FOREST RESOURCE MANAGEMENT INFORMATION SYSTEMS: THE ROLE OF THE MINICOMPUTER[1]

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INTRODUCTION

Computer-based management information systems (MIS) became popular in the 1960's as organizations rushed to harness the potential power of the digital computer for assisting in the management of the organization. Although touted as a panacea for decision makers, most applications produced far less than promised. Nevertheless, interest in such systems has not diminished. On the contrary, it has increased dramatically in recent years. Consequently, many forest resource agencies and firms are accelerating their efforts to develop and utilize such systems.

Today we wish to briefly describe some of our experiences with the development of various facets of a computer-based MIS. Special attention will be focused on the role of the minicomputer in the developmental as well as operational stages of such systems. Following a brief description of the characteristics of a MIS we present an overview of two systems developed at the College of Forest Resources under our general direction. The first system is concerned with land management and is useful for examining the physical, biological and environmental consequences of alternative wildland use decisions. This system consists of a set of computer simulation models linked to a geographic resource data base by an information storage and retrieval system. The second system concerns the development of a series of product conversion models which are useful for examining alternative material flows in terms of product yield and energy, labor and capital requirements. Manufacturing processes modeled include saw, veneer and pulp mills.

Components Of A Management Information System

We define a MIS as a complex system composed of a series of interdependent components. Chief among these are: (a) a computerized resource data base, (b) an information processing system, (c) a decision analysis system and (d) a decision maker. The principal function of a MIS is to facilitate the transformation of raw data -- retrieved from a data base -- into information which in turn is converted into action through the process of decision making. Information, then, is the knowledge derived from the acquisition, organization and analysis of data. The primary focus of a MIS is related to the management of a system and not the collection and storage of vast quantities of data. To better understand the characteristics of a MIS each of the above components will be briefly described.

Information Processing System

The information processing system provides the facilities necessary to acquire, store, update, retrieve, and display data in a timely and meaningful format. While it is a vital component of any MIS, it alone is not sufficient to guarantee the success of the system. Unfortunately this has not always been recognized by many potential users.

Resource Data Base

The resource data base contains all the data which describes the system being managed. This may consist of: (a) data describing the status or condition of particular units of land or bodies of water, (b) sample plot or other survey data, (c) financial performance data, or (d) other auxilary data such as market surveys or general economic indicators needed by management. Recently, there has been considerable interest in geographic or spatial resource data bases where the locational parameters as well as the attributes describing a specific unit of land or body of water are stored. This type of data base provides the opportunity for a decision maker to: (a) evaluate the impact of alternative decisions, and (b) retrieve and display (i.e., map) various resource values within a location-specific context.

Two general approaches are commonly used for constructing computer-based spatially-oriented resource data bases: polygon and grid (cell) systems.

Polygon systems.--Polygon systems are characterized by groups of areas of irregular size and shape which permit considerable flexibility in terms of spatial resolution and accommodate the use of automatic digitizing equipment in the conversion of source data from maps to computer data files. Typically, a separate overlay or profile is constructed for each attribute included in the information system. Such data stratification is accomplished prior to data storage, thus necessitating multiple accesses to retrieve a complete description of a specified spatial extent. This type of system, however, provides the capability to obtain high resolution reports and graphical displays of areal characteristics.

Grid systems.--Grid systems are generally characterized as a grid of fixed or variable sized rectangular cells, or both. In effect a grid cell is a special case of a polygon -- i.e., a regular polygon (rectangle) -- where the inherent characteristics of rectangles can be used to simplify the software required to manipulate the data files. The boundaries of the cells are fixed, and the set of attributes representing the characteristics of the area circumscribed by the cell can be referenced in entirety by referencing the cell,

thus allowing the complete description of a specified area to be obtained by one data base access.

Decision Analysis System

The decision analysis system consists of those application programs which are used to predict the probable consequences of alternative management strategies. The information processing system provides the needed input for these programs. Various analytical procedures such as mathematical programming, computer simulation, and financial analysis are used in this regard. When tied to a spatially-oriented resource data base, these procedures facilitate the prediction of location-specific impacts of future strategies. More generally, however, resource data are aggregated into management units before being analyzed by the decision analysis system. Probable impacts of alternative strategies are ultimately summarized and passed on to the decision maker for final action.

Although a MIS is heavily dependent upon adequate computer facilities for its success, such facilities alone are not a sufficient guarantee. Nevertheless, keeping in line with the theme of this meeting we will discuss the role of computers in the development of a MIS. First it is important to recognize that computer requirements vary in accordance with: (a) the particular component of a MIS being considered and (b) the stage of system development. Minicomputers can play an important role in developing certain types of models in the decision analysis system but a large-scale computer system may be more appropriate to use once the models are implemented in an operational framework. Similarly, a minicomputer may prove useful in the data acquisition phase of defining a resource data base. However, the interrogation, retrieval, summarization and display of information in an operational setting may be best accomplished using the data base management facilities of a large-scale computer system. Other factors which influence the type of computer facilities necessary to provide the needed service include: (a) the size and complexity of the decision models and/or resource data base, (b) the availability and cost of minicomputers vs. large-scale computers, (c) the experience of the personnel responsible for the MIS project and (d) the need for, and availability of, input/output and data storage devices. All of these factors must be weighed before the appropriate computer system can be selected. Furthermore, the multiplicity of factors which influence this decision make it difficult to produce any type of generalized recommendation.

With this brief overview of computer-based MIS we now turn to discussion of the two computerized systems we have helped develop. In discussing these systems we will stress the role played by both minicomputers and large-scale computers during the development and implementation of both systems. While our experiences may not be completely applicable to your particular situation we are hopeful that some useful ideas can be gleaned from the discussion which follows.

APPLICATIONS OF MIS

A Wildland Use System

This system was developed under a 4-year grant from the National Science Foundation. The objective of the study was to develop a multi-resource simulation system which could be used by policy analysts, as well as by middle managers, to evaluate alternative wildland management programs in terms of their physical, biological and environmental consequences. The system was designed as a series of simulation models which could handle either major land use allocation decisions (i.e., timber production, recreation usages, etc.) or specific resource management decisions (i.e., fertilize forests, harvest using a specific system, etc) as inputs and produce outputs consisting of the consequences of these decisions expressed in terms of goods and services (i.e., cu ft of wood produced, number of recreation user days produced, etc.) and environmental impacts (i.e., nitrate concentration in streams, stream sedimentation, etc.). These simulation models are linked to a geographic data base via a computerized information system. The whole system is referred to as the Snohomish Valley Environmental Network (SVEN) because the models were developed for-and applied to-the Snohomish River Basin (500,000 ha) just east of Seattle in the Cascade mountains. The applicability of this system outside this area is presently being studied.

The basic design criterion underlying the development of SVEN was to construct a set of simulation models capable of being operated independently as well as linked together in a multi-resource system model. Each model describes a major component or subsystem of a managed forest ecosystem. While it is not feasible to model all facets of each selected subsystem, an attempt was made to include at least one example of each major model type. The major subsystems included in the study are (a) forest production, (b) outdoor recreation, (c) fish and wildlife, (d) forest insects, (e) meteorological, hydrologic, and atmospheric processes, and (f) information storage and retrieval. A very brief description of the models included within each of these subsystems follows.

The forest production subsystem is composed of three models. These are (a) timber production, (b) timber harvesting, and (c) forest residue reduction. These models complement each other in simulating the environmental, physical, and economic effects of alternative forest management practices. The timber production model consists of a set of growth functions used to simulate the growth of forest stands over time if managed according to a prescribed set of management practices. Included in the model are regeneration, fertilization, and thinning alternatives. The model is capable of handling either clear-cutting or shelterwood harvest operations. The timber harvesting model reflects the harvesting of stands using several options such as tractor, helicopter, balloon, highlead, skyline, and mobile crane yarding systems. The harvesting model also includes the amount and cost of road construction, assuming different standards, and the use of buffer strips along streams. In addition to generating the volume of logging residue resulting from a harvest operation, the forest residue reduction model contains several options for disposing of residue. Options include broadcast burning, hand piling and burning, and mechanically chipping or crushing.

The primary objective of the recreation model is to predict the demand for outdoor recreation activities as a function of (a) socioeconomic and demographic variables, (b) dominant land use, and (c) land management decisions. A second objective is to simulate the resulting environmental impacts

associated with these land uses. The procedure developed by Chicchetti, Davidson, and Seneca (1969) was adopted for the purpose of estimating the number of user days for each of 11 recreational activities for a population unit given its socioeconomic characteristics and the availability of various recreational resources. The procedure was designed to predict recreational activities which are either area or site specific. In addition, the approach can be used to project future activity levels for a changing population and changing recreational resources. Once the number of user days for each of 11 activities are determined, the resulting environmental impacts are generated.

The wildlife model simulates the population dynamics of black-tail deer as influenced by land-use decisions, man-induced manipulations of the ecosystem, and recreational hunting pressure. Although attempted, it was not possible to develop a fisheries population dynamics model that could interface with the other SVEN models. This was primarily due to the extreme spatial and temporal requirements of a realistic fisheries model. Instead, an exhaustive summary of the published literature relating the effects of land use on aquatic resources has been compiled and made available in the form of an indexed information retrieval system.

A pest management model simulates the interrelationships between the population dynamics of the Douglas-fir bark beetle, an array of host material, and management control tactics. The model permits a large array of alternative control strategies to be evaluated. Presently, all impacts are evaluated in physical terms.

The main objective of the hydrologic model is to quantitatively simulate responses of the hydrologic system to manipulations of the forest ecosystem. Since a unit area yield prediction approach was adopted, the hydrologic model contains considerable flexibility in predicting mean monthly water discharge for variable size watersheds. Further, flow rates and water quality parameters can be measured at any point within a watershed once the contributing area is defined. In addition to predicting mean monthly runoff, the hydrologic model predicts the following water quality indices (a) suspended sediment, (b) water temperature, (c) dissolved nitrates, and (d) dissolved oxygen.

The objective of the atmospheric model is to provide quantitative estimates of pollutant concentrations resulting from emissions within the forest ecosystem. The forest management practice which most significantly affects air quality is burning forest residues for the reduction of fire hazard and the promotion of regeneration. Other sources of air pollution include wildfire and exhaust from motor vehicles. A mass transfer or box model was selected as the most reasonable approach for determining the level of pollutants within the Snohomish River basin. Many atmospheric transport models are based on diffusion theory; however, diffusion type models were deemed infeasible since the mountainous terrain of the Snohomish basin and the nature of the pollution sources violate the underlying assumptions. The model focuses on how air quality standards would restrict forest management activities rather than how activities would influence air quality at a specific time during the year.

The information storage and retrieval subsystem links the resource data base (described below) and the simulation models discussed above. The information subsystem was designed to provide the capability of supporting the assessment of environmental impacts at various degrees of space-time resolution. The major purposes of the information subsystem are to (a) provide for efficient storage, retrieval and updating of information during execution of the multi-resource system model, (b) provide information to support model development, and (c) respond to queries requesting information in the form of maps, summaries, or listings.

A resource data base was developed to describe the resources of the Snohomish River basin. A cell size of 40 acres was selected to record the status of each cell in the basin. Each cell can be accessed by referring to its watershed identification, township, range, section, and cell number, or by referring to the x-y coordinates of the particular cell. Three files make up the resource data base. A cell file contains information which describes the status of each cell within the basin. A stream file operates in conjunction with the cell file. This file contains locational and identifying information for each stream in the basin. The stream file provides the capability for routing water throughout each major watershed and hence provides one of the most unique features of the SVEN system. A user may trace waterflow both upstream and downstream and/or define the watershed for any point within the basin. Interaction between the cell and stream files allows models to determine the factors affecting the hydrology of any point in the basin. Currently only locational and identification information is contained in this file. Other attributes such as stream gradient, streambed gravel condition, flow histories, etc., may be easily added as the information becomes available. The soils file is the third file which makes up the resource data base. This is a static file which contains information on the soil resources of the Snohomish River basin.

The SVEN information subsystem was primarily designed to interface directly with the multi-resource system model thus permitting rapid and efficient updating of the resource data base over time. Further, it was designed to support the mathematical modeling of nonpoint sources of pollution arising from forest management activities and land use decisions. To best attain these objectives, the subsystem was developed as a set of separate functions which could be called upon by model programs or user written programs. A control language allowing for simple and direct inquiry of the resource data base was developed. This control language permits users unfamiliar with data formats and calling sequences to access and utilize the full power of the SVEN system and resource data base. The SVENESE language only manipulates the SVEN cell file. The information handling capacities of the SVEN system consist of the abilities to (a) access and update the attributes of a specified cell in a random or sequential fashion, (b) extract a set of cells each of which satisfy a given condition, (c) dump a cell set in numeric or English form, (d) summarize an attribute over a cell set, (e) plot an attribute over a cell set in a particular plotting region (single character, shaded, or three dimensional options are available), (f) modify a cell set by providing a FORTRAN subprogram containing the modification instructions, (g) define macro SVENESE commands, and (h) insert FORTRAN instructions in line with SVENESE commands.

The SVEN system is currently operational on a large-scale computer system (CDC CYBER 173), at the University of Washington. However, certain models were originally developed on a minicomputer and later reprogrammed for the larger system. The information system and some of the individual models were designed and implemented on the large-scale computer from the outset.

In summary, it appears that given sufficient computer size model and development can be carried out on either a mini or large-scale computer but all models should be converted to the large-scale computer system for operational production runs. In our case this was necessary because the models were linked to a geographic data base which was designed and implemented on a large-scale computer. While a dedicated minicomputer may be capable of providing an equivalent service we feel that the large-scale computer is preferred. One reason concerns the rapid evolution of data base management (DBM) technology which has been developed for large-scale computers. Anyone dealing with geographic data bases would be well advised to become thoroughly familiar with available data base management systems before selecting his computer facilities.

A Product Conversion System

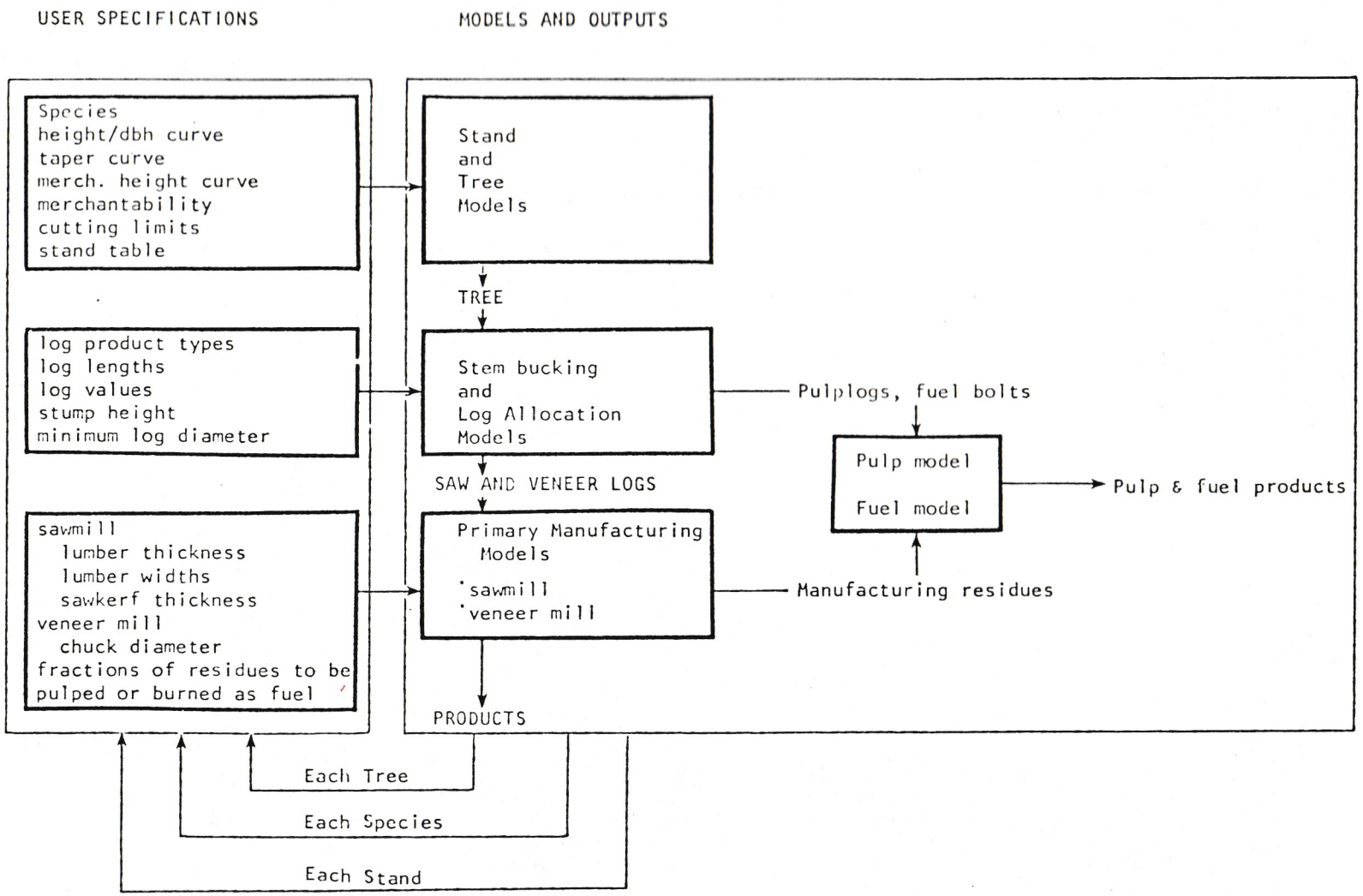
This system was developed under a 3-year grant from the National Science Foundation, the Cooperative States Research Service (USDA), and the Hondurian Forest Service. The objective was to develop a series of conversion models which simulate the manufacturing processes and provide the basis for evaluating materials flow in terms of time and product yield and capital, energy and labor requirements. The product conversion models developed to date have included a series of lumber manufacturing models, a veneer production model, a pulp production model and a fuel model.

To date, these models have been particularly useful as processing components of a tropical forest utilization system (TFUS) but they are, of course, equally applicable to temperate zone conditions. Figure 1 illustrates schematically the configuration of this system. A tree model and stand model and a roundwood allocation model are additional components of the system designed to evaluate the match of tropical forest systems with appropriate wood material conversion systems. One version of the roundwood allocation model is an optimization model based upon dynamic programming while the other varsions are essentially heuristic in character. The TFUS operates as a total systems model through an integrating component that calls upon the appropriate building blocks from the forest characterization and conversion model groups.

Lumber is manufactured in a variety of processing systems ranging from simple pit sawing to highly sophisticated band saw operations. The lumber manufacturing simulation models accommodate this variety. The lumber simulation models are based upon the geometry of converting a truncated cone into rough green lumber meeting appropriate dimensions specifications. The models can handle logs where a circular cross section is assumed or where an elliptical cross section assumption is made. Four classes of model are available, namely:

Figure 1

Configuration of the Humid Tropics Utilization System Simulator



1. Live sawing deterministic model.
   This model utilizes a specified opening face, board thickness, board width and kerf width input. It then simulates the conversion typical of a pit saw, a sash gang saw, a horizontal moving band saw or live sawing with conventional circular or band head saw installations.

2. Live sawing stochastic model.
   The stochastic model is an adaptation of the deterministic model except that dimensions reflect the variability of a log break down operation where mean and standard deviation of board thickness is specified and successive boards are characterized through use of a normal random number generator.

3. Cant model.
   This model characterizes log breakdown into cants and sideboards with the cants further processed in a re-manufacturing operation. In its present form this model is deterministic.

4. Live sawing yield optimization model.
   The optimization model predicts lumber yield and size mix for a moving carriage head rig where a saw to knee dimension is identified that maximizes yield. This model deals with the optimization problem also handled by the U.S. Forest Service best opening face (BOF)[1].

In addition to these models of the breakdown of logs into lumber a sawmill design model has been developed. This model provides a basis for evaluating a variety of equipment configurations for a lumber manufacturing installation based upon the yield output of one of the log breakdown models.

A veneer manufacturing model simulates the yield in the production of rotary cut veneer. As in the case of the lumber production models the veneer model can handle logs with either circular or elliptical cross sections. The veneer manufacturing model allows for specification of block size and shape, core size, block taper, and spurred trim. It is essentially a yield and residue prediction model.

Available also is a veneer mill design model which utilizes the output of the veneer manufacturing model to evaluate equipment configurations and in-process material handling and inventory requirements.

The pulp model estimates the mass of dry unbleached kraft pulp that could be produced from a given volume of roundwood and/or manufacturing residues. This is accomplished on the basis of the specific gravity and alpha cellulose content of the wood and the desired kappa number of the pulp. The yield relationship is based on a regression analysis of laboratory data from a variety of sources. Also available is a form of the model which produces estimates of the requirements of the pulp process for fuel, labor, capital, and chemical inputs.

The fuel production model provides an estimate of the net usable energy (BTU's or KCAL) obtainable from a volume of roundwood and/or manufacturing residues. This model converts the volume of green wood to weight and, based on the theoretically or experimentally derived upper calorific value, systematically considers energy losses required to drive off moisture in the wood, to raise temperature to the combustion level, etc., to arrive at an estimate of the useful energy which would be available for heating, conversion to drive machinery, or other purposes.

The TFUS has been developed using both a large-scale computer (CDC CYBER 173) and minicomputer (Data General Nova and Hewlett-Packard 9825 A). The Nova and Hewlett-Packard minicomputer systems are particularly appropriate for application of TFUS to use in situations or countries where large computers are often not available and where relatively low cost minicomputers can be justified as dedicated instruments. The individual model building blocks are all designed to work in a stand alone mode or as components of an integrated system depending upon the sophistication of the available computational facilities and the storage and file manipulation capacity of the equipment. Thus maximum flexibility is obtained.

There are, however, certain trade-offs to be considered when operating these or similar models on large vs. minicomputers. Computational time is often slower on smaller computers such that it may take more computing time to obtain results. In addition, if a small computer system is not equipped with sufficient central memory and is not augmented with sufficient disk or other convenient storage capacity for storing programs and data files, the burden on the user to load programs and to record intermediate results may become excessive.

SUMMARY

The principal characteristics of a computerized management information system are reviewed with particular attention focused on spatially-oriented resource data bases. Two computer-based systems are described - a land management application and a product conversion application. Factors influencing the choice of a minicomputer vs. a large-scale computer during the development and implementation of these two systems are described. While difficult to generalize we believe that the minicomputer can best be used during the developmental stages of model construction while the large-scale computer is better suited for operational usage. Other factors influencing this decision are also described.