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DECISION SUPPORT SYSTEMS FOR ACADEMIC ADMINISTRATION

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Decision Support Systems arrived in academic administration in the 1980s with a great deal of enthusiasm and controversy. What are they? What can they do for you? This issue introduces the reader to Decision Support Systems (DSS) and discusses how DSS might help academic administrators make decisions. It includes (1) a description or definition of DSS, (2) a brief historical development sketch, (3) an illustration of an application of DSS in academic administration, and (4) references on the subject of DSS.

Decision Support Systems Defined

Probably the most important feature of DSS is that it represents a shift in emphasis, from the various tools and techniques commonly employed in the decision-analysis process, to the decision maker. Thus, DSS does not represent a new method or technique for decision analysis but, rather, a fundamental shift in orientation. DSS may be considered as a *philosophy* of decision analysis which places greater emphasis on assisting and involving the manager in the decision-making process, but always leaving the ultimate decision to the decision maker.

It is well known that people, not machines, make most decisions, and people will not use solutions provided by machines or analysis techniques unless they understand, or at least feel comfortable with, the solution procedure and results. The objective of decision support systems is to involve the manager/decision maker in the decision-analysis process while simultaneously relieving that person of the burden of developing and performing detailed analysis, i.e., decision support. The field of DSS includes the methods and approaches for supporting decision making by employing the latest technological developments in interactive computing and decision-science modeling.

DSS represents a convergence of the rapidly developing technologies and bodies of knowledge in the following areas: (1) computer hadware and software technology, especially microprocessor systems, (2) data processing and information-systems theory and applications, and (3) management-science/operations-research modeling and analysis techniques, including both analytical- and simulation-modeling approaches. An illustration of how DSS draws on a combination of other bodies of knowledge and technologies is shown in Figure 1.

CONVERGING TECHNOLOGY AND BODIES OF KNOWLEDGE

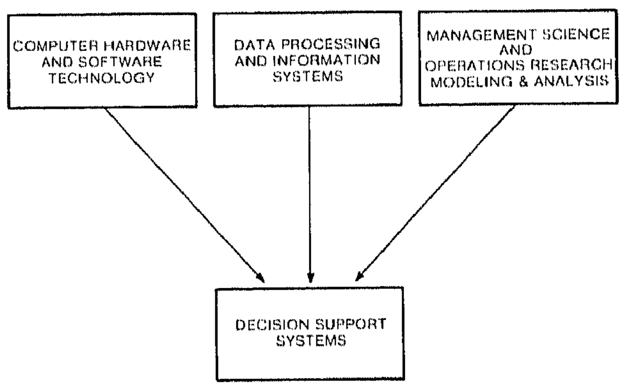


Figure 1. Decision support systems (DSS), including use of state-of-the-art technology in computer hardware and software as well as use of the extensive bodies of knowledge in information-systems and management-science modeling and analysis techniques.

Components of a DSS. The primary components of a DSS include the following:

1. The decision maker
2. The data base, including internal files, external files, and managerial files
3. Decision-relevant models, including prewritten catalogued packages and flexible custom-developed models
4. Interactive computer hardware and associated software

5. A communication or command language for user dialogue with the remaining system

THE DSS CONCEPT

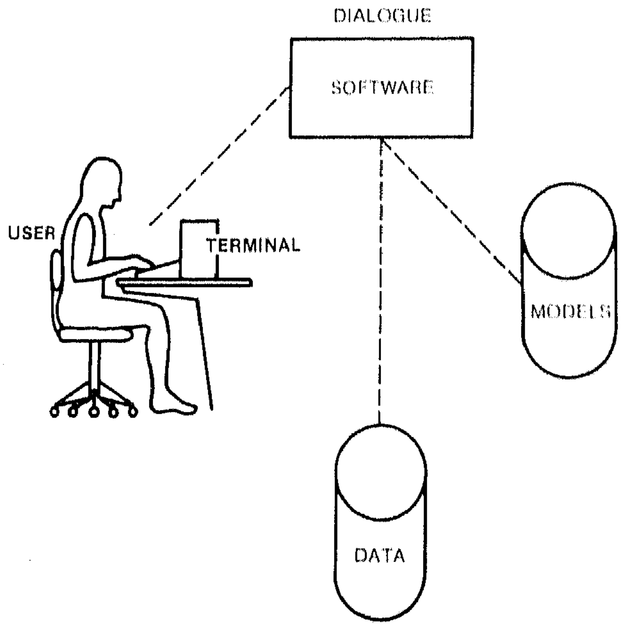


Figure 2. The DSS concept, in which the decision maker is an integral part of the decision-analysis system.

Figure 2 provides a pictorial illustration of the components of a DSS, including the interconnecting linkages. The analyst or research associate in institutional research/academic planning will quickly observe that Figure 2 illustrates a system already in existence at many academic intitutions. The only difference is that the user shown in Figure 2 is typically an analyst rather than a manager or administrator. The DSS concept is to include the *decision maker* in the decision-support system to as large a degree as possible. This goal is becoming increasingly feasible as a result of readily available on-line computer terminals, or microcomputers, and user-friendly software packages for communicating with data bases and performing complex analyses.

The characteristics of a DSS. The characteristics of a DSS include the following:

1. It is *computer based.* (It provides a powerful capability for information storage and analysis.)
2. It is *interactive.* (The system employed is on-line real-time which results in fast response to "what if" questions.)
3. It includes a *user friendly* command language. (The conversational language provided allows maximum accessibility to managers.)
4. It *utilizes models.* (Information analysis and synthesis is performed by mathematical and/or simulation models which have reached a high stage of development.)
5. It proves *easy access to data bases.* (The most modern data-base storage and management technology is employed.)
6. It proves *graphics.* (Numerous output displays are possible.)
7. It allows a *flexible decision-analysis process.* (The user is allowed to deal with unstructured, nonrecurring problem situations.)
8. It *supports managerial judgment.* (It provides support in the decision process rather than replacement in the form of a "solution.")

The focus of DSS is to make maximum use of the latest technology in computers and software to make it as easy as possible for managers to interact with and make use of powerful computerized systems for information management and problem analysis. This is, of course, the *objective* of DSS. This objective, as yet, has not been fully achieved. However, casual reflection will yield the conclusion that progress has been made at an almost startling rate. The mushrooming software development that has accompanied the microcomputer boom is an example of the race to make computers readily accessible and usable by the layman.

Figure 3 illustrates a complete DSS system as a block diagram showing the decision-maker subsystem, the data-base subsystem, and the decision-models subsystem, which was presented by Sprague and Watson (1976, p. 660). The system they portray includes transaction data for a business firm, e.g., production, finance, marketing. However, in an academic institution, these categories could become admissions, student records, personnel, academic affairs, research division, graduate school, extension division, etc.

Historical Development of DSS

The evolutionary stages leading to DSS can be summarized as follows:

1960s: Basic data-processing systems were developed and employed. Most such systems involved a single data-processing task, and the jobs were self-contained, such as payroll. The output was generated in the form of scheduled reports which summarized the transaction data process.

Late 1960s and early 1970s: Integrated data-processing systems were developed and employed. Such systems included the use of more than one data file. Routine reports were generated, and simple decision models were supported, such as inventory control.

Late 1970s: Management Information Systems (MIS) were developed and employed. Partially integrated data bases were included in MIS, including partitioning by major business functions, such as marketing, finance, or production. Reports could be generated on demand rather than on a fixed schedule. Also, reports oriented toward upper management were more commonplace.

1980s: Decision support systems were developed and employed. DSS included integrated systems of data base, decision models, and decision maker. Such systems provide a mechanism for the decision maker to interact with the data and models in a convenient and supportive manner.

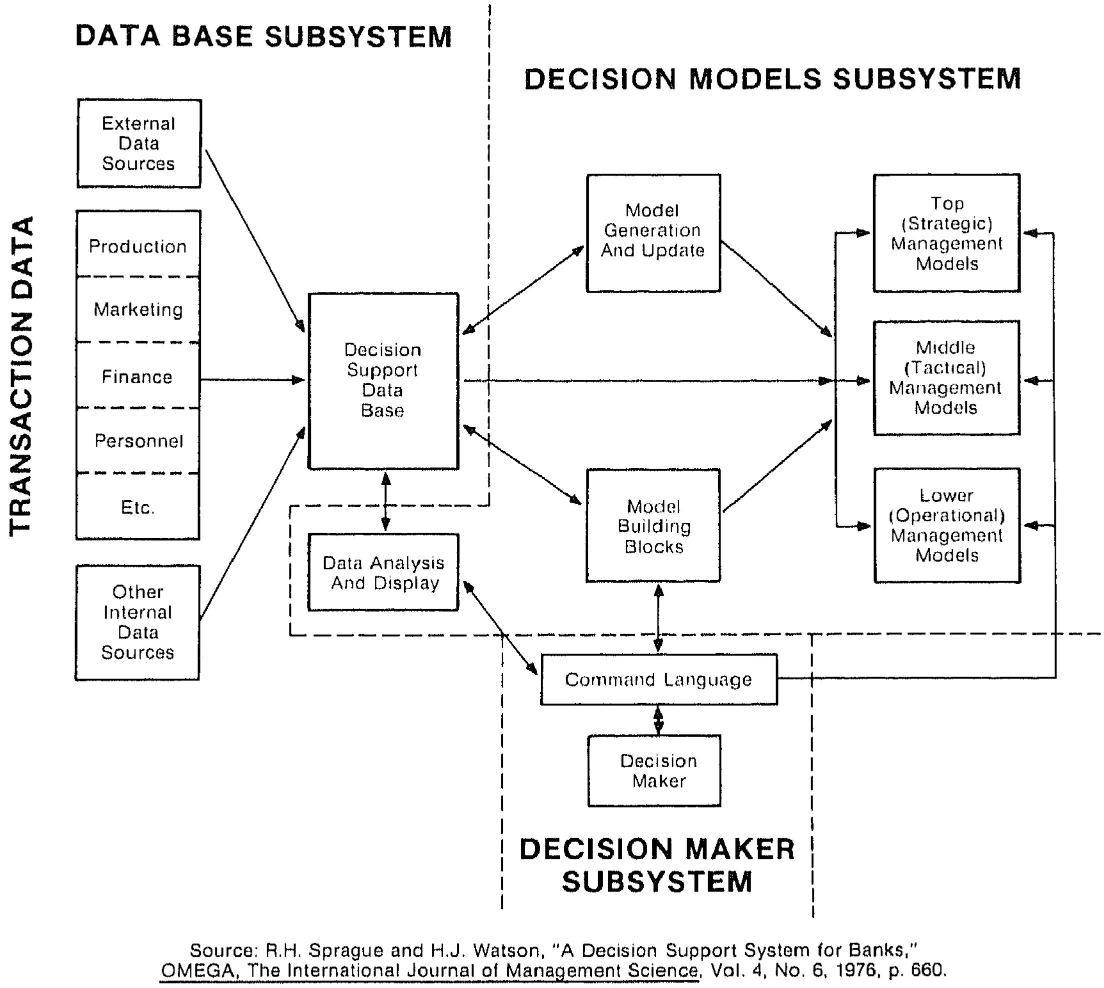


Figure 3. The decision support system, including three primary components: decision-maker subsystem, data-base subsystem, and decision-models subsystem.

Note: From "A Decision Support System for Banks" by R.H. Sprague & H.J. Watson, 1976, *OMEGA: The International Journal of Management Science, 4*(6), p. 660. Reprinted by permission.

Milestones in DSS literature. Milestones in the literature, leading to the field of DSS are as follows:

1963: Bonini produced a Ph.D. dissertation on the simulation of information and decision systems in firms.

1969: Ferguson and Jones published an article in *Management Science* on a computer-aided decision system.

1969: Gershepki published an article in *Harvard Business Review* on building a corporate financial model.

1970: Boulden and Buffa published an article in *Harvard Business Review* on corporate models and on-line, real-time systems.

1971: Scott Morton published a book entitled *Management Decision Systems: Computer-Based Support for Decision Making.*

1976: Keen published an article in *Sloan Management Review* on interactive computer systems for managers.

1977: Alter published an article in *Management Review* on the taxonomy of decision-support systems.

1978: Keen and Scott Morton published a book entitled *Decision Support Systems: An Organizational Perspective.*

1980: Fisk and Sprague published the proceedings of a conference entitled *Decision Support Systems: Issues and Challenges: Proceedings of an International Task Force Meeting.*

DSS software. Numerous firms have developed software which is often referred to as a DSS. Such software is not a complete DSS in the same manner described in this paper. However, this software does represent an important component of a DSS, in that a command language is included along with various data storage, modeling, and report-generation capabilities. A detailed description of the DSS software packages and information about the firms that produce them is provided in Naylor (1982).

References on DSS. A large body of published material has been produced on the topic of decision support systems. An effort has been made to edit and screen the available references; a complete biographical listing of what the authors believe to be the most relevant and highest quality available sources on DSS is given at the end of this paper.

An Application of DSS in University Administration

The DSS example presented in this paper was developed in order to analyze tuition-and-fee policy alternatives at a major state university. The system was designed to enhance the administration's capability to effectively deal with tuition-and-fee policy issues at a detailed and sophisticated level without directly handling large amounts of data, structuring the problem, formulating and solving complex analytical models, and composing a series of reports to document the results. The DSS is intended to support the planning, decision-making, and policy-setting processes by providing a way to readily analyze the effect of changes in the variables and parameters that impact tuition charges and by providing a means to test present and alternative policies under different scenarios. The targeted users for this system are middle- and upper-level administrators—those directly involved in the decision-making activities of the institution.

The DSS is presented in three sections: (1) a discussion on modeling the tuition-and-fee allocation process, (2) an explanation of how the system is used, and (3) a brief description of the system's software structure.

Modeling the tuition-and-fee allocation process. Tuition charges are established, as shown in Figure 4, by allocating the institution's annual revenue requirement to tuition charges for each individual student category. Each student category is assessed a different tuition charge; the distinction between student categories is based on academic level, residency status, campus location, etc. The initial step in the process is the determination of the institution's expected operating expenses over the duration of a planning horizon. Subsequently, the revenue required to cover the expenses is established by source (state funds, tuition, fees, private, etc.). Once the tuition-revenue requirement has been established, it must be allocated to the different student categories, based on a set of university goals, constraints, and priorities.

The third step is the heart of the DSS, in that it generates the tuition-and-fee charge structure—a set of tuition charges for all student categories based on specific assumptions, expectations, and conditions. It represents a compromise between the institution's financial considerations and its philosophical concerns.

A goal-programming (GP) model, as shown in Figure 4, is used to allocate the revenue requirements and thereby establish the charge structure. GP is a mathematical programming technique that is used to solve problems involving multiple, conflicting, and incommensurable objectives. It attempts to satisfy a set of rank-ordered objectives (goals) rather than to optimize a single objective, as in linear programming. A GP model is composed of a set of mathematical relationships, called goals. Each goal is formulated as a functional relationship between the decision variables (e.g., the desired tuition charge for each student category in each year) and a target that the goal function is attempting to satisfy. A priority structure is established by ranking the goals and assigning each goal to a priority level, in the order of importance to the decision maker. In a sequential manner, according to the ranking specified by the priority structure, the GP algorithm determines the values of the decision variables that minimize the deviations from the desired goal levels. The resulting solution is the tuition-charge structure that *best* reflects the specific set of rank-ordered goals.

The goals that comprise the GP model are descriptions of the university's tuition philosophy and policy in mathematical form. Table 1 provides a list of all of the goals that are included in the DSS, and Table 2 lists some of the factors that are included in the goal formulations.

As indicated in Table 1, there are three goal categories that are used to establish the tuition-charge structure—aggregate goals, individual goals, and comparison goals.

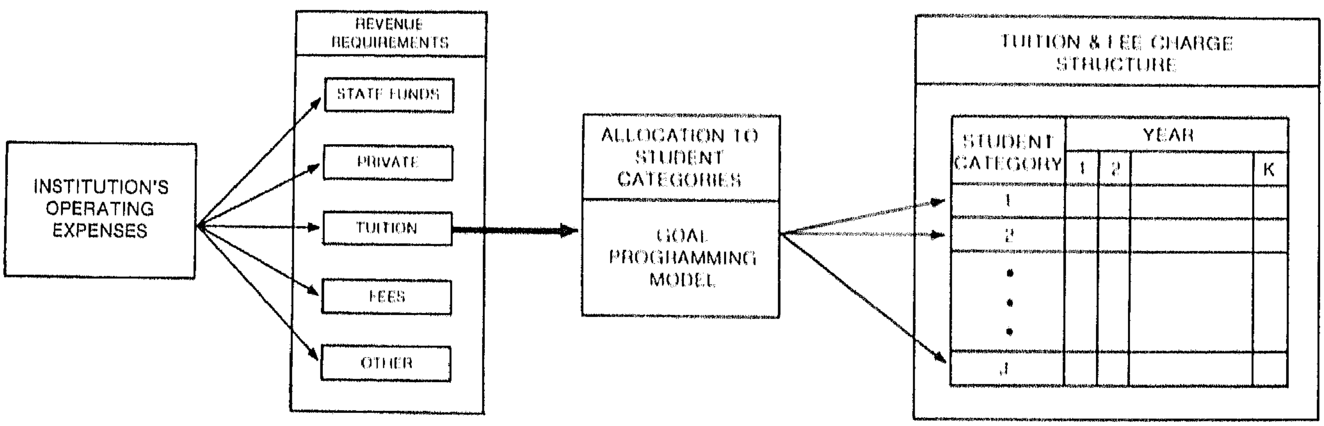


Figure 4. Tuition charges, established by allocating the institution's annual revenue requirements to tuition charges for each student category.

Table 1

Goals That Are Included in the DSS

A. Aggregate Goals
1. State-level tuition revenue requirement
2. Supplemental funds revenue requirement
   a. In each year
   b. Total over the entire planning horizon

B. Individual Goals
1. Tuition charges as a percentage of average total cost per student
2. Percentage change in tuition charges over time
3. University's position in relation to peer institutions

C. Comparison Goals
1. Absolute relationships
   a. Single student category
   b. Pairwise comparison between two categories
   c. Four student categories
2. Relative comparisons between two student categories

Table 2

Factors That Are Considered in the Goal Formulations

A. Planning Horizon
1. Starting year
2. Length or span

B. Enrollment
1. Forecast or projections
   a. Level
   b. Mix
2. Student credit-hour load
3. Retention between sessions
4. Tuition waivers

C. Policies (Present and Alternative)
1. University
2. State government

D. Cost Information
1. Economic forecasts
2. Historical data
3. Inflation rates
4. Operating expenses
5. Capital projects

E. Student Charges
1. Fees
2. Dorm and dining
3. Charges at peer institutions

Aggregate goals include all of the student categories in the goal formulation. For example, a university's overall revenue needs are specified by a goal that includes the revenue generated from all of the student categories (e.g., the state-level tuition-revenue requirement in Virginia or the desire to raise supplemental funds for additional salary compensation, equipment, etc.), either in each year or over the duration of the planning horizon.

In contrast to the aggregate goals, individual goals consider each student category by itself, or apart from the others. An individual goal is used to differentiate tuition charges among student categories based on a specified proportion of total cost—the student's assessed share of the institution's cost of operation. An individual goal is used to specify the university's tuition position relative to similar schools within its peer group, thereby reflecting its desire to remain competitive in certain student markets. Another use of an individual goal is to control, for each student category, the year-to-year change in tuition charges.

Comparison goals directly specify absolute or relative relationships between the student categories. For example, an absolute goal is used to establish a different charge for on-campus and off-campus programs. A relative goal is used to reflect a policy that nonresident students pay at least twice the in-state rate.

The DSS presented in this paper provides the framework for the administration to explore tuition and fee issues. It is a comprehensive package; it integrates data and reports with modeling and analysis, but in a manner that does not require the user to be an expert in computers and management science. The system operates interactively—providing immediate feedback, facilitating "what if" analyses, and satisfying the user's need to explore and test alternatives.

Figure 5 illustrates conceptually how the user interacts with the system in a typical application. Since the data and the user are influenced by exogenous factors—economic, political, and demographic conditions—the specific actions that are taken will vary from application to application, but the overall process should be similar to that shown in Figure 5.

As previously described, tuition charges are established by a goal-programming model, imbedded in the DSS, that allocates the revenue requirements to student categories. There are two basic inputs to the GP model—parameter estimates and goals—both of which are controlled by the user, as illustrated in Figure 5. From a predefined set, the user decides which goals to include in the analysis and ranks them in the order of importance to the university, thereby constructing a priority structure. The parameter estimates either are obtained directly from the user or are calculated by supporting models. The user controls the data (enrollment levels, cost information, inflation rates, fee charges, etc.) that drive the support models. The DSS automatically formulates the goals, translates them into the form required by the optimization routine, estimates the appropriate parameter values, solves the problem interactively, and generates a set of reports. Once this has been completed and the charges have been established, control is returned to the user, as illustrated by the feedback loop in Figure 5, for the purpose of exploring and testing alternatives and of performing sensitivity analyses.

The specific steps that are involved in a typical application of the DSS are shown in Table 3. The figure at the left of the table indicates that the user has the choice of starting the session at various points or being guided through each step of the process. The figure also indicates that the user can "loop" through the process and easily explore alternatives and perform sensitivity analyses.

As shown in Table 3, the process of establishing tuition charges using the DSS involves dual and shared responsibilities between the DSS and the decision

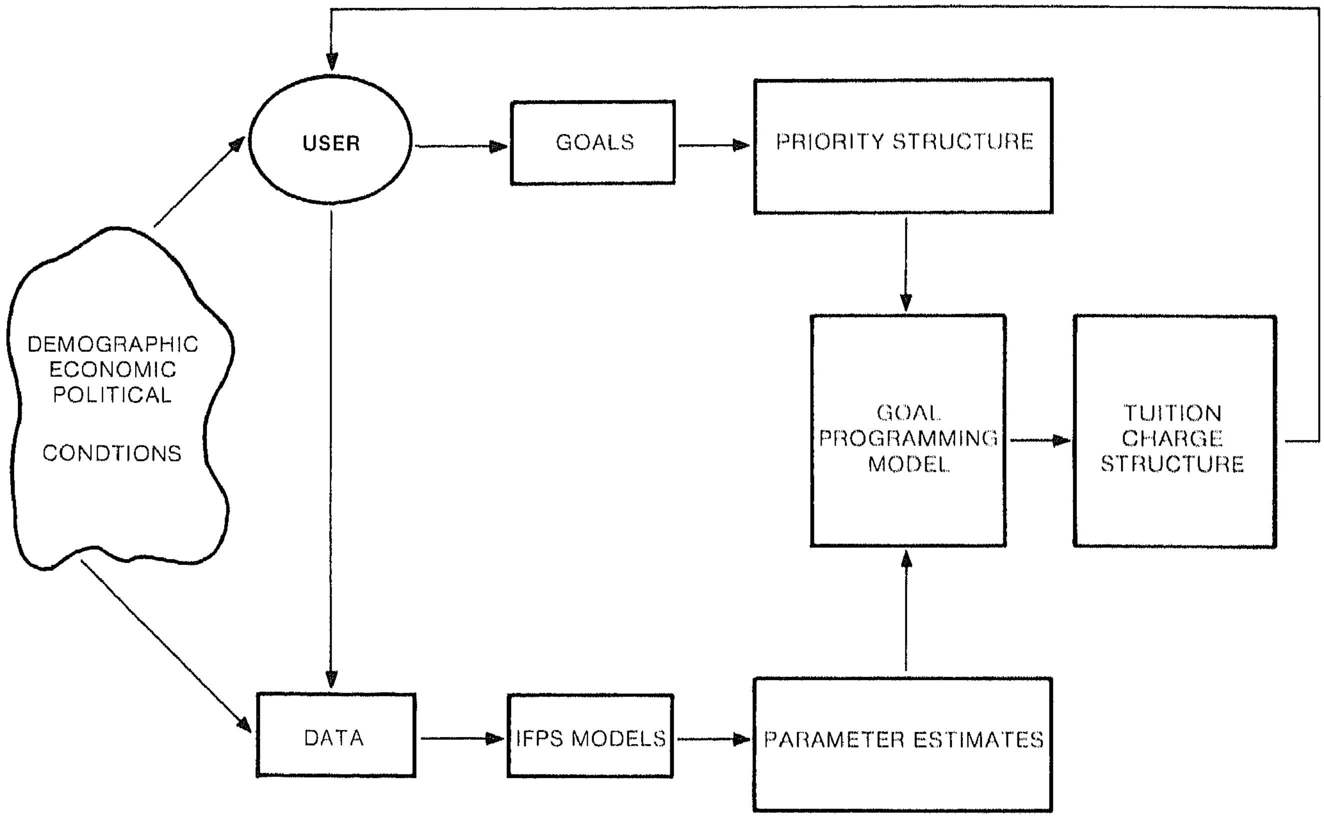


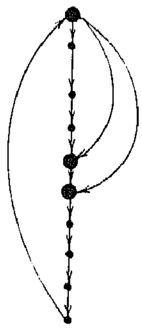
Figure 5. Interaction between the user and the decision support system in a typical application.

maker. The decision maker is responsible for accessing the system, defining the problem framework, selecting the goals, and setting the priority structure. The DSS formulates and solves the model, and generates the necessary reports as well. The responsibility for providing the necessary information for the remainder of the steps is shared by the DSS and the decision maker. While the DSS calculates most of the model's parameter values, some must be directly input by the user. Likewise, while the decision maker supplies most of the goal-target values, some are automatically calculated by the DSS. The final step in the process, analyzing the solution, is also a joint effort; the DSS supplies the reports and information to the decision maker who ultimately selects the "best" solution. Once the basic problem has been defined and the basic data supplied, the user can omit many of the steps and quickly test alternative priority structures or measure the effect of changes in the goal-target values.

The steps outlined in Table 3 and the shared responsibility between the DSS and the decision maker demonstrate two key DSS concepts: (1) the system *supports* administrative judgments and does not replace them and (2) the system improves the effectiveness of the decision-making process and does not just improve its efficiency.

Table 3

The Process of Establishing Tuition Charges, Involving Dual and Shared Responsibilities between the Decision Support System (DSS) and the Decision Maker (DM)



Steps	Responsibility
Access the system	DM
Define the problem framework: planning horizon, datasets	DM
Select the goals to be included	DM
Provide the parameter values	DSS/DM
Establish the goal-target values	DM/DSS
Set the priority structure	DM
Formulate the problem	DSS
Solve the problem	DSS
Generate management and back-up reports	DSS
Analyze the solution	DM/DSS

Software structure and the DSS architecture. The basic software structure of the tuition-and-fee DSS is represented schematically in Figure 6. The system is divided into three major subsystems—the dialog subsystem, the model subsystem, and the data subsystem. According to Sprague and Carlson (1982), it has been more effective, in building the DSS, to separate the functions of the three subsystems than to intermix them. Sprague and Carlson also point out that just as the software structure separates the functions, it must also provide a mechanism to integrate them through a DSS architecture. Each of the subsystems is further partitioned into components in order to facilitate construction and testing but, more importantly, to provide flexibility in the system and to facilitate modification, extension, and updating. Figure 6 shows how, in this particular DSS, the software interfaces connect the three subsystems and their components, thereby forming an integrated and unified system.

The dialog subsystem is probably the most important since it provides the interface between the user and the system. Bennett (1977) includes the user, the computer terminal, and the software system as parts of the dialog subsystem. He also defines the dialog experience as containing (1) action language (the user's communication with the system), (2) display or presentation language (what the user sees on the display screen of the terminal), and (3) knowledge base (what the user must know in order to use the system effectively).

The DSS dialog subsystem, represented in Figure 6, contains a single executive-control program and a series of component-control programs. The executive-control program is the primary link between the user and the DSS. It manages the user's session with the DSS through the display of available options and through control mechanisms that initiate operations when certain conditions exist. For example, when certain changes are made by the user (e.g., change the planning-horizon definition), specific operations must be performed both by the system (e.g., change the problem-definition data file) and by the user (e.g., enter new goal-target values). The executive-control program also provides the user with direct access to the common or shared data files. Most of the interface between the models and the data is provided by the component-control programs.

The DSS contains fifteen component-control programs that perform five basic functions: data control, goal formulation, priority structure definition, problem solution, and report generation. Three are used to handle the data files, especially those containing the enrollment and financial data. Seven programs are used to formulate the goals by these means: (1) prompting the user for information when needed, (2) utilizing the appropriate models and data to estimate the parameter and goal-target values, (3) translating the goals to the proper format for the GP solution algorithm, and (4) generating reports to document the results and supply supporting information. Another component program is used to control the input of the priority structure by the user and to translate it to the proper format for the GP model. Three of the component-control programs are used to solve the GP model. One is used to set up the problem in a file that is readable by the solution routine; another provides a listing of the GP model in equation form; the third program contains the com-

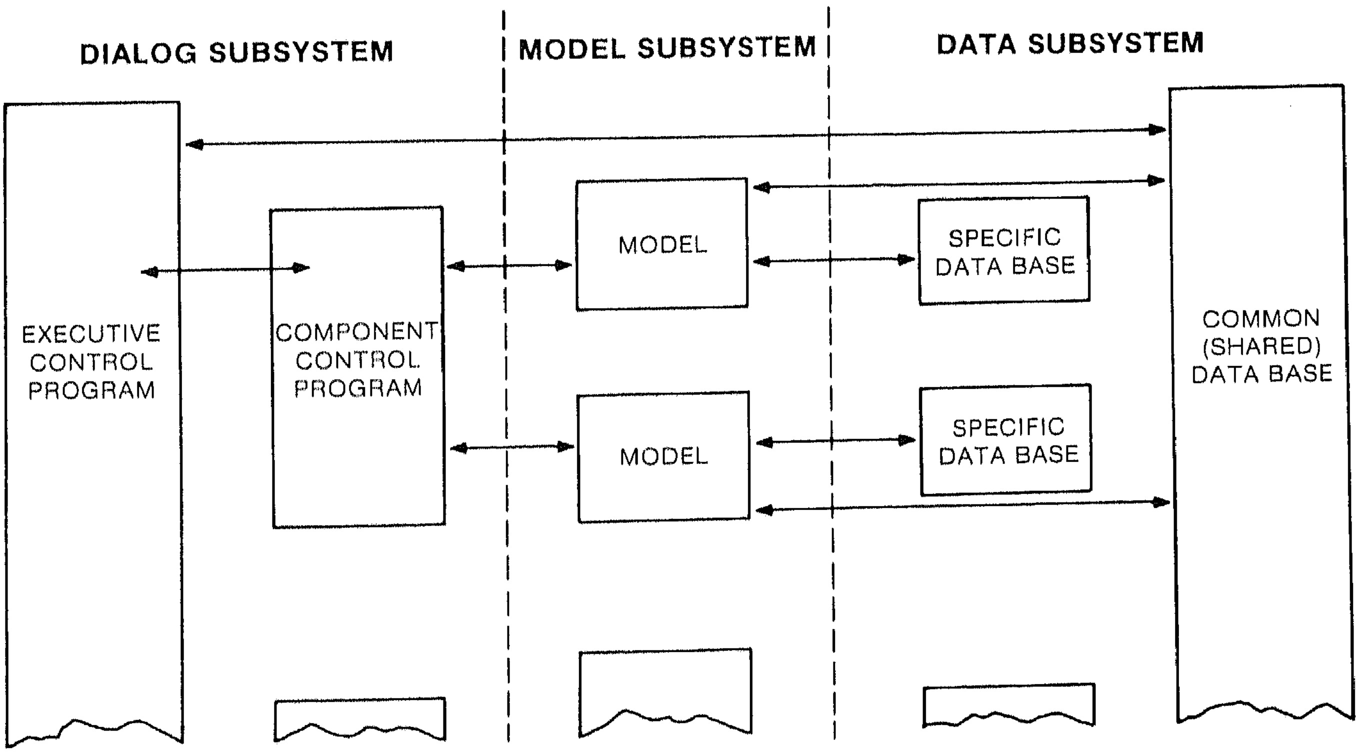


Figure 6. The basic software structure of the decision support system, divided into three major subsystems: dialog, model, and data.

mands necessary to generate a solution and store the results. The final control program provides the user with a menu of reports that are available for printing and a choice regarding the type of printer to be used.

The data subsystem, through its memory function, serves to integrate the dialog and model subsystems. It organizes, processes, and stores information, and manipulates and converts data for use in the different components of the DSS as well. The data subsystem supplies input data to the models, provides workspace for intermediate calculations, stores output reports, and maintains displays and memory aids for the user. As shown in Figure 6, the data subsystem contains a common or shared data set and a series of data sets that are unique to a specific model. The common data set, for example, contains the enrollment-projections file and the problem-definition file, both of which are used by most of the models. In contrast, the file containing the yearly supplemental revenue goals is a specific data set, used by only one model.

The model subsystem is the analytic portion of the DSS. Most of the models are used to calculate parameter and goal-target values. One interactive optimization routine is used to solve the goal-programming model. By imbedding the models within the DSS, input values are automatically supplied and reports that document the solution are automatically generated. The model subsystem is a collection of separate models, each dealing with a distinct problem. This separation facilitates model development, testing, modification, and extension, but it also creates a demand for an interface among the models themselves as well as with the dialog and data subsystems. The model subsystem is integrated with the dialog subsystem to provide control over the model's operation and use; it is integrated with the data subsystem to receive input data and to generate output information. The link between the data subsystem and the dialog subsystem provides the user with a display of the model solution.

Summary

When should the DSS process be used? What will it do for the user? What are the main points to remember? The DSS process, or approach to decision analysis, should be used in all cases where decision making takes place. The sophistication and complexity of the decision support system should be tailored to the difficulty and complexity of the problem situations being faced. Decision support systems provide the user with on-line, interactive information and analysis concerning the problem under study. However, decision support systems do not provide the *answer* to the problem. That is, they are not used typically as optimization models. A good decision support system should assist the decision maker in understanding the basis on which a decision can be reached.

One main point to remember is that decision support systems should be no more complex or sophisticated than the decision maker desires them to be or than the problem situation mandates. A good decision support system also allows the interjection of the decision maker's own experience and wisdom concerning the problem, and it provides the answers to "what if" questions that may be posed by the decision maker. If the computerized, interactive decision support system is not "user friendly," then it is not a desirable DSS.

In summary, decision support systems are simply a recognition of the need to make maximum use of the state-of-the-art technology, in terms of computerized equipment and software, while recognizing the need to emphasize the human input and ultimate decision-making authority.

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