INSTITUTIONAL AND AD HOC DSS AND THEIR EFFECTIVE USE

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Abstract

The term decision support system (DSS) applies to the subset of management information systems that truly support decision-making processes. This term excludes structured decision systems that essentially present the appropriate decisions for management approval, as is the case in many inventory-control or billing systems. This paper differentiates between two classes of decision support systems: institutional DSS, which deal with decisions of a recurring nature, and ad hoc DSS, which deal with specific problems that are usually not anticipated or recurring. An understanding of these two classes of decision support systems facilitates making explicit both their common and different computational needs. This analysis has provided a basis for the development of computational facilities to support effectively their common needs. This paper briefly describes some of those computational facilities and illustrates their use in systems (institutional and ad hoc) which are being effectively used to support regional energy decisions in New England.

Introduction

The complexity, interrelationships and rapidity of events in the private and public sectors have accelerated the need for more support in making the unstructured decisions that may have marked social, economic and human effects on a corporation or the government. This increased need for more rapid and effective decision making is being driven by:

1. The problems associated with scarce resources, across a broad spectrum of resources (Brown, 1976).
2. The increasing complexity of the society in which we live (Forrester, 1975).
3. The growing demand for human services and the need for increased productivity in this area (Hollomon, 1975); it has been estimated that over 66 percent of the American work force is employed in providing services, (teachers, lawyers, accountants).

Addressing all these needs involves analysis and identification of elements needed to fornulate decisions. The common element is information—information for decisions that can minimize the negative impact of limited resources, cope with the complexity of our society in both the public and private sectors and effectively manage the distribution of services. The inadequacy of present tools for providing the necessary information to assist in the decision-making process is being felt here and now.

Several frameworks of management information systems have been developed in the literature (Alter, 1976; Altshuler and Plagman, 1974; Anthony, 1965; Davis, 1974; Ginzberg, 1975; Simon, 1960). One such framework for information systems is depicted in Figure 1 (Gorry and Scott Morton, 1971). This framework is built upon the work of Simon (Simon, 1960) and of Anthony (Anthony, 1965). Depicted across the top of Figure 1 are the management acticities being addressed; depicted vertically are the types of problems being addressed.

The framework of Figure 1 has provided the basis for differentiating between structured decision systems (SDS), which are designed to handle structured problems, and decision support systems (DSS), which are intended

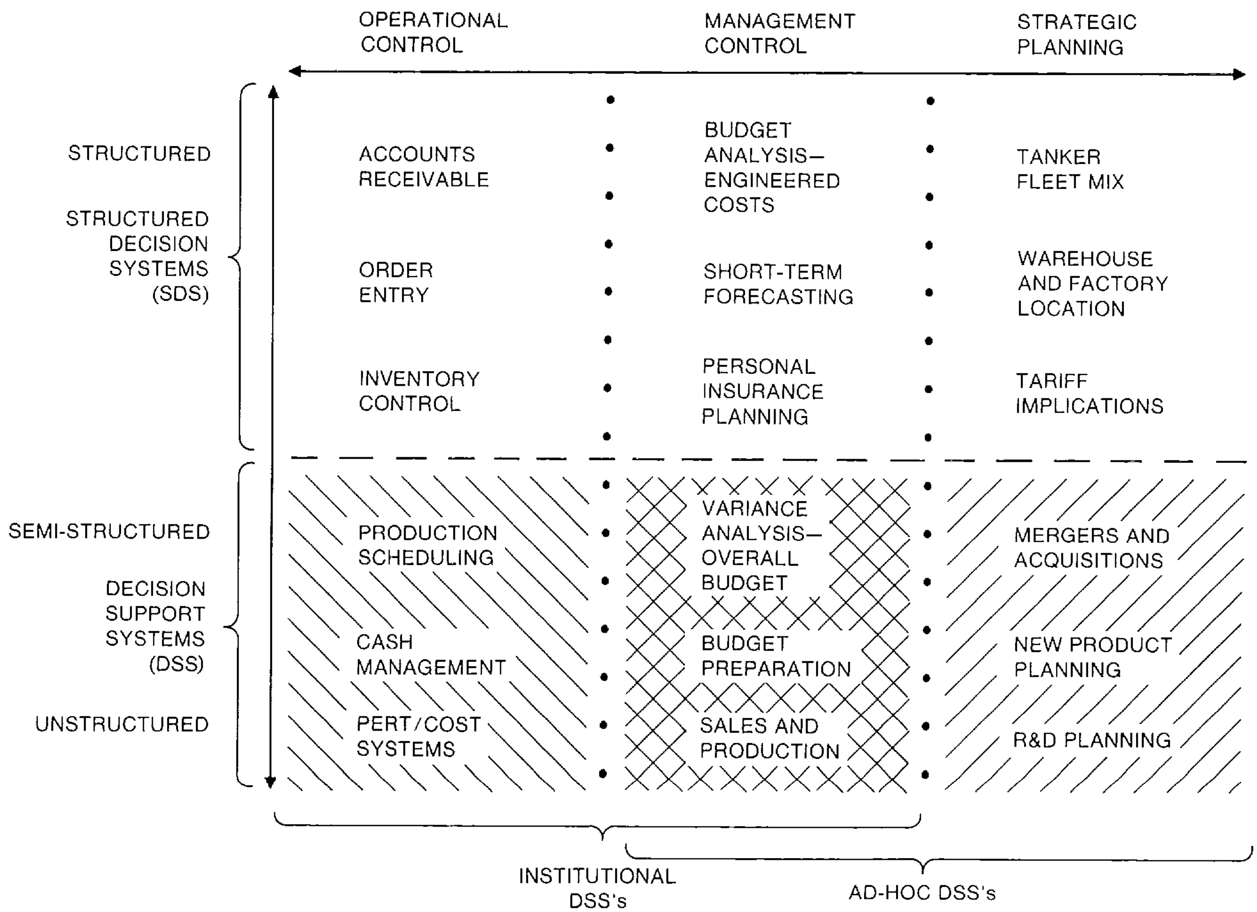

Figure 1

to assist the manager in dealing with unstructured problems. It has been noted by Gorry and Scott Morton that structured decision systems "encompasses almost all of what *has* been called management information systems (MIS) in the literature" (Gorry and Scott Morton, 1971: p. 61). This paper focuses on decision support systems.

Logical Decision Groups

As noted by Scott Morton: "Those semistructured problems in key decision areas represent the next area of opportunity for using computers to enhance the effectiveness of the organization" (Scott Morton, 1975: p. 118). To realize this potential, it is necessary to understand the nature of the decisions and how they may be organized into logical decision groups.

For example, an investment manager in the trust department of a bank is responsible for the management of one or more portfolios. The decision to trade in or not to trade in a specific security for a specific portfolio on a specific day is *a* decision relevant to a portfolio manager (Gerrity, 1971). It is unlikely that a completely new decision support system would be developed to handle only that specific decision. Rather, we would probably define a *decision type* that encompasses decisions of the type, "Should I trade in stock X for portfolio Y today?" A more general decision support system could then be developed appropriate to that decision type.

In practice, it is common to develop a decision support system for a *logical decision group* consisting of several different, but related, decision types (a security's expected return, for example, and a security trade for a portfolio). This is done for both technical and operational reasons, such as: There may be similarities in the data or models needed which make it easier to implement one system to handle several related decision types than to implement

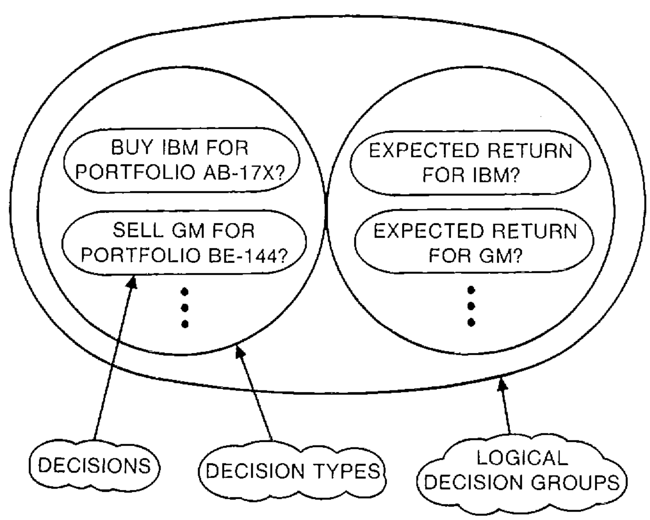

Figure 2

several separate DSSs. Over a short period of time a single manager may have to make several different decisions, many of which may be interdependent; it may be operationally more convenient to the decision maker to use a single DSS for all of the decisions rather than switch between multiple DSSs. The actual contents of a logical decision group are, of course, application- and situation-dependent.

The relationship among decisions, decision types and logical decision groups is depicted in Figure 2. We further distinguish between two types of decision support systems, institutional and ad hoc, which have some similarities with the operational control and strategic planning categories of the Gorry-Scott Morton framework, as indicated in Figure 1.

Referring to Figure 3, in an institutional DSS there are many specific occurrences of decisions of each type, such as security purchases. As a result, the primary focus is on defining the decision types, and there are usually relatively few decision types in the logical decision group of the DSS. In an ad hoc DSS, on the other hand, there may be relatively few occurrences of decisions of each type, such as mergers. As a result, the primary focus is on defining the logical decision group and ways to have it encompass as many decision types as reasonably possible.

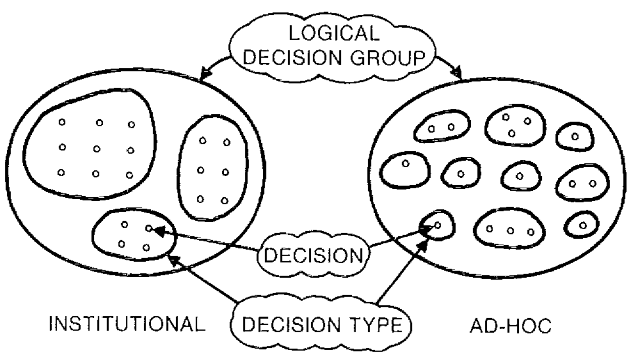

Figure 3

Institutional decision support systems deal with decisions of a recurring nature, such as a portfolio management system or an energy-consumption monitoring system. In such systems, it is usually possible to define the general nature of the problem and approaches to decisions of that type over several years. Furthermore, since the problem definition remains relatively stable once it is understood, it is possible and common to invest considerable money and time in the design and development of systems to address that decision type.

The design of an institutional DSS focuses on precisely defining the inputs and outputs to the key decision types. Then a great deal of attention can be given to tuning such systems because they will be used extensively over a period of many years.

An ad hoc decision support system is concerned with aiding decision making for a wide variety of problems that are not usually anticipated or recurring. Examples in the private sector include new product opportunities and merger offers. In the public sector there are similar problems, such as assessing the impact of proposed legislation, price changes or new technologies. In such cases the specific problem and its decision type being addressed at any time are usually poorly defined, the decision is needed very soon and the decision maker's perception of the problem and even the inherent nature of the problem may change during the process (Pounds, 1969); collective bargaining (Siegel, 1969) is such an example.

The design of an ad hoc DSS must focus on responding quickly with needed information and analysis on a one-time basis for a specific decision from the logical decision group. As a result, the concerns for operational cost and tuning are much less significant than in an institutional DSS.

There have been various examples of institutional DSSs reported in the literature (Alter, 1976; Bennett, 1974). Since there have been few concrete examples of operational ad hoc DSSs in the literature, let us cite a brief example in use that illustrates the information system requirements.

Regional Energy Project

Consider the range of problems that must be addressed by a regional public policy decision maker in New England with regard to energy. At the height of the energy crisis during the winter of 1973–74, the major concern was managing the distribution of oil to minimize the impact of shortages throughout the region (Donovan and Jacoby, 1973). Less than six months later the problem had changed completely. New England was no longer in a shortage situation, as there was a backlog of full tankers in Boston harbor. Instead, the region was beset by a new series of problems, primarily economic. Prices of energy had gone up more than 50 percent in that three-month period. Certain industries and sectors within the region were thus adversely affected.

As the region realized its vulnerability to price fluctuations in energy, the problems of the policymaker shifted from ones of handling shortages to ones of analyzing methods to conserve fuel; analysis of impacts of tariffs, decontrol and natural gas or oil prices on different industrial sectors and states within the region; analysis of the merits of refineries, and analysis of impacts of offshore drilling on New England's fishing industries. These are but a few of the problem areas which New England policymakers face and on which they need effective decision support.

An ad hoc DSS to address these problems, named the New England Energy Management Information System (NEEMIS), has been developed and is described later.

Table 1 depicts a summary comparison of institutional and ad hoc decision support systems. As can be seen, the key areas of distinction relate to the recurring and operational nature of the decisions being supported, the scope of these decisions and the ability to predict the data and analysis needed. In an institutional DSS, the decision types are first defined and then aggregated as appropriate to form a logical decision group. In an ad hoc DSS, the scope of the logical decision group is defined and specific decision types are defined as necessary.

The NEEMIS project typifies the ad hoc DSS characteristics. There is a wide variety of differing users being supported, ranging from researchers at M.I.T. concerned about issues such as public policies, legislation and economic impact, as well as state energy offices, governor's staff and congressional staff. Although all of the work

	Institutional DSS	Ad Hoc DSS
Number of decision occurrences for a decision type	many	few
Number of decision types	few	many
Number of people making decisions of same type	many	few
Range of decisions supported	narrow	wide
Range of users supported	narrow	wide
Range of issues addressed	narrow	wide
Specific data needed known in advance	usually	rarely
Specific analysis needed known in advance	usually	rarely
Problems are recurring	usually	rarely
Importance of operational efficiency	high	low
Duration of specific type of problem being addressed	long	short
Need for rapid development	low	high

Table 1: Comparison of Institutional and Ad Hoc Decision Support Systems

centers around energy, which is the major cohesive force tying together the logical decision group, the actual decisions being supported range from issues of taxation to conservation policies in state office buildings, to tariff and import-export controls, to impact on unemployment and general economic conditions. As a result of the range of these topics, the precise data required for a particular decision type as well as the kind of analysis and analytical techniques required can vary widely. Furthermore, most of these decisions are of a one-time nature; once the particular decision has been made, the specific ad hoc DSS to support that decision or that decision type may no longer by needed—although components may be used for related decisions in the logical decision group. It is much more appropriate to consider the particulars of the logical decision group in designing such a DSS rather than the particular decision types in depth.

A portfolio management system typifies the institutional DSS characteristics. Although the decisions supported are unstructured and do require both man and computer interaction, most of the data and analysis techniques requirements are known fairly well in advance. In a case such as a portfolio management system (Gerrity, 1971), specific consideration is needed of stock market prices, trends and earnings, as well as the holdings on each account. Furthermore, the particular kinds of analysis desired, as well as graphical presentations in the form of barcharts or graphs, may be fairly well-identified. As a result, the portfolio management system can be viewed as a menu-type of system where the user can pick what he wants to do from a relatively well-defined set of existing facilities. Furthermore, such a system is often used by a very large number of similar individuals (50 or 100 portfolio managers) and may be used to support similar decisions over a very long period of time (five or 10 years). As a result, there is far more emphasis on careful tuning, both for operational ease and for efficiency of operation.

Development Tools Needed

It has been noted in the literature, in various phrasings, that decision support systems should provide the manager with "analysis, models and flexible access to relevant information" (Gorry and Scott Morton, 1971: p. 56). A primary difference between institutional and ad hoc DSSs has been in the tradeoff between flexibility and operational efficiency. In an institutional DSS, the emphasis is usually on the efficient handling of both the computer and the user interface for the predefined decision types to be supported. This usually means that a specialized data base and specific models form the basis of the DSS. In an ad hoc DSS, the emphasis is on flexibility, both for the data base and the modes; there is much less concern for operational computer efficiency.

Although there are many operational decision support systems in use (Alter, 1975), most of these are institutional DSSs. In many cases these systems have often been costly and risky to develop. In such systems, although the decision types to be supported are recurring and fairly stable over long periods of time, the particular facilities that can effectively support the decision making may be difficult to determine. As a result, after expending considerable cost and time to design and implement an institutional DSS, it is still possible that the system may not be found useful or usable by the decision makers due to organizational or human factor considerations and, even if used, may not actually improve decision making.

In many cases the actual effectiveness and usability of an institutional DSS can only be determined *after* it is in use. This can be a major problem, since it may take many months, even years, to develop such a system, using conventional techniques. For this reason, it is typical to find that many changes and additions are needed to bring such a system from operational to usable. Even then, it is possible that the effectiveness of the system is not sufficient to yield benefits commensurate with its ongoing operational costs, let alone the development costs. As a result of these substantial costs and risks, such a project may be abandoned at any point along the process.

Many of the problems can be relieved if it is possible to develop a flexible prototype or breadboard system rapidly, in weeks rather than months or years. Its impact on decision-making effectiveness can be better evaluated, and operational problems can be identified and, in many cases, resolved by rapid modification of the prototype. Although certain differences will exist between the prototype and actual system, primarily regarding efficiency and ongoing operational cost, the decison to invest the major resources needed to develop the actual system can be based upon much better information on the necessary characteristics of the system and its likely decision-making benefits. In this way, the actual implementation costs and risks should be significantly reduced, and expected effectiveness of the system can be much more reliable and realistic.

There are many other substantial benefits to developing such a prototype system. It is much easier to gain user involvement in the design process, since the prototype provides a concrete basis for study and discussion. Furthermore, the prototype may be useful as a training and education vehicle for the managers who will later be the users of the institutional decisional support system to be implemented. Further, capabilities may be present to allow such a prototype institutional DSS to move rapidly into a form that enables tuning for efficient operational use.

The tools needed to help develop an ad hoc DSS are very similar to the requirements needed to build a prototype institutional DSS, as described above. In an ad hoc DSS, time and low fixed costs are the important factors, not operational costs, since these systems are often only used once or very infrequently. Hence it becomes extremely important to be able to integrate existing models and data bases, to be able to access the data in ways not previously thought of and to be able to gather and assimilate new data series quickly.

It is not feasible to build a total information system that contains *initially* all of the facilities likely to be needed for an ad hoc DSS. Besides the enormous cost, time and effort that would be required to construct such a system, it is highly unlikely that it could contain all of the needed facilities (data and models), since the basic definition of an ad hoc DSS is that these facilities are not usually known in advance. We have found that it is necessary to have a computational capability that will allow for the rapid and unplanned assimilation of data bases (and data base systems), models (and modeling systems) and other facilities that may be useful in a decision support system (such as graphics interfaces)—even if such systems had never been used together before and are, in fact, operationally incompatible. Such an integration of facilities would permit a possible scenario such as the following: Data could be provided and manipulated from two data management systems, IMS (IBM, 1975a) and SEQUEL (Chamberlin and Boyce, 1974) and both systems could provide data to an analytical facility such as EPLAN (Schober, 1974), where statistical and regression functions could be performed on that data and the results placed back in the data base in a form that could be displayed differently through a graphics system such as GADS (Carlson *et al.*, 1974) or DAISY (Morgan, 1976). A facility that has many of these capabilities and is now operational in an actual setting is briefly described in the following section.

Generalized MIS

After a detailed study of 56 decision support systems, Alter concluded:

> "Although the (current) technology is adequate for applications involving single data bases, simple time-shared models, standard calculations . . . and so on, it is quite lacking as regards access to and manipulation of data from large or broad data bases, development of representational models, development and modifications of large-scale systems of any type . . . and so on." (Alter, 1975: p. 18)

The generalized management information system (GMIS) described in this section is an initial experimental effort employing certain new technologies and approaches to address these needs. Other efforts that are attempting to address these problems include the work on the consistent system initiated by the Cambridge Project (Cambridge Project, 1971) and the work on the applications control system/applications control language (ACOS/ACOL) at the National Bureau of Economic Research (Hill and Ruderman, 1976). The GMIS system is operational and is being used as the base for decision support systems to aid energy impact analysis and policymaking as part of the NEEMIS project.

GMIS has been designed to allow for the rapid assimilation and integration of seemingly incompatible computer programs and data series. That is, a necessary analytical program may exist on one computer, while another computer may have a needed data base management capability, yet the two systems are incompatible because they run under different operating systems (Madnick and Donovan, 1974). By being able to combine such facilities, the analyst can respond to a policymaker's request more generally and at less cost by building on existing work.

GMIS has been developed as part of an MIT/IBM joint study agreement. The virtual machine (VM) concept (Donovan and Madnick, 1975; Goldberg, 1974; IBM, 1976; Madnick, 1969) is used to allow several apparently separate computers ("virtual machines") to be efficiently simulated on one real computer. Enhancements to the virtual machine concept and additional software have been jointly developed by MIT and IBM to make communication between these various simulated (virtual) machines possible. Thus, despite the fact that programs may have been designed to operate on different computers which cannot normally communicate with each other, the programs and data series that are relevant to the particular problem facing the policymaker can be quickly made available by GMIS.

Figure 4 depicts a sample use of the GMIS facility showing two analyst users and a representative GMIS virtual machine configuration. In this configuration there are six virtual machines (it is functionally equivalent to six physically separate computers, although in the NEEMIS project a single physical IBM System/370 Model 158 is used). Actual configurations may use many more virtual machines. The VM Manager Machine, only one is ever used, executes the software which manages the virtual machine configuration and relieves the user of any direct concern or complexity regarding the configuration. The analytical machines are the principal interface to the user and host the analytical facilities to be used. The data base

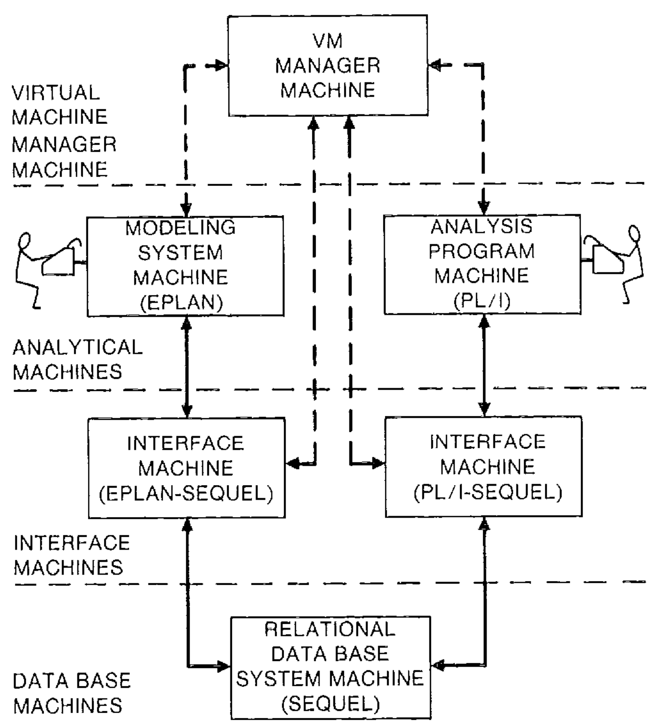

Figure 4

machine hosts the data base management systems and data bases to be used. The interface machines provide the interface and necessary transformations of data and commands between the analytical machines and the data base machines.

A sample use of the configuration depicted in Figure 4 might proceed as follows. One analyst wishes to use a model that operates on an APL/EPLAN analytical machine. The data needed for the model may reside on a separate SEQUEL data base machine, since most analytical systems, such as APL/EPLAN, have limited data base management capabilities compared with the flexibility and power of a data base system such as SEQUEL, and the data may also be needed by other analytical machines.

The analyst requests access to the needed data; this request is sent to the appropriate interface machine (set up automatically by the VM manager) and forwarded to the data base machine. The data is retrieved by the data base machine and sent to the interface machine which reformats the information, if necessary, for the analytical machine's use. At the same time, if another analyst using another analytical machine, such as a data analysis program written in PL/I, wishes to use the same information, a similar sequence of events is employed. The specific research and mechanisms that provide the basis for GMIS are described in references (Donovan, 1976b), (Donovan and Jacoby, 1975), (Donovan and Madnick, 1976) and (Gutentag, 1975).

In the example above, note that the analytical and data base facilities may be fundamentally incompatible with each other, both in terms of normal interfacing capabilities (APL/EPLAN and SEQUEL and both stand-alone systems that are not designed to interface with other languages or programs) and their underlying operating system environment (APL/EPLAN may be running under DOS/360, PL/I may be running under CMS and SEQUEL has its own special-purpose operating system). Modeling capabilities accessible on GMIS include TROLL, TSP, EPLAN and DYNAMO. Analytical tools include PL/I, FORTRAN and APL. Statistical facilities available include MPSX and APL/STATPACK II. The data base systems presently available on GMIS include SEQUEL and Query by Example; being considered are IMS and MUMPS. Furthermore, a large collection of specific models and data series have been gathered as part of the NEEMIS project as described in references (Donovan, 1976a) and (NERCOM, 1976).

New England Project

The NEEMIS project, which was originally conceived and initiated in December 1973 (Donovan and Jacoby, 1973), is a cooperative effort by the New England Regional Commission (NERCOM), the New England State Energy Offices, IBM, the MIT Sloan School's Center for Information Systems Research (CISR) and the MIT Energy Laboratory. The NEEMIS project's principal mission is to provide the region with the capability to take effective action regarding regional energy problems. The project provides four major resources to assist in supporting decisions:

1. An advanced computational capability (GMIS).
2. Data series, including demand, supply and constraint data.
3. Models, including economic impact, forecasting, demand and conservation models and programs.
4. People who are specialists in energy, economics, data processing and/or public policy.

Computer terminals were installed in New England state energy offices in 1975. The physical computer used is an IBM System/370 Model 158, with some 2,300 separate data series with an average size of 4,000 records. There are 12 major models in the system. An average load on the system includes 12 simultaneous NEEMIS users located at state energy offices, NERCOM and MIT.

NEEMIS has been and continues to be used to provide decision support for a variety of energy-related issues (NERCOM, 1976; NEEMIS, 1976), including economic impact studies of energy prices, conservation monitoring and policy analysis, effect of oil embargo on natural gas consumption, trends in automobile registration, contingency plans for shortages of natural gas, impacts of prices on home heating consumption, effects of tariffs and decontrol, analysis of the merits of refineries, analysis of impacts of offshore drilling on New England's fishing industries, cost effectiveness of various home and building improvements, implications of changes in the entitlements programs, economic impact of federal legislation, economic and social impact of converting from major petroleum use to coal, impact of alternate electric pricing schemes, impact of a moratorium on nuclear plant operation, analysis and development of strategies for possible embargoes, evaluation of incentive programs to encourage new energy technology, forecast future energy demand and so on.

One application of the NEEMIS Project was development of a prototype institutional decision support system for conservation monitoring and analysis. It was instrumental in attaining a significant energy saving in the New England states. All six states felt energy conservation within state-owned buildings was a desirable place to start a major conservation effort for four reasons:

1. Large dollar savings possible. For example, Lt. Gov. O'Neill of Massachusetts noted that a 20 percent reduction in the state's $50 million heating bill could result in a $10 million savings.
2. Federal funds are available to the states for such efforts. Public Law 94-163 provides $150 million over the next three years to initiate conservation efforts.
3. Leadership role. The state government could provide an example and the mechanisms for the private sector to follow.
4. Reduction in future costs. Energy costs are rising (100 percent in New England since 1974) and will continue to rise, hence conservation slows the growth in future state budgets.

While the above are compelling reasons for conservation in state buildings, how does the policymaker make that happen? In the private sector studies have shown that price is a compelling force in space heating conservation (Donovan and Fischer, 1976). That is, if the price goes up, people will tend to conserve more. In state buildings, however, it is not clear that the people who can affect conservation measures also pay the bills. Hence, price provides limited direct incentives to institute efforts such as lowering thermostats, increasing insulation and so on.

For the public sector, a two-pronged approach was developed: Conservation monitoring of state buildings—that is, monitor the monthly consumption in all buildings to allow cursory analysis making explicit which buildings are most likely candidates for savings—and detailed analysis of buildings that appear to be large or disproportionately large consumers of energy to determine what changes, behavioral or structural, should be instituted.

Hence it was decided that an institutional DSS for long-term monitoring and analysis of state buildings should be constructed. It is important however, to note the constraints that were placed on the system, the major one being time. The effort was started in response to Connecticut Governor Ella Grasso's mandate: Reduce consumption this winter (1975-76) in state facilities by 5 percent. That mandate was made at the beginning of the season.

Consider what that mandate means as far as implementation of such a system is concerned. How large an effort is required to build such a monitoring and analysis system?

Considering first only the monitoring and cursory analysis portion, the system must contain information on building characteristics (location, floor space, type of usage, percentage of each type of energy source used for heating), vendor characteristics (location, type of energy supplied), supplier relationships (which vendors supply what to which buildings) and deliveries made (date, vendor, building, amount supplied, type of energy).

In addition, various supplemental information was needed, such as administrative hierarchy information about the various state agencies and organizations, such as the state police department—its characteristics, budget, subordinate agencies, buildings owned—and weather data to normalize for weather conditions by location and date. The incoming data must be screened and validated for reasonableness and completeness, then incorporated into the cumulative data base.

For cursory analysis, it was necessary to produce both regular executive reports, such as monthly consumption by fuel type aggregated by major departments making explicit comparison with prior year's consumption adjusted for weather, and on-demand reports, such as total state energy expenditure during the first five months of a year or a list of residual fuel oil suppliers to the state.

Based upon estimates from conventional inventory control systems, if traditional system building approaches were used (writing a collection of FORTRAN, COBOL or PL/I programs), many months—if not years—would be needed to construct a system adequate to meet merely the monitoring and cursory analysis requirements. The governor's mandate precluded this approach.

Furthermore, we have been assuming that the problem was well-enough understood to allow the immediate specification of all inputs, outputs and algorithms necessary. Otherwise, the system would have to be revised, possibly many times, resulting in even more delay before becoming operational. In fact, we found that even for what appeared to be the relatively straightforward task of monitoring the reporting of monthly consumption, we had to make major changes in the reports, type of data gathered, sources of that data and computations.

For example, it quickly became apparent that reports which simply listed consumption by month for a particular building were not of enough assistance to the state energy officers in determining which buildings they should focus efforts on. We found that reports that provided direct comparisons between buildings such as depicted in Figures 5(a) and 5(b) were helpful. Further, we found that once the monitoring system become operational, the way

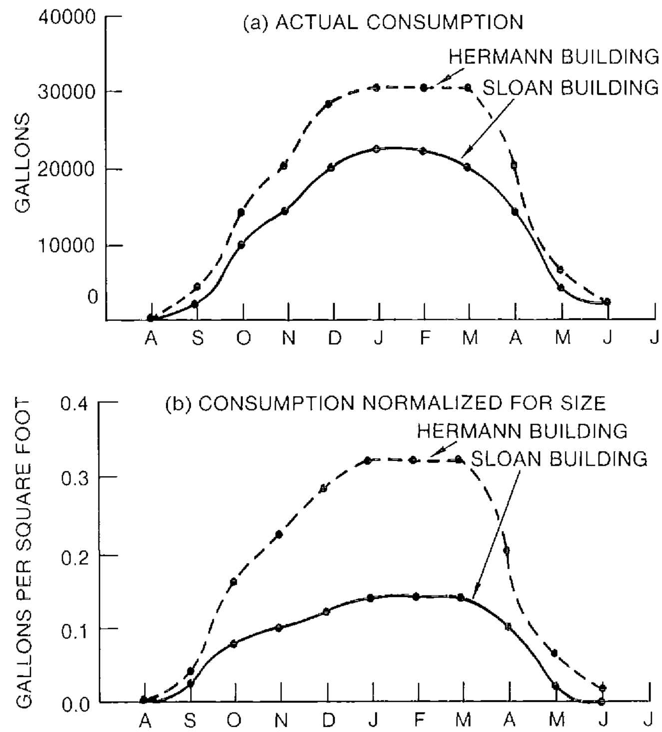

Figure 5

data was accessed and presented needed to be changed.

The states requested reports not only on individual buildings but by departments and other administrative entities that consist of several buildings. During this period, we learned that collecting accurate and timely consumption data from the end customer was both difficult and time-consuming. An alternative and much more satisfactory mechanism of data gathering was found by obtaining information directly from the energy suppliers to the state buildings.

Notice that many changes in the data needed, the data acquisition procedures and uses and reports necessary occurred after the (prototype) decision support system was put into use. If a prototype had not been built, the need for this change probably would not have been realized until the full-scale operational DSS had been constructed many months later, necessitating major redesign resulting in further delays.

The NEEMIS development of the consumption monitoring and cursory analysis system used a configuration of virtual machines that included the analytical languages APL (Pakin, 1972) and EPLAN (IBM, 1975b; Schober, 1974) in one virtual machine and the data management system SEQUEL (Chamberlin and Boyce, 1974) in another. SEQUEL is a relational system (Codd, 1970) which provides considerable flexibility and allows access to the data under multiple and different criteria. APL/EPLAN provided an interactive analytical facility that facilitates complex operations on vectors and convenient plotting of results.

Note that neither APL/EPLAN nor SEQUEL separately would be adequate to serve the needs of monitoring and cursory analysis. Furthermore, these facilities cannot normally be combined since they are operationally incompatible; that is, they operate in different operating system environments. Combining these facilities, using GMIS, provided the basis for the prototype institutional conservation monitoring system. This version of the conservation monitoring system was completed in time for use in the winter of 1975–76 (Berry, 1976).

Consider secondly the construction of mechanisms to perform detailed building analysis. This was potentially an even more difficult problem than the monitoring system, especially if traditional approaches had been used. Using the cursory analysis reports, the states were assisted in deciding on which buildings they should concentrate their efforts. However, the decision of what specific actions should be initiated is left unresolved. For example, an output from the cursory analysis system is displayed in Figure 5.

This graph depicts the monthly consumption of the two buildings and the same information normalized for square footage. Note that the Hermann Building has significantly higher consumption, both in total consumption and consumption per foot; hence it is a likely candidate for conservation measures. What should be done? Add storm windows? Change the heating system? Insulate?

Two approaches could be taken. First, experiment with the building itself—very costly. Secondly, build a computer model of the building and experiment with it—very time-consuming. Hence if the second approach is taken, it is important to build upon the work of others. We were able to obtain three existing general building analysis models: NECAP (NASA's Energy Cost Analysis Program) Henninger, 1975, CERL (Thermal Loads Analysis and Systems Simulation Program) Hittle and Sliwinski, 1975, ECM (Energy Conservation Manual) Dubin-Mindell-Bloom, 1975.

NECAP and CERL, an extension of NECAP, already existed as large-scale computerized models. (It has been estimated that more than $1.2 million was spent on the development of the current NECAP program and its earlier versions). ECM is a simplified manual analysis procedure. These systems are complementary and they can be used to validate each other. For these advantages to be effectively realized, however, the models should be integrated into one cohesive system.

Using the model integration capabilities of GMIS, the NECAP and CERL programs were transferred. The simpler ECM model was computerized by the NEEMIS staff. All of these models required that certain additional information be added to the data base to perform detailed analysis of a building. Information needed for a NECAP analysis included: structure of building, types of heating and cooling units, ventilation, shading of building, number of days of sun, data for each exterior wall, door, window, roof and floor and schedules for people, lighting and equipment usage.

The specification of the NECAP model for a particular building requires considerable more data on the characteristics of that building than the ECM model. For the NECAP model, as an example, seven mandays were required to gather the additional information for a large medical laboratory. Although the resulting detailed NECAP model simulation for that building produced consumption results that were very close to actual energy consumption, the detailed data required for NECAP makes such a procedure difficult for analyzing a large number of buildings. The ECM procedure can be used for a much more aggregate level of analysis and requires data that be fairly easily obtained. For most common types of buildings, ECM produces results that are also very close to actual energy consumption.

Using the model integration features of the GMIS technology, it was possible to have all three models available for use in the winter of 1975. Procedurally, the cursory analysis is used to focus attention on buildings that appear to offer high potential for energy conservation. The ECM model can be used to experiment with many simple conservation options for the selected buildings. For buildings that have unusual characteristics or are being considered for extensive changes, the NECAP model may be used for more detailed and accurate analysis.

Hence, the ability to assimilate existing models, to assimilate data series and to change computations and structures of that data quickly were all-important to the construction of this DSS. The particular approaches we used facilitated this.

In the specific case of Governor Grasso's request to reduce energy consumption, the Connecticut Department of Planning and Energy Policy, with the support of department heads and employees throughout state government and the use of the NEEMIS system, was able to meet and exceed the goal by reducing energy consumption by 7.5 percent (discounted for weather), a savings of more than $1 million (Brooks, 1976).

The effectiveness of the prototype provided the basis for the implementation of a long-term, high-performance institutional DSS for Connecticut and the adoption of such a system by other New England states. Furthermore, there have been two additional benefits over direct energy saving to such a consumption analysis facility: It provided a basis for the states' eligibility for a portion of the $150 million in federal funds available under Public Law PL-94-163 for energy conservation and it allowed the states to take a leadership role and encourage the private sector to institute similar conservation programs.

A variety of ad hoc DSSs have been developed and used as part of the NEEMIS project. A somewhat extreme but not atypical example occurred when, during a presentation of NEEMIS at the November 7, 1975, New England Governors' Conference (Donovan and Keating, 1976), Governor Noel of Rhode Island requested an analysis of the impact on his state of a proposed decontrol program in light of likely OPEC oil prices. These results were desired for use in a meeting with President Ford scheduled for later that afternoon. In this case, as in many others faced by the NEEMIS project, the GMIS facility, in conjunction with the models and modeling systems and the data series and data base systems already assimilated into the system, made it possible to construct an ad hoc decision support system and expediently provide the necessary analysis.

One of the important uses of NEEMIS has been the independent regional evaluation and assessment of proposed or enacted federal legislation. Depending upon the outcome of such an analysis and its thoroughness, it is possible for the states to make concerted efforts in favor of or in opposition to specific legislation. Although such a study may be of a one-time nature, the necessary analysis can be quite extensive.

In a recent major effort, the NEEMIS project was able to provide the analysis instrumental in the removal of a tariff resulting in an estimated saving to the New England region of more than $400 million. This was done by helping develop a legal case to force the removal of a tariff on petroleum products imposed in 1975. The information showed that the states were an "aggrieved party" and hence were eligible to bring suit against the federal government for the imposition of such a tariff. The decision support system developed showed in fact that the New England region was being more adversely affected by the tariff than any other region in the country, paying 38 percent more for its energy than the national average.

In a similar study, the New England region was successful in changing an entitlements program that affected the region adversely economically. This was done by developing the information that was used to show grievance and then support the case and arguments for a more equitable arrangement. It has been estimated by the New England Regional Commission that the change in the entitlements program has saved the region in excess of $100 million (NERCOM, 1976: p. 8).

Conclusions

Common to many of the problems facing our country is the necessity to support decisions. Ad hoc decision support systems, a relatively new phenomenon, are different from the more traditional structured decision systems or institutional decision support systems. In an ad hoc DSS the nature of these problems is such that they are constantly changing, the data needed to solve them is not always known in advance and solutions are needed in a short time frame.

The computational needs of an ad hoc DSS include data bases and models. But the most taxing requirements are for speed of availability and adaptability. One way to meet these needs is to be able to rapidly assimilate existing models and modeling systems, data and data bases and other needed software. We have developed a particular implementation approach, GMIS, which exploits the virtual machine concept to accomplish these goals.

Our experience in using GMIS for energy-related decision making in the NEEMIS project has indicated the effectiveness of these technologies in developing decision support systems. However, other approaches for integration of separate modes, data bases and computers must be studied for wider applicability. To further enhance the effectiveness of decision support systems, work in understanding the decision-making process and characteristics of different types of DSSs must be done. This paper is a call for further attention to be given to these areas.

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