine the different modules of the DSS in various ways in processing various problems. The DSS is able to process abreviated commands as the human learns the communication language.

Adaptable - The DSS is somewhat dynamic; capable of changing or being easily changed as the decision environment changes. New modules are easily added.

Convenient - It doesn't require the human to input volumes of data during operation. It uses existing data sets whenever possible. It accepts abbreviated input, menu selection formats, digitizer pad data, so as to reduce the human burden.

Quick - The DSS operates within an environment of fast access and turn-around. Typically DSS's are operational on time-shared computers or dedicated mini computers.

Helpful - It requires limited external documentation to operate the DSS. It can "help" the human when he/she doesn't remember a command or can't remember what to do next. It is polite, forgiving, and guides the user out of mistakes.

Reliable - The DSS is free of bugs; it recovers from human error. The computer hardware is not prone to breakdown.

- COMPUTER-BASED
- INTERACTIVE
- CONVERSATIONAL (ENGLISH-LIKE COMMANDS)
- FLEXIBLE
- ADAPTABLE (DYNAMIC)
- CONVENIENT (DATA INPUT)
- QUICK (ACCESS AND TURNAROUND)
- HELPFUL (LIMITED EXTERNAL DOCUMENTATION REQUIRED)
- RELIABLE (HIGH SYSTEM INTEGRITY)

FIGURE 2.2 CHARACTERISTICS OF A DECISION SUPPORT SYSTEM

3. STRUCTURE OF A DECISION SUPPORT SYSTEM

3.1 Concept of a DSS

Figure 3.1 illustrates the basic concept of a DSS. On the one hand, we have the decision maker. The decision maker has certain goals and objectives within the environment in which he/she operates. This, together with his/her intuition, judgement, and experience, establishes the human component.

The other major component is the DSS, itself. It is normally operational within a computer environment. It has data available to it, either its own or else data available from some other data base. In addition, the DSS possesses its own information processing activities, including data reduction, modelling, and analysis. These activities are often highly sophisticated, although there are divergent points-of-view in this respect.

Some DSS designers argue that the manager/decision maker will not utilize a DSS which employs sophisticated information processing components. These designers prefer rules-of-thumb, graphs, tables, and other intuitive procedures to complex linear programming models, and the like. The thinking is that the decision maker doesn't trust something he doesn't understand. This is only partly true.

First, managers/decision makers will come to trust something which they have seen "work" many times, even though they don't understand it. A good example is the automobile. Many people use it without knowing why it works. Second, many DSS designers argue that managers/decision makers being produced by current university programs, are much more knowledgeable in the use of sophisticated decision models.

An outside factor in the design and operation of the DSS is the environment within which the decision maker operates. This environment includes his/her superiors and their reaction to computer based decision making. The usual pattern of DSS development is that the process is initiated by a casual request for help in some decision making activity. From this point on, the DSS designer charges, full steam ahead, with a grandiose system in mind. This is often a mistake. If the decision maker and environment are not highly receptive to computer methods, it is better to begin slowly, producing a series of small successes while gaining the confidence of all concerned.

3.2 Structure of a DSS

Burch and Strater (1974) identified five basic activities (functions) associated with an effective information system. These are (1) interrogation, (2) modelling, (3) filtering, (4) monitoring, and (5) externally. We may also employ these terms (slightly modified) to describe the basic structure of a DSS. Brief descriptions of each are:

Interrogation - interaction between the human and the DSS. Either the

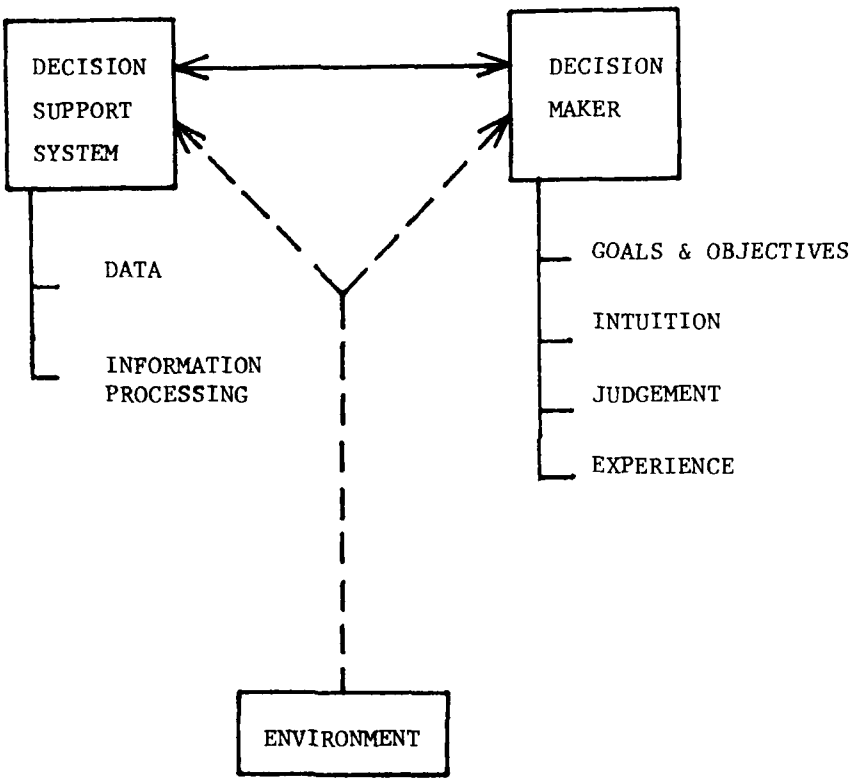

FIGURE 3.1 CONCEPT OF A DECISION SUPPORT SYSTEM

human and the DSS may request information from (initiate) or provide information to (react) the other.

Modelling - the process of employing mathematical or computer models (eg., linear programming, simulation, queueing, heuristics, artificial intellegence, other algorithms) to develop strategies and information.

Filtering - reducing, summarizing, aggregating, and otherwise combining (in a less sophisticated manner than modelling) data into information. Examples include means, variances, plots, bar charts, etc.

Monitoring - continuously observing the data and provide informational comments to the decision maker on an automatic basis. An example might be, "THE MACHINE UTILIZATION RATIO EXCEEDED 75% THIS PERIOD!"

Gathering - the process of obtaining data from sources external to the DSS. Sources include other parts of the organization or outside the organization.

In Figure 3.2 we have utilized these terms in the design of the elements of a DSS. Carlson (1976) refers to the data base exhibited in Figure 3.2 as an "extracted" data base compiled from relevant sources (in the decision maker's view).

Intermediaries

It is not essential that the decision maker interact directly with the DSS. Some decision makers, particularly high-level managers, will not spend time doing anything except reading executive summaries. They are going to delegate responsibility for developing recommendations to others in the organization, who will interact directly with the DSS. These "others" are called *intermediaries* in the DSS literature.

3.3 Interfacing is the Key to DSS

In addition to the obvious emphasis on giving the decision maker exactly what he/she needs, no more and no more less, the greatest concern in DSS is in how he/she gets it. More generally, the greatest single emphasis in DSS is on the interface between the human and the computer.

The DSS designer is intently involved in expanding the range of man-machine communications devices beyond the basic typewriter terminal, card reader, and printer. Because humans can process complex patterns of information, DSS designers are currently attracted to graphics terminals. Such devices can employ colors, flashing backgrounds, lines and points to produce complex graphs, scatter plots, bar charts, etc., as well as basic alpha numeric data.

DSS designers are equally concerned with freeing the decision maker from expending a great amount of effort to input commands and information into the computer. Devices like light pens, touch panels, joy sticks, and track balls, are used to provide menu choices, positional information, and the like. Figure 3.3 illustrates the current range of interfacing mechanisms which may be employed between the human and the computer. DSS designers attempt to optimally utilize as many of the different mechanisms as possible.

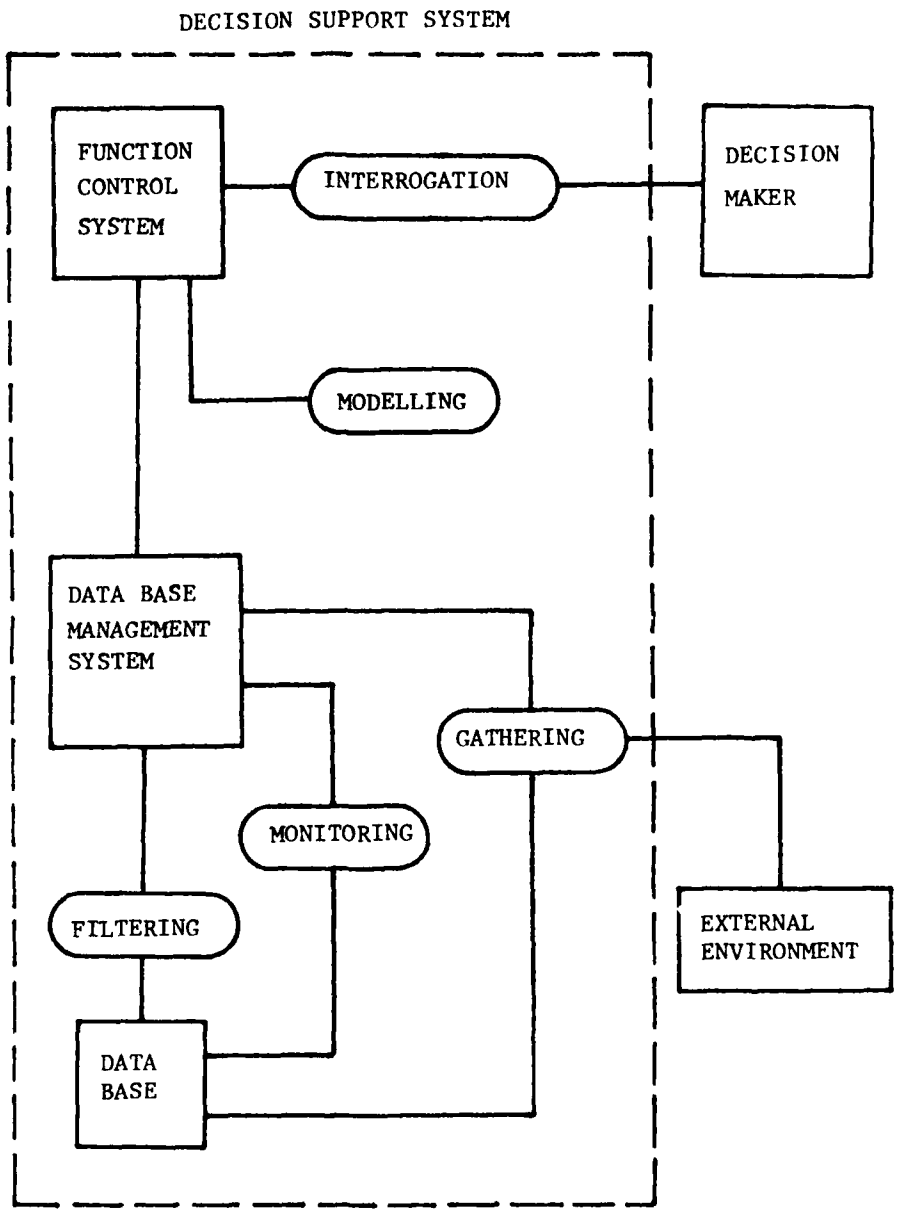

FIGURE 3.2 STRUCTURE OF A DECISION SUPPORT SYSTEM

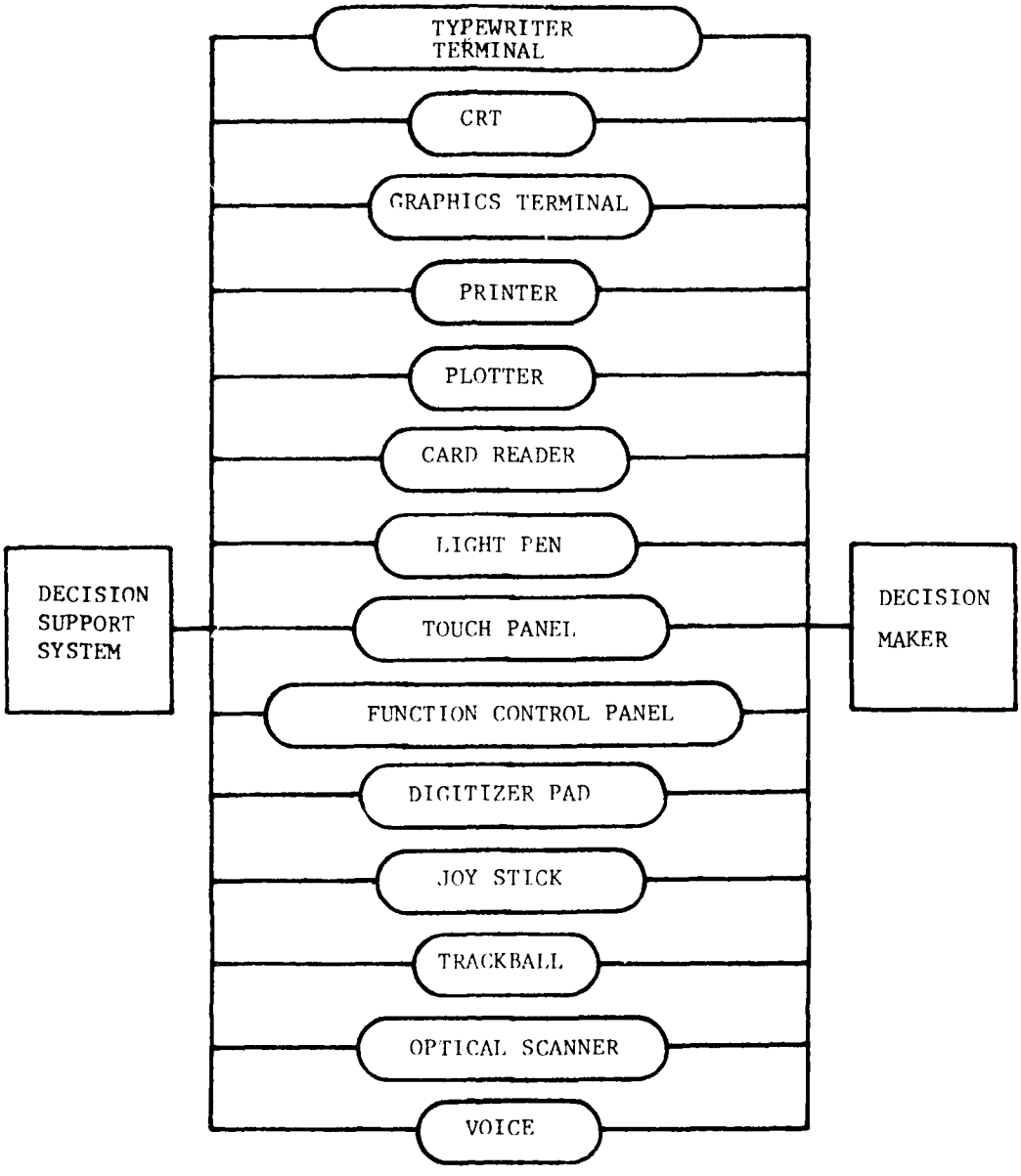

FIGURE 3.3 INTERFACING MECHANISMS FOR A DECISION SUPPORT SYSTEM

often employing several of these interfacing methods in the same DSS.

3.4 DSS Draws on Other Methodologies

Decision Support Systems development draws on three other important areas: (1) Operations Research/Management Science, (2) Computer Science, and (3) Behavioral Science. Each of these sciences contributes significantly to the design of a DSS. We shall briefly discuss each area and the contribution it makes.

Operations Research/Management Science

Operations Research and Management Science (OR/MS) have historically emphasized the development and use of mathematical and computer models and methods in problem solving and decision making. Considerable emphasis has been placed on (1) improving our ability to develop more realistic models of the decision making environment, and (2) developing efficient algorithms and computer codes for analyzing larger and more complex models. The ultimate goal of OR/MS has been to supply the decision maker with "optimal" or "good" courses of action which are realistic relative to the limitations and constraints on the particular decision situation.

The methods developed by OR/MS may generally be classified into two areas: descriptive and prescriptive. Descriptive methods attempt to present (describe) characteristics of the decision situation (system) when a particular course of action is selected. Good examples of such methods are queueing and simulation.

Prescriptive methods attempt to specify (prescribe) the "best" course of action available among a number of choices. Two major prescriptive areas are optimization and heuristics. Optimization methods produce the very best strategy or course of action given the conditions of the model. Heuristics attempt to produce good solutions given the conditions of the model.

Obviously an extensive repertoire of useful OR/MS models and methods will be vaulable in a DSS. These models are usually modularized so that the decision maker can combine them in different ways depending on the decision situation and on the results at each step of the process.

Computer Science

Computer Science has historically emphasized the information storage, processing and retrieval aspects of problem solving and decision making. This emphasis has occurrred in both the hardware and software areas.

Computer hardware has improved continually since its initial introduction. Computers have become larger - including more central memory, and greater amounts of disc and other peripheral memory. At the same time, computers have become increasingly faster - in processing central memory and in communication between central and peripheral memory. Both advances in time and speed have enabled decision makers to process greater amounts of data and to analyze larger models of the decision situation.

Computer science has also concentrated on information storage and retrieval. Such concepts as list processing and search methods have come out of this concentration, This has also tended to be the historical focus of those researchers and practitioners of Management Information Systems (MIS). That is, they have concentrated on efficient data base design and handling methods.

Finally, considerable effort in Computer Science has been directed toward development of Artificial Intelligence, The general idea behind artificial intellegence is to provide the computer with the ability to "learn" from its experience in a particular situation so that it can expand its ability. Two significant areas of concentration have occurred in theorem proving and game playing. An example in game playing involves computers playing chess with humans or other computers, and improving their ability to play from their experience in each game. While not currently too practical, Artificial Intellegence has obvious future benefits in DSS.

Behavioral Science

Behavioral Science is concerned with the behavior (actions and interactions) of individuals and groups. The ultimate success of any DSS depends on an awareness of the human decision maker and the organizational environment. Several areas of Behavioral Science are central to DSS design and implementation.

Individual and group psychology is important to DSS. What will an individual/group accept or reject? What situations make a DSS comfortable or uncomfortable? These are improtant research areas, even though they are often overlooked. For example, most high-level managers reject the use of a typewriter, but they will accept the use of a function keyboard (it usually looks like a calculator). What kinds of interpersonal relationships are established during group decision making and in what ways will this affect the outcome?

Human Engineering issues are clearly significant. How much information can a human reasonably process? What formats are best - tables or figures? How many colors can be used? How many different interfacing devices can a human handle simultaneously? We can continue indefinitely generating such relevant questions for human engineering in DSS.

Researchers into the implementation process obviously provide insight into how innovation in organizations occur. Such research results can suggest reasonable strategies for DSS implementation in the decision making process. Also, greater knowledge of the cognitive process, through which individual decision makers arrive at decisions, may suggest (1) ways to design DSS so that they are more acceptable to decision makers, and (2) DSS designs which reflect the particular cognitive process of a decision maker.

Synthesis of These Three Methodologies Into DSS

DSS attempts to integrate the significant decision making aspects of the three methodologies of Operations Research/Management Science, Computer Science, and Behavioral Science. In review, these elements are:

OR/MS - Modelling and analysis.

Computer Science - Information storage, processing and retrieval.

Behavioral Science - Individual/group decision making behavior.

Figure 3.4 illustrates the methodologies involved in DSS design, development, and implementation.

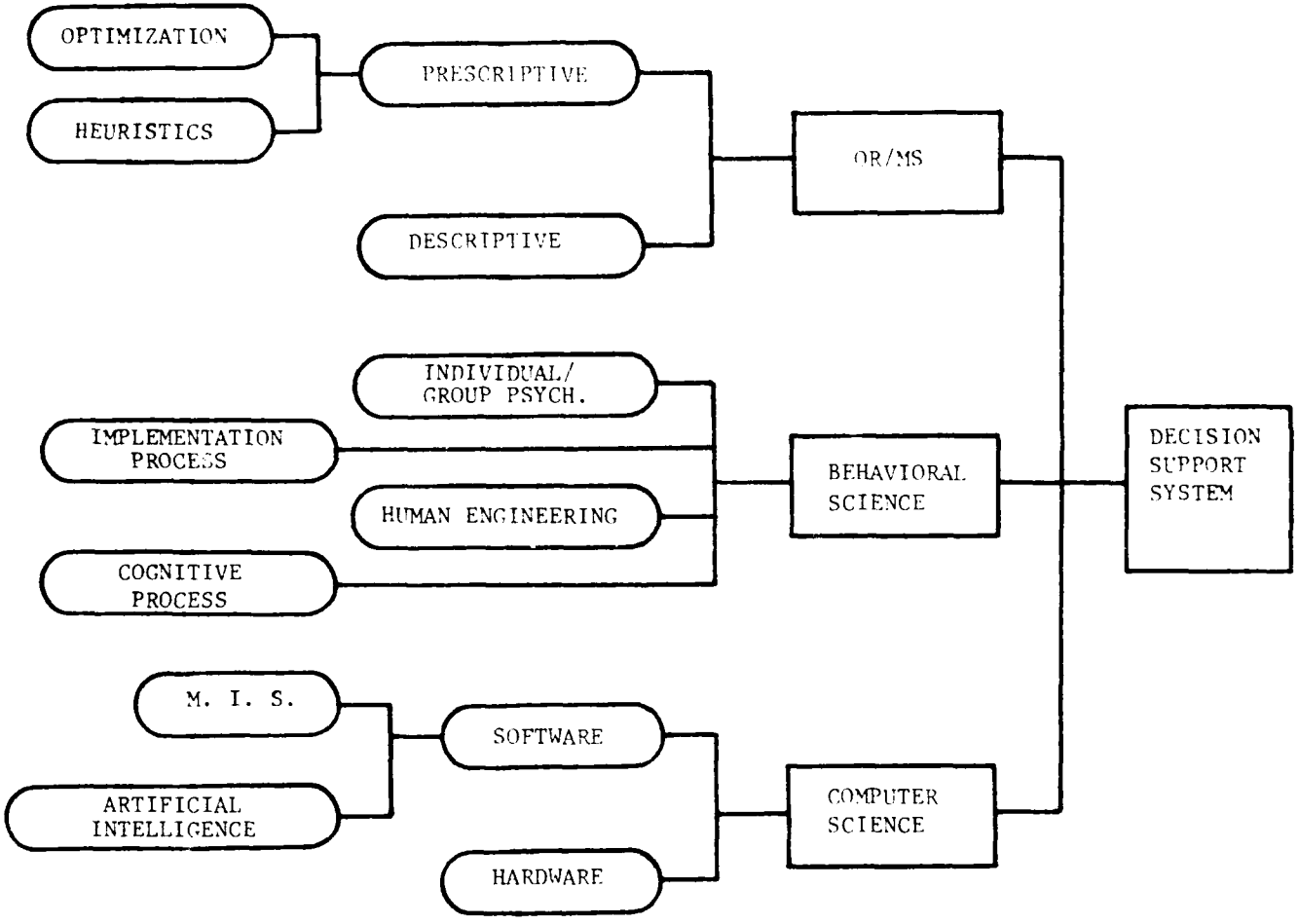

FIGURE 3.4 METHODOLOGIES BEHIND A DECISION SUPPORT SYSTEM

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

A number of conclusions may be drawn from this study. Some of these are:

(1) Decision Support Systems (DSS) are interactive, conversational computer systems supporting decision makers.

(2) DSS emphasize the human-computer interface in decision making and problem solving.

(3) DSS rely heavily on human judgement, intuition, and experience.

(4) DSS are characterized by such terms as: computer-based, interactive, conversational, flexible, adaptable, convenient, quick, helpful, and reliable.

(5) DSS development draws on three other important areas: modelling and analysis from Operations Research/Management Science; information storage, processing, and retrieval from Computer Science; and individual/group decision making behavior from Behavioral Science.

(6) DSS is an outgrowth of the evolution of technologies in Computer Science, Operations Research.Management Science, and Behavioral Science.

4.2 Recommendations

These study results point to several recommendations for continued development of DSS. They include:

(1) An analysis of the models and methods from OR/MS useful in DSS.

(2) A Human Engineering analysis of the opportunities and limitations for human-computer interaction in DSS development.

(3) An analysis and evaluation of the implementation process in the Behavioral Science literature with the goal of developing an approach for DSS.

(4) An evaluation of the Computer Science/Management Information Systems literature of information storage, processing and retrieval useful for DSS design.

(5) An evaluation of the available interfacing hardware and software useful in DSS design.

(6) A field test in one or more Army installations to evaluate DSS methods and designs.

(7) An evaluation of the essential team characteristics for successful DSS implementation. (This comes from the recognition that an individual's objectivity is often marred by his/her advocacy!)

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