**A Taxonomy of Decision Support Systems**
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*Sloan Management Review (pre-1986);* Fall 1977; 19, 1; ABI/INFORM Global
pg. 39

# A Taxonomy of Decision Support Systems

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Computer systems for decision making and decision implementation vary widely in terms of *what* they do and *how* they do it. The decision support system is not a homogeneous category. Through a series of case examples, the author develops a taxonomy of seven distinct types of decision support systems. The end result is a guideline for designing and implementing systems, and a framework for further communication and research. *Ed.*

## Introduction

As evidenced by the title of a recent well-attended conference,[1] *decision support system* (DSS) is a buzzword whose time has arrived. Now that most corporations have survived the growing pains of learning to develop and use data processing systems, many of the most innovative new systems clearly fall under the general heading of decision support. Unfortunately, there is relatively little organized knowledge about DSSs. Although a certain amount of conjecture has been generated concerning the *nature* of decision support systems and the significance of various system characteristics, even the conjectures are often contradictory.

This article discusses a taxonomic scheme that was one of the main findings of an exploratory study of decision support systems[2] undertaken in response to this dearth of information. The purpose of the study was to gain a better understanding of the dynamics of these systems and the key issues leading to their success or lack of success. As will be discussed, one of the conclusions in this regard was that these key issues differ across various types of DSSs.

In embarking upon this research a definitional question arose immediately: What are decision support systems? How can they be recognized and distinguished from other systems? Taking the approach of looking first and defining later, the following general distinctions emerged. Business computer applications can be stereotyped into two categories: electronic data processing (EDP) systems and decision support systems (DSS). The main difference between DSS and EDP systems is related to their basic

[1] Conference on Decision Support Systems, San Jose, California, January 24-26, 1977, sponsored by IBM San Jose Research Laboratory, Sloan School of Management, M.I.T., Wharton Business School, and ACM-SIGBDP.

[2] See Alter [2].

purposes. EDP systems are designed to automate or expedite transaction processing, record keeping, and business reporting; DSSs are designed to aid in decision making and decision implementation. While most DSSs are used to facilitate management, planning, or staff activities, EDP systems emphasize intrinsically clerical activities. Whereas the general orientation of EDP systems is toward mechanical efficiency, that of DSSs is more toward the overall effectiveness of individuals or organizations. The manner of usage is also quite different. Unlike the EDP user, who typically receives reports on a periodic basis, the DSS user often initiates each instance of system use, either directly or through a staff intermediary.

Although the DSS vs. EDP dichotomy is weakened by overlaps due to the multiple purposes and orientations of many systems, implementers and users who participated in the study had no real difficulty in identifying DSSs used in their organizations. Starting with detailed case studies of eight systems[3] a sample of fifty-six DSSs was eventually compiled. The data used in the analysis consisted of mini-case studies of each of the systems. Each mini-case was a structured story of the system in terms of interview responses to questions under the following headings:

- General background,
- System history and characteristics,
- Types of use and impact,
- Limitations and types of disuse or abuse,
- Factors in favor of or opposed to getting started, and
- Factors in favor of or opposed to successful implementation.

As the sample grew, it became increasingly clear that the *decision support system* is not a homogeneous category. Quite to the contrary, many of the systems in the sample differed vastly in what they did and how they did it. This led me to wonder why people who talk about DSSs often seemed to talk about DSSs *in general*. It appeared that this was much like talking about pets in general, without distinguishing between dogs and cats and piranha fish and turtles. I concluded that one of the main products of the research should be a taxonomy of decision support systems which differentiated the sample in a useful and understandable manner.

A first step in attempting to develop such a taxonomy was to examine the usefulness of commonly used system-labeling schemes such as:

- *Functional Area*: marketing, production, finance;
- *Decision Perspective*: operational control, management control, strategic planning;[4]
- *Problem Type*: structured vs. unstructured;[5]

[3] See Alter [1].
[4] See Gorry and Scott Morton [3].
[5] See Simon [8], Gorry and Scott Morton [3], and Mason and Mitroff [5].

- *Computer Technology*: interactive vs. batch;
- *Modeling Approach*: simulation vs. optimization.

Unfortunately, few significant conclusions seemed to emerge when the systems in the sample were grouped in terms of these schemes. For instance, financial projection systems for operational planning seem very similar in concept and structure to several systems for strategic planning. Likewise, the significance of interactive computation seemed to diminish greatly when decision makers were not hands-on users of systems. Difficulties in deciding whether one repetitive business problem was more versus less structured than another also reduced the usefulness of that distinction.

### A Taxonomy of Decision Support Systems

The taxonomy that seemed most useful in categorizing the systems in the sample was based on what can be called the *degree of action implication of system outputs* (i.e., the degree to which the system's outputs could directly determine the decision). This is related to a spectrum of generic operations which can be performed by decision support systems. These generic operations extend along a single dimension ranging from extremely data oriented to extremely model oriented:

- Retrieving a single item of information,
- Providing a mechanism for ad hoc data analysis,
- Providing prespecified aggregations of data in the form of reports,
- Estimating the consequences of proposed decisions,
- Proposing decisions, and
- Making decisions.

The idea here is that a decision support system can be categorized in terms of the generic operations it performs, independent of the type of problem, functional area, decision perspective, etc.

Clustered from this viewpoint, the fifty-six systems in the sample fell into seven reasonably distinct types which can be labeled as follows:[6]

A. *File drawer systems* allow immediate access to data items.

B. *Data analysis systems* allow the manipulation of data by means of operators tailored to the task and setting or operators of a general nature.

C. *Analysis information systems* provide access to a series of data bases and small models.

D. *Accounting models* calculate the consequences of planned actions based on accounting definitions.

[6] Mason [4] describes a parallel but more abstract taxonomy suggested by Churchman.

E. *Representational models* estimate the consequences of actions based on models which are partially non-definitional.

F. *Optimization models* provide guidelines for action by generating the optimal solutions consistent with a series of constraints.

G. *Suggestion models* perform mechanical work leading to a specific suggested decision for a fairly structured task.

Figure 1 illustrates that this taxonomy can be collapsed into a simple dichotomy between data-oriented and model-oriented systems. Such a simplification loses a great deal of information, however, by grouping systems which differ in many significant ways.

Each of the seven types of DSS will be discussed briefly with references to specific examples. The last section of the article will summarize some of the differences in key issues across the various types.

*A. File Drawer Systems*

File drawer systems are basically mechanized versions of manual filing systems. The purpose of file drawer systems is to provide on-line access to particular data items ( e.g., status information concerning entities ranging from overdue invoices and available seats on future airplane flights through inventory items, stock portfolios, lots flowing through a shop, etc.).

System A1 is a CRT-based inventory control system used in manufacturing complicated, high technology hardware on a one-of-a-kind basis.

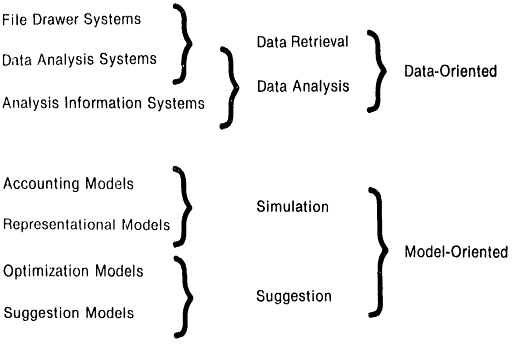


Figure 1 Data-Oriented vs. Model-Oriented Decision Support System Types

Since a single missing part can halt the progress of this complex assembly process, it is very important that the location and status of all available parts are known at all times. In addition to day-to-day use in finding and reallocating parts, the system is used by plant management in a weekly meeting. At this meeting the current needs of various projects are examined, and existing inventory is reallocated or transferred from project to project to expedite a smooth work flow.

System A2 is a CRT-based shop floor information system which tracks the flow of production lots of integrated circuits through a manufacturing process which involves over fifty steps and suffers from a serious yield problem. The input to the system consists of daily work reports submitted by operators. The system stores this information and maintains a history of each lot by step. Included are the yield, the release date, identification of the person who did the work, and so on. In addition, various aggregations of productivity data by operators and by lot are provided. The data is accessed by means of thirteen standard retrieval commands. The system is used by section chiefs to monitor work flow and to detect yield problems and production bottlenecks.

Typically, the hands-on users of such systems are nonmanagerial personnel ranging from clerks to foremen who use the system to support their day-to-day operational tasks. The concept is a very simple one: people performing ongoing operational tasks should have immediate access to the information they need, and should be able to obtain the most current version of that information. In some cases, it is proprietary commercial information to which access is sold (e.g., commodity and service trading systems which provide availability information concerning ships for charter, lumber in stock, apartments for rent, etc.).

*B. Data Analysis Systems*

Data analysis systems are generally used by nonmanagerial line or staff personnel in analyzing files of current or historical data.

System B1 is a CRT-based analysis system in a bank. It is used by division comptrollers to generate customized monthly variance reports which are used in budget control sessions with responsible cost center managers. By allowing these comptrollers to screen, analyze, and annotate budget variances before they are sent to cost center managers, the system expedites the budget control process and facilitates communication between the involved parties. This system also contains planning aids which help division planners generate their one-year and five-year budgets by doing simple projections, comparisons, and extensions of line items.

System B2 is a generalized financial analysis system which is basically an interpretive language for use by financial analysts. It is used in an oil company to analyze investment opportunities and to consolidate plans at the corporate level. The purpose of the system was to improve upon a disorderly series of programs which did particular calculations and consolidations. It replaced all these programs with a unified system which could handle most financial analysis needs and which would produce reasonably consistent reports.

The data analysis systems in the sample fell into two categories: *tailored analysis systems* and *generalized analysis systems*. Tailored analysis systems are designed specifically to meet particular analysis requirements related to a definite job or task. The data in these systems is often historical, although current status information may be included. These systems allow analysts to manipulate the data and to produce analysis reports on an ad hoc basis. Generalized analysis systems are specialized programming languages whose purpose is to allow users to perform fairly general kinds of analysis of data bases and to program simple models. Such systems are viewed as off-the-shelf tools for use in many settings. Given a data base in an appropriate format, some of these systems provide the user with the capability to analyze the data by means of operations such as data retrieval, pictorial representation, summarization of the data, and calculations. Others are oriented more toward facilitating the creation of simple models. Unlike tailored analysis systems which address the special analysis needs of particular tasks, generalized analysis systems are designed to be readily transferable and relatively context free. The border between file drawer systems and tailored analysis systems is fuzzy. Although there exist systems whose sole purpose is the retrieval of data items and other systems whose sole purpose is the analysis of files of information, systems also exist which attempt to serve both functions.

*C. Analysis Information Systems*

Throughout the first twenty years of computer-based *management information systems*, one of the most common complaints was that these systems simply were not flexible enough to satisfy the changing information needs of managers. Typically, such management information systems were basically transaction processing and record keeping systems. Although these systems could be used conveniently to generate standard periodic reports, their requirements for efficiency precluded the generation of management information relevant to decisions or situations whose essential components varied over time. The purpose of *analysis information systems* is to provide management information through the use of a series of decision-oriented data bases and small models.

System C1 is a growing marketing information system in a consumer products company. Its data bases include internal sales, advertising, promotion, and pricing data, plus a number of proprietary marketing data bases which are purchased from marketing research firms. The system is used by staff personnel for many types of ad hoc reporting. In addition, it is used by a research group in developing methodologies for forecasting sales and analyzing the effectiveness of competitive actions. The data is accessed through a report generator and a statistical package.

System C2 is a sales analysis system developed at an industrial equipment company. In addition to detailed sales data, it contains internally generated and purchased information about customers and potential customers, plus forecasts from industry sector economic models. It is used for product planning through the development of growth forecasts by industry sector, and of corresponding forecasts for product growth within industry sectors. Viewed by its originators as a tool kit of data and small models for the purpose of supporting planning, an attempt is made to limit the system's use for day-to-day reporting and analysis.

The basic idea underlying these analysis information systems is to recognize the incongruities between transaction processing systems and decision-oriented information systems, and to proceed accordingly. Analysis information systems are designed to extract relevant data from EDP systems and to augment this data with external data. By maintaining this type of analysis data base, it is possible to access that data freely and without being constrained by the operational requirements of scheduling and running a large-scale corporate data center efficiently. In some cases, such systems are basically vehicles by which a staff man or staff group tries to have an impact on the ways in which decisions are made. The *modus operandi* is highly incremental: start with an existing data base and set of models, identify a new business problem, develop a solution that extends the system, and use the credit gained to expand the scope of future efforts.

### *D. Accounting Models*

Accounting models use definitional relationships and formulas to calculate the consequences of particular actions.

System D1 is a voyage profitability estimator used by a shipping company via time sharing. This program performs a standard profit calculation which is used to decide what charter rate should be charged for a particular voyage. The formula that is used involves ship and voyage characteristics including tonnage, speed, rate of fuel consumption, port costs, and so on. Because much of this data is stored in advance, what formerly required fifteen to twenty minutes of calculations now requires three to five minutes of specification using the terminal. In addition to merely saving time, this makes it possible for charter clerks to explore tradeoffs between speed and fuel consumption.

System D2 is an on-line source and application of funds budget used for operational decision making and financial planning over a two year horizon in an insurance company. The inputs are cash flow projections from various lines of insurance and investment areas. The output is an overall cash flow by month. The system output is used at weekly meetings of an investment committee to help in allocating funds across investment areas and to minimize the amount of cash that is left idle in banks.

The accounting models in the sample were used to facilitate planning by generating estimates of income statements, balance sheets, or other outcome measures. The inputs to these systems were estimates by business unit (product, department, etc.) of various elements of costs and revenues. Using accounting definitions and estimated line items rather than actuals, these systems performed the kinds of extensions and additions that are performed by a clerk or a computer in producing a business statement. Such systems contained little or no sense of any mechanism whereby the firm's actions are related to outcomes in the market. For instance, it was typical to use sales as a fixed input rather than as a function of price or other competitive actions. On the other hand, one of the key attributes of these models was their understandability by managers.

*E. Representational Models*

Representational models include all simulation models which are not primarily accounting definitions (i.e., which use at least partially non-definitional relationships in estimating the consequences of various actions, environmental conditions, or relationships). Whereas an accounting model might start with product sales and prices that were determined external to the system, a representational model might start with only price and then calculate sales based on a model representing the causal mechanism by which price determines sales. On the boundary between accounting definitions and representational models are systems such as E1 — some of whose statements are definitions, while others are cost accounting approximations to the relationships between variables.

System E1 is used by a large chemical company to simulate and cost out flows of materials among a hierarchy of mining sites, production facilities, inventory depots, and sales locations. The purpose of the model is to provide a quick and reliable method for evaluating a variety of yearly budgeting alternatives at a variety of planning levels. Based on individual models of each point in the flow pattern, the system calculates volumetric outputs and costs which are then aggregated upward. This helps rationalize the development of yearly budgets by allowing management to examine the profit impact of alternatives involving changes in volumes, prices, distribution patterns, production costs, transportation modes, inventory levels, raw materials sources, etc.

System E2 is an aggregate market response model which relates levels of advertising, promotions, and pricing to levels of sales for a particular brand. The model is used by a consumer product company to track the marketplace and the effects of competitive actions. The model was developed in a team setting by reconciling an analysis of historical information with individuals' subjective opinions concerning response parameters.

It is possible to classify simulation models in terms of the uncertainty inherent in the relationships in the models themselves. Thus, simulation models can be viewed along the following dimension: (1) accounting definitions, (2) models in which the form of the relationship is accurate while parameter values may be inaccurate, and (3) models in which the form of the relationship may not be a good representation of the underlying process. Clear-cut accounting models are on one end of the spectrum, and representational models are on the other end. Many models fall between the two extremes.

The location of a model along the above continuum has many implications for its potential usefulness and acceptance. Accounting models are typically viewed as specialized adding machines that perform calculations a person would otherwise perform manually. Much of the effort in building such a model involves the clarification of accounting definitions and relationships that are internal to the company. On the other hand, representational models are frequently viewed as attempts to develop an understanding of the possible relationship between future actions and future outcomes. Much of the effort in building these models involves the creation of approximate relationships that attempt to roughly describe the linkages between actions and outcomes. In using an accounting model, the accuracy of the model itself should not be an issue; rather, the main questions should concern the quality of the estimated values provided as inputs. In using a representational model, one of the main issues is whether or not the model is a reasonable representation of the situation being studied. At the same time, an important part of the benefit of such a model comes from the increased understanding that is gained by trying to develop explicit relationships describing how part of the business environment works. Related to accuracy, but only partially, are the credibility and acceptance of a model. In many cases, representational models tend to have credibility problems. Because they are approximations, it is often possible to question important relationships and to wonder whether these relationships produce misleading results. At the same time, however, representational models that pass the test of credibility can be a very valuable source of understanding concerning the interaction between internal and external forces in the future.

### *F. Optimization Models*

Optimization models are used in studying situations that can be described mathematically as complicated puzzles whose goals involve combining the pieces in a way that attains a specific objective such as maximizing profit or minimizing cost.

System F1 aids in determining the start dates of three-week, twenty-member training classes in a training school for personnel who exhibit a high attrition rate. The inputs to the model include the company's forecasted service demands, current staffing levels, the acceptable level of shortfall during peak periods, and so on. Constrained by these inputs and some complex rules concerning consecutive start dates and school administration, the system uses a smoothing algorithm to generate a set of start dates with relatively (although not necessarily *optimally*) low cost. The system is used iteratively in developing an understanding of the effect on the current year's plan of potential modifications in policy inputs such as the maximum shortfall acceptable during peak periods.

System F2 was a linear programming model used by a consumer products company faced with short-run supply problems. For many of the raw materials the company used, both availability and supply had suddenly begun to fluctuate. One way to make the best of a bad situation was to respond to these fluctuations by adjusting product recipes in a way that met production requirements at minimum cost. It took a staff analyst two weeks to set up a small linear programming model that produced an optimal set of product recipes based on somewhat simplified assumptions concerning the flexibility of production facilities. The system was used sporadically over the course of a year as a way of providing guidelines for production adjustments.

The systems classified here as optimization models are used as analysis tools rather than as a way of generating a definitive answer that can be acted upon directly. In other words, this approach for supporting decisions can be used in situations that have enough structure to develop an optimizing model that can be used as part of the analysis. Many applications of optimization techniques such as linear programming are of this type. There are other types of applications, however, in which there exists enough structure that a model can produce a direct suggestion of action. These models will be described in the next section.

*G. Suggestion Models*

Suggestion models generate suggested actions based on formulas or mathematical procedures which can range from decision rules to optimization methods. The purpose of such systems is to expedite or bypass other procedures for generating the suggestion. In a sense, suggestion systems are even more structured than optimization systems, since their output is pretty much *the answer*, rather than a way of viewing tradeoffs, the importance of constraints, and so on.

System G1 performs some complicated calculations which are needed in adjusting the rates on particular group insurance policies based on the historical relationship between premiums and claims for those policies. The system was developed to eliminate part of the clerical burden associated with renewal underwriting and to help assure that rate calculations are consistent and accurate. Using the system has become part of the job of a large number of underwriters in an insurance company. Instead of calculating renewal rates by hand and in a relatively undisciplined manner, the underwriter fills out coded input sheets for the system, which calculates a renewal rate under a series of standard statistical and actuarial assumptions that may or may not apply to the policy. Upon receiving the output, the underwriter reviews the accompanying documentation and decides whether these calculations correctly represent the situation. If not, the coding sheet is modified in an appropriate manner and resubmitted.

System G2 was used to expedite the assembly of a standard piece of electronic equipment over the course of a one-year production contract. Each unit of equipment contained ten diodes, each of which had a particular resonant frequency. Due to problems in producing the diodes, this measurable frequency varied from one diode to the next. Due to peculiarities of the electronics, 200 among the millions of different combinations of diodes of particular frequencies could be used in any unit of the equipment. The weekly input to the system was the inventory on hand of each type of diode. Using linear programming, the system maximized the number of units produced with this inventory. The output of the model fed a program which generated a separate circuit diagram for each unit to be assembled. In this way, a complicated manual matching problem (analogous to little league scheduling) was automated.

The suggestion models in the sample were a potpourri of applications which had a single common theme (i.e., performing a calculation whose output was a specific recommendation for action). These applications differed greatly in impact and significance. The user of an optimal bond bidding model stated that it had increased the profits of his bank because neither he nor any other person could possibly match the model's performance in generating solutions to an intrinsically combinatoric problem of choosing bond coupon rates which satisfy a series of complicated constraints at minimal cost to the bond underwriter. The developer of a system which calculated rates for group insurance policies felt that this system had probably saved money by preventing rate errors which had occasionally gone unnoticed. The implementer of a system which forecasts production requirements by product line and type felt that this system had an important impact on production planning since only very aggregate forecasts had been available previously. On the other hand, most of the remaining suggestion systems in the sample had their primary impact through saving time and/or aggravation by allowing someone to avoid spending several hours each week doing a task manually (and somewhat less optimally).

### Comparative Findings

By merely asking what type of operation a decision support system performs, it was possible to classify each of fifty-six DSSs into one of seven categories. The categories range from type A, systems whose basic purpose was to retrieve simple aggregations of raw data, through type G, systems whose basic purpose was to suggest actions based on formulas or mathematical procedures. Aside from performing different types of operations, do the various types of DSS actually differ in significant ways?

Figure 2 summarizes some of the important characteristics of the systems of each type encountered in the sample. Each entry in Figure 2 is an attempt to describe in a single qualitative phrase the commonalities or predominant values of each characteristic within the systems of each type.

FIGURE 2 CHARACTERISTICS OF PARTICULAR DECISION SUPPORT SYSTEM TYPES

| CHARACTERISTICS | DECISION SUPPORT SYSTEM TYPES | | | | | | |
|---|---|---|---|---|---|---|---|
| | A FILE DRAWER | B DATA ANALYSIS | C ANALYSIS INFORMATION | D ACCOUNTING | E REPRESEN-TATIONAL | F OPTIMIZATION | G SUGGESTION |
| TYPE OF TASK | operational | operational or analysis | analysis | planning | planning | planning | operational |
| HANDS-ON USER | nonmanagerial line personnel | nonmanagerial line personnel or staff analyst | staff analyst | staff analyst or manager | staff analyst | staff or nonmanagerial line personnel | nonmanagerial line personnel |
| DECISION MAKER | nonmanagerial line personnel | nonmanagerial line personnel manager, or planner | manager or planner | manager, planner, or line personnel | manager | manager or nonmana-gerial line personnel | nonmanagerial line personnel |
| KEY ROLE | hands-on user | hands-on user | intermediary | intermediary, feeder | intermediary | intermediary | hands-on user |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| KEY USAGE PROBLEM | user motivation and training | can people figure out what to do with the system | how effective is the intermediary | integration into planning process | understanding | understanding | user motivation and understanding |
| SYSTEM INITIATOR | managerial | entrepreneurial | entrepreneurial | user or managerial | entrepreneurial | mixed | mixed |
| KEY DESIGN AND IMPLEMENTATION PROBLEM | defining the data; procedural changes | deciding how to use system; assessing impact on decisions | focusing usage and development; control mix of projects | getting people to participate seriously in planning process | richness vs. understandability | richness vs. linearity and understanding | designing rules sensibly |
| KEY CHANGE ISSUE | changing information sources and procedures | unfreezing job image and way of approaching problems | using system as a vehicle for change | unfreezing procedures people are familiar with | unfreezing ways of approaching problems | unfreezing ways of approaching problems | unfreezing standard procedures; avoiding a fear reaction |
| KEY TECHNICAL PROBLEM | system crashes; retrieval from large data base | flexible retrieval from broad data base; generality vs. power | flexible retrieval from broad data base | checking consistency of intention, meaning of numbers | modeling technology | modeling and solution technology | task modeling |

(The sample contained seven, eight, three, eleven, twelve, six, and nine mini-cases of systems in categories A through G respectively.) Without getting into an elaborate methodological discussion, there is clearly some question of whether or not these mini-cases constitute a sufficient basis for generalizations by type. On the other hand, many of the commonalities by the system type in the data were relatively striking (e g., in many instances, most or all of the occurrences of a particular problem were within one type of system or two types with a similar characteristic).

To the extent to which its summary characterizations are accurate, Figure 2 indicates that systems of various types do differ in many significant ways. Consider, for instance, the notion of the *key role* in successful system usage. Since the planning and analysis systems (C through F) were often used through intermediaries who structured and performed much of the analysis, the success of these systems was especially dependent on the ability of the intermediary to maintain effective communication with decision makers. In the systems for operational tasks (especially A and G), intermediaries were not a main issue because the hands-on user was the decision maker.

The key usage problem varied greatly across the sample. In the systems for operational tasks (A and G), user motivation and training were major issues, especially since the system development efforts were often initiated by the users' superiors. In the data analysis systems (B), a recurrent problem was that system implementers and proponents incorrectly assumed that potential users would figure out how to apply the systems; in the more successful cases, either users were trained to use the system in a relatively repetitive manner or the implementers themselves were the users. For the representational and optimization models (E and F), the key impediment to successful usage was a lack of understanding of how the model worked and what it really represented. This was a direct consequence of the fact that the users of these models were typically intermediaries rather than decision makers.

Although the implementation patterns of the systems varied greatly, it was interesting that most of the data analysis systems, analysis information systems, and representational models (B, C, and E) were initiated by internal or external entrepreneurs. These individuals often found themselves in a position of attempting to sell their innovative ideas to managers and potential users. On the other hand, the need for most of the file drawer systems and accounting models (A and D) was identified by users or their superiors. One possible inference is that these latter types of DSS are more easily visualized and appreciated by nontechnical personnel.

Key design and implementation problems varied by system type. Since the file drawer systems (A) were all used by a large number of people, and often involved procedural changes in the way data was collected and reported on a day-to-day basis, the process of defining the data and handling the procedural changes was especially important. The data analysis systems (B) were typically viewed as a way of making it convenient to analyze specialized data bases. In addition to the previously mentioned problem of deciding how to use these systems in changing situations, it was often difficult to assess the degree to which the analysis had a significant impact on decisions. The analysis information systems (C) in the sample were entrepreneurial efforts that grew incrementally; a key issue noted by the developer in each case was that of focusing usage appropriately and controlling the mix of projects that were undertaken. The purpose of most of the accounting models (D) in the sample was to compute the combined result of planning inputs submitted by people in different parts of the company; a significant problem for these systems was to get people to participate seriously in the planning process by submitting numbers that were well thought out. The tradeoff between richness and understandability was a key issue for both representational models and optimization models (E and F); as these models became richer and more detailed, they also became more difficult to explain. For suggestion models (G), the key design issue was whether or not it was actually possible to develop a standard method or set of rules for computing a suggested decision. In half of the sample cases, the specification of the method was considered a major breakthrough.

Systems of different types brought different kinds of change. File drawer systems, accounting models, and suggestion models (A,D, and G) brought changes in organizational procedures and information handling methods. The successful use of data analysis systems (B) by line rather than staff personnel seemed to require major changes in the user's job image. The success of advanced models (primarily E and F) often required changes in the way people thought about situations and solved problems.

Finally, the main technical challenges varied in a manner quite consistent with the generic operation performed by the system. In the data-oriented systems, the main technical challenge involved attainment of an appropriate balance between flexibility and efficiency in retrieval from a data base. In model-oriented systems, developing the model itself was the main technical challenge since current modeling methods are insufficient for many types of analysis of the future.

**Conclusions and Implications**

This article has attempted to support the hypothesis that a particular taxonomy is appropriate and useful. Since there is no statistical methodology for supporting such a hypothesis, the article has proceeded by proposing an organizing principle (generic operations), describing a taxonomy based on that principle, describing two examples of each type of system, and comparing the types of systems in terms of key characteristics. If it has been demonstrated that the taxonomy is an appropriate classification scheme, the question that remains is whether or why it is useful. I believe that the taxonomy is useful in a number of ways:

- As a guideline for designing systems,
- As a guideline for implementing systems, and
- As a framework for communication and research.

*A Guideline for Designing Systems*

One of the main implications of the taxonomy itself is that there are many different ways to use computers in supporting decision making. In designing a DSS, one of the first steps is to choose the type of system that will be developed. A potential use of the taxonomy is as a guideline in this process. In other words, a system designer might attempt to sketch out a system of each type as a potential *solution* to the *system design problem,* and would then combine the most useful features of each solution into his final design. Thus, the taxonomy would provide a substantive framework which would help in generating quite different approaches for supporting a particular decision. Whether this would actually be a fruitful exercise is a researchable question that has not yet been explored. Be this as it may, the sample did contain indirect supporting evidence in the form of several cases which at least suggest that the exercise of generating alternative designs might be useful. In one of these cases, a consultant felt very strongly that a representational model was needed for advertising decisions, whereas several users were more worried about the unavailability of data. After a period of trial and error, an effective procedure was developed in which a staff specialist provided briefings based in part on his use of a representational model (E) and in part on his use of a data analysis system (B). In another case, a plan to build a very expensive detailed simulation model (E) for raw materials allocation was abandoned when a staff man in a different department demonstrated that the same analysis could be done inexpensively with a rather simple optimization model (F). In a third case, a portfolio analysis system was installed to help portfolio managers think about portfolios from many different viewpoints (e.g., risk profiles, industry breakdowns, detailed sorted listings, etc.). After initial experience with this data analysis approach (B), it became clear that many portfolio managers wanted displays of what a portfolio would look like if particular decisions were made. To handle these *what if* inquiries, an accounting model (D) was added to the system. As a result, system usage increased. In all three cases, the consideration of different types of systems led to a better overall solution.

The taxonomy also provides insight for system user groups and system development groups concerning the types of systems that are currently installed and are on the drawing boards in their organizations. If none or few of the types of DSS are being used, the taxonomy provides a reference point in asking why existing applications encompass only a limited number of approaches for supporting decisions. One possible conclusion is that for this particular organization, computer-based decision support simply does not have high priority. Alternatively, the users may not be familiar with the different approaches that can be used, and the designers may have been reluctant to try to initiate types of systems that are new and untested in the organizational setting. The fact that most of the B, C, and E systems in the sample were initiated by internal or external entrepreneurs gives added credence to the notion that people whose main activities are not computer-related may have a very limited appreciation of how computers can aid in decision making. For these individuals, the taxonomy may be valuable as a framework for understanding the technical approaches that are or are not being suggested or used by resident systems groups.

*A Guideline for Implementing Systems*

The comparative findings in the previous section indicate that key implementation issues vary across the different types of DSS. These findings complement the growing body of knowledge concerning the general topic of implementation.[7] This knowledge is useful because it provides guidelines for implementers and alerts them to early warning signals that may be symptomatic of incipient implementation difficulties. The comparative findings provide an additional framework for anticipating and avoiding potential problems. For instance, while implementing a data analysis system, a designer should be especially concerned about the user's willingness and/or ability to figure out how to apply the system in novel situations. In developing an accounting model, the implementer should put special effort into assuring that the input estimates are well thought out. In developing a representational model or optimization model, the implementer should be concerned about possible misunderstandings of what the model means and how it can or cannot be used.

Although it is obviously impossible to assure implementation success by merely understanding what did or did not work in the past, implementation success rates should benefit from organized knowledge about implementation if this information can be used to anticipate and avoid potential problems. To the degree to which the various types of DSS really are quite different, it is not only desirable, but also necessary to accumulate and analyze empirical data about the various types of systems. From the viewpoint of the MIS or DSS researcher, a stronger restatement might be as follows: unless taxonomies of this sort are taken into account in the research design, contradictory or inconclusive results can be *expected* because taxonomic contingencies (rather than *noise* per se) may well swamp the effects being studied.

*A Framework for Communication and Research*

Finally, the taxonomy provides a framework for communication and research. In light of the continual state of confusion that has surrounded

[7] See [6], and Schultz and Slevin [7].

terms such as management information system (which usually is not used by management), interactive system (which rarely interacts with decision makers), distributed processing (which has many meanings currently), the need for understandable taxonomies in the computer applications field should be clear. The findings described here — both the taxonomy itself and the fact that DSSs of various types differ in many important ways — illustrate that the term *decision support system* can have vastly different connotations for different people. Consider, for instance, the respective viewpoints of a user of a file drawer system and of a user of a very large optimization model. Whereas the file drawer user might conclude that the essence of decision support lies in on-line access to data, the optimization user might feel that on-line access is completely beside the point since each run of his DSS might require two hours of preparation and setup. Rather, he would probably identify accurate and complete modeling as the key issue in producing a useful DSS. Although the opinions of both users might be appropriate with regard to their own systems, neither conclusion would be appropriate for all or even most DSSs. Thus, whether it is this particular taxonomy or another, a classification scheme for DSSs is needed merely to help users and implementers communicate their experience in this emerging area.

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