

APPLICATIONS OF A COMPUTER SIMULATION MODEL
TO LOGISTICAL DECISIONS IN A UNIVERSITY

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ABSTRACT

APPLICATIONS OF A COMPUTER SIMULATION MODEL TO LOGISTICAL DECISIONS IN A UNIVERSITY

by George Merrill Van Dusen

A means was sought in this study of demonstrating how a specific model might be employed to describe the operations of a university so that educational administrators can become aware of the potential of a systems approach as an aid in rational decision-making.

It was the purpose of this study to: (1) describe in non-technical language a systems model and an implementation of the model using data descriptive of Michigan State University as developed by a research group in the College of Engineering; (2) identify aims, objectives, and problems concerning the future direction of Michigan State University as suggested by a selected group of educational administrators responsible for policy decisions in this institution; and (3) show how some of these identified concerns and objectives were addressable to a specific computer simulation program which is an implementation of the theoretical model describing the university as a system.

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The theoretical model used in this study identifies the university as a total system composed of interacting sub-systems or components. Mathematical models have been constructed for selected representative components of the system and the interconnection pattern among components. Each component defines a specific operation or function of the university to the overall educational process and the associated units of production. It delineates how the university uses its resources--personnel, space, and equipment--in the production of educated manpower and other services.

The development of a simulation computer program (MSUSIM2) which includes data for the College of Engineering was the tool used to conduct experiments. By using this program it was possible to vary selected parameters to reflect conditions and policies of Michigan State University as recognized by a selected group of educational administrators.

Interviews were conducted with thirteen administrators at Michigan State University to offer input for the experiments according to aims, objectives, and problems regarding the future direction of this Institution. The interviews yielded a broad range of response from detailed and specific alternatives to generalized goals and objectives.

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As a result of the interviews the following conclusions were drawn. Administrators desire more descriptive information as an aid in planning and decision-making. The significance of enrollments and the importance of finances are recognized as critical elements in planning. Policy decisions are made in isolation without an awareness of other areas on campus. A need exists for evaluation of present programs and personnel before the development or expansion of innovations.

Seven experiments were designed which were addressable to the conclusions drawn from the interviews. The parameters which were manipulated in the simulation program reflected changes in enrollments, finances and policies as suggested by the administrators. Experiments were conducted that reduced the number of new freshmen and increased the number of new sophomores, juniors, and seniors admitted to the University. One experiment was conducted to examine the effects of a change in graduation requirements for students in a specific major. The final experiment was a composite of changes plus simulated salary increases for faculty members in the College of Engineering.

The following conclusions were drawn as a result of the experiments. A reasonable confidence in the calculations performed by the computer was developed by manual calculations of anticipated changes. The user of this simulation program can then be reasonably

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sure that the calculations are accurate and express reasonable relationships. The specific model used in this study can be used to simulate enrollment projections, calculate appropriate demands and costs, and change selected parameters. As changes are introduced it is possible to trace some interrelationships of the results of the changes. The interaction of the variables made it possible to observe that when policy changes are made in isolation the results of these changes affect the total operations of the University. To the extent that an accurate data base exists, the simulation program provides a tool for administrators in the College of Engineering to conduct a number of experiments concerning the present and future direction of the College.

The development of management information systems to aid administrators can only be effective if accompanied by an organizational structure to insure communications in the system. This communication linkage must be recognized as an important mechanism for decision-making in order for the administrator to make maximum use of the analytical tools in carrying out management functions.

APPLICATIONS OF A COMPUTER SIMULATION MODEL
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By

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CHAPTER I

THE PROBLEM AND DESIGN OF THE STUDY

Analytical tools and techniques such as systems analysis, modeling, and simulation, generally developed by analytically trained people "outside" the area of educational administration, have been suggested in recent years for assisting educational administrators in decisions concerning the present and future direction of colleges and universities. At the present time, there is little evidence that educational administrators are becoming particularly adept at or evidencing thrust toward possible adaptations of these analytical techniques to educational problems.

One attempt to apply systems analysis to educational problems has been the work of a research group in the College of Engineering at Michigan State University. This research effort describes a university as a system and exemplifies one approach to mathematically depict the operations of a university. If an approach of this type is to be understood by educational administrators for assessment and possible implementation, there is a need for an explanation and demonstration of its potential. A means was sought in this study of demonstrating how a specific model

might be employed to describe the operations of a university so that educational administrators can become aware of the potential of a systems approach as an aid in rational decision-making. The study encompasses the following questions: (1) What is the systems model developed by the Systems Science Group at Michigan State University? (2) What are some of the specific strengths and limitations of this model? (3) For what might it be useful? (4) How might the model be used?

Purpose of the Study

It was the purpose of this study (1) to describe in non-technical language a systems model and an implementation of the model using data descriptive of Michigan State University as developed by the Systems Science Group in the College of Engineering; (2) to identify aims, objectives, and problems concerning the future direction of Michigan State University as suggested by a selected group of educational administrators responsible for policy decisions in this institution; and (3) to show how some of these identified concerns and projects are addressable to a specific computer simulation program which is an implementation of the theoretical model describing the university as a system.

The Need and Importance of the Study

The need and importance of the study largely stems from three sources: (1) the expressed concern by educational leaders

for decisions regarding educational planning to be based on factual data; (2) the expressed concern by educational leaders for administrators to become aware of analytical tools as aids in educational planning; (3) the current commentary which suggests the potential of systems analysis for approaching educational problems.

The literature related to educational administration has long emphasized the need for careful planning in decision-making. Dodds, commenting about the university president's role in the decision-making process, presents a summary of the need for facts in decision-making:

Any administrative action is based on a combination of established facts and conjecture. The circumstances leading up to a decision may be well established or known only in outline; it consequently may be relatively certain or almost totally obscure. Yet decisions must continually be made; the refusal to decide between alternatives constitutes a decision in itself This chronic predicament requires a degree of philosophical resignation on the part of the president, to be sure, but it also calls for efforts to enlarge the scope of the known and reduce the scope of the unknown. The more facts the better the hunches.¹

Moore suggests there is a need to delineate between the administrative and leadership functions performed by the university president. He reasons that both functions cannot be conducted by the same man and one of the basic distinctions relates to planning.

¹Harold W. Dodds, The Academic President--Educator or Caretaker? (New York: McGraw-Hill Book Company, Inc., 1962), p. 177.

The administrator, in dealing with the here and now of the institution, must be astute at effecting the best collage of data suggesting priority and direction. The descriptive data developed by the administrator provide the reference points for the leader as he attempts to predict trends and visualize what the future holds. The leader uses data as might an historiographer--his real world is the future.²

Francis A. Horn strongly emphasizes the importance of decisions involving the present and future direction of educational institutions being based on relevant and factual data when he states:

. . . to continue to operate colleges and universities in the future as they have been operated in the past, to go on making decisions by such unscientific and ad hoc means as have prevailed, can only lead to the failure of higher education to meet the challenge and opportunities ahead, if not, indeed to down right disaster.³

Educational decision makers face a difficult task in the formulation of policies to provide direction and leadership for colleges and universities. There is evidence in the literature which suggests that educational administrators should become familiar with tools and techniques which might aid in this endeavor.

Mauch⁴ was one of the early educational writers to urge educators to consider a systems analysis approach. He suggested

²Samual Moore, "Leaders are Leavers," The Journal of General Education, XX, No. 4 (January, 1969), p. 293.

³Francis H. Horn, "A University President Looks at Institutional Research," The Role of Institutional Research in Planning (Madison, Wisc.: The University of Wisconsin Press, 1963), p. 4.

⁴James Mauch, "A Systems Analysis Approach to Education," Phi Delta Kappan XLIII, No. 5 (January, 1962), pp. 158-161.

that it offers an opportunity to consider alternatives in resource allocation and planning. Meals emphasizes the strengths, limitations and potential for systems analysis in examining educational planning and suggests a role for the administrator as follows:

Systems analysis will not cure all the real and presumed ills of education. It will not alone eliminate a single evil or replace one traditionally trained administrator. Moreover, such benefits as may be derived from a systems approach will occur gradually as educators adapt some new attitudes and adopt a few new tools.⁵

Bern presents a rationale for developing "educational engineers" and offers a two-step program to accomplish this task:

1. Consultation with and study of educational institutions such as M.I.T., military organizations such as the U.S. Naval Training Devices Center, research and development centers such as System Development Corporation, and education and training research laboratories of industrial organizations such as the Hughes Aircraft Company. In effect this would be a survey and analysis of areas where considerable cross-fertilization of education and engineering has already taken place and where it is therefore likely that the seeds of educational engineering of the future are germinating.

2. The development and institution of courses and a curriculum leading to a professional degree in educational engineering.⁶

Judy and Levine suggest that educators need to have analytical techniques to work with: "In the administration of scarce resources,

⁵ Donald W. Meals, "Heuristic Models for Systems Planning," Phi Delta Kappan, XLVIII, No. 5 (January, 1967), 203.

⁶ H. A. Bern, "Wanted: Educational Engineers," Phi Delta Kappan, XLVIII, No. 5 (January, 1967), p. 235.

university officials deserve managerial tools as powerful and sophisticated as those available to managers in business and government. The necessity of reaping the maximum return from our educational investment is no less."⁷

In 1966 Rourke and Brooks completed a study of computer usage in colleges and universities in the United States. They suggest that the applications of operations research and systems analysis to educational problems were in part responsible for the conclusion that there is a "managerial revolution in higher education."⁸ This same survey also provides some background on the use of computers in simulation and related activities at the time of the survey. Rourke and Brooks asked, "Are you now using or do you plan in the near future to use computers for the simulation of campus operations, heuristic problem solving, or other forms of advanced computer analysis?" The response to this question is shown in Table I.

Because systems analysis has been developed primarily for use in business, government and the military to analyze resource management, there are some educators who dismiss these techniques

⁷ Richard W. Judy and Jack B. Levine, A New Tool For Educational Administrators (Toronto: University of Toronto Press, 1966), p. vii.

⁸ Francis E. Rourke and Glenn E. Brooks, The Managerial Revolution in Higher Education (Baltimore, Md.: Johns Hopkins Press, 1966), p. vi.

TABLE I
COMPUTER USAGE FOR ADVANCED ANALYSIS⁹

Response	Number	Percent
Not at present	53	37
Plans in progress	11	8
Yes	2	1
No response	77	54
TOTAL	143	100

as having no value for education. Millett expresses this point of view, ". . . ideas drawn from business and public administration have only a very limited applicability to colleges and universities."¹⁰ The differences in functions performed by education as compared to other institutions is the argument usually presented by critics such as Millet. Dill, in discussing Litchfield's global theory of administration, also supports Millett's position:

Despite Litchfield's arguments that much of a science of administration will be applicable to all kinds of organizations, laboratory groups, business firms, and government administrative agencies differ in important respects from schools, colleges, and universities.¹¹

⁹Ibid. 143.

¹⁰ John D. Millett, The Academic Community: An Essay on Organization (New York: McGraw-Hill Book Company, Inc., 1962), p. 4.

¹¹ William R. Dill, "Decision-Making," Behavioral Science and Educational Administration, Sixty-third Yearbook of the National Society for the Study of Education, Part II (Chicago: University of Chicago Press, 1964), p. 205.

An example of the counter argument is offered by Corson. He states, "the assumption that the university is different and not subject to assistance from the considered experience of other institutions seems to be the crucial barrier to imaginative development of new and improved means of governance."¹² Caffrey and Mosmann¹³ indicate that most American colleges and universities lag behind government and industry in using systems techniques for two reasons: (1) A refusal to face the problem; and (2) a refusal to pay for its solution.

The importance of this study is also suggested by the growing interest for informing educators about analytical tools and techniques. A Symposium sponsored by the U.S. Office of Education was held in November, 1967 to bring together the analysts and the educational administrators to discuss the implications and adaptations of systems analysis to educational problems. David S. Stoller identified the purpose of the meeting in his opening remarks:

The symposium is set up to accommodate as wide a range as possible--from the educator interested to learn what is happening in operations analysis (and who may have little mathematical background) to the sophisticated model builder engaged in modeling the entire educational system of a country--and even he may find there are developments he hadn't heard of before.¹⁴

¹² John J. Corson, Governance of College and Universities (New York: McGraw-Hill Book Company, Inc., 1960), p. 200.

¹³ John Caffrey and Charles J. Mosmann, Computers On Campus (Washington, D.C.: American Council on Education, 1967), p. 38.

¹⁴ David S. Stoller, "Symposium Theme: Operations Analysis of Education, " (Opening speech at the Symposium on Operations Analysis of Education sponsored by the U.S. Department of Health, Education and Welfare, Washington, D.C., November 19, 1967), p. 1.

The discussions at the conference ranged through such topics as site locations of urban schools, bussing schedules, measuring student achievement, and modeling of universities. Chauncey in the foreword to Pfiffer's report states his assessment for the conference as follows:

One of the most valuable outcomes of these sessions was the dispelling of some myths about the computer as a control instrument over individuals and over the educational process It must be said that a system does not of and by itself, produce better education. It should, however, if used seriously, present educators with the opportunity to face up more exactly to what they want to achieve, a program of how they hope to go about it, and the courage to assess honestly the outcomes of their actions.¹⁵

The Ford Foundation has taken an active role in the financial support for implementation of systems analysis projects at educational institutions. In April, 1968 grants totaling \$2 million were received by Stanford University, The University of California at Berkeley, Princeton University, and The University of Toronto to support the development and testing of new management techniques in the solutions of problems of higher education.¹⁶ Generally, these programs are applications of systems analysis techniques to university problems.

A potential aid for assisting the educational administrator in decision-making has grown out of the work of the Systems Science

¹⁵ John Pfeiffer, New Look at Education, with a Foreword by Henry Chauncey (New York: Odyssey Press, 1968), p. VIII.

¹⁶ American Council on Education, Higher Education and National Affairs, XVII No. 14 (April 19, 1968), p. 2.

Group in the College of Engineering at Michigan State University.

In 1964 this group initiated a research project sponsored by the Economic Manpower Commission entitled "A Systems Approach to Higher Education." A progress report prepared in September, 1967, summarizes the original intent of the project as follows:

. . . to determine, first, whether it was possible to develop a valid mathematical description, or systems model, of the university, and, second, whether usable and effective information processing programs based on this model could be implemented on a computer to answer important questions concerning allocation policies. The theoretical structure of such a model was developed in the early stages of the project and refined more recently. With the cooperation of the Office of Institutional Research considerable attention has already been devoted to the problems of providing an adequate data base from which to work.¹⁷

Contained in the same report is the challenge to educational administrators at Michigan State University which largely provides the impetus for the study undertaken:

The project now stands on the threshold of practical application of the system method in decision-making. The last steps towards the use of the model cannot be taken by system specialists and computer scientists alone. It has become increasingly important for the university administration to become acquainted with the objectives of the project, its potentials and limitations and to provide suggestions for the direction of future efforts.¹⁸

¹⁷ Herman E. Koenig, Martin G. Keeney, and Rita Zemach, Systems Analysis and Planning in University Administration (East Lansing, Mich.: Division of Engineering Research, Michigan State University, 1967), p. 4.

¹⁸ Ibid.

The need for factual information as an aid for educational administrators has been suggested. Systems analysis and related techniques have been identified by some educators as offering possible tools to aid in the decision-making process. The use and sharing of these analytical techniques is in the beginning stages. A specific project using systems analysis at Michigan State University has been offered as a possible aid for administrators.

Operational Definitions

Components are the parts of a system. Mathematical models are constructed for each component of the system and the interconnection pattern among components. Each component defines a specific operation or function of the university. The components of the university in this study are labeled sectors.

A Model is a mathematical description of the system. Thus, the model in this study consists of a mathematical description of the identifiable interrelated sectors within the system. It is merely one conceptualization of how the components of the university are interrelated.

A Parameter is a variable whose assigned value is changed to reflect different conditions of the system. Enrollment, Faculty Salary Scale, Cost of Supplies and Services are merely three examples of numerous parameters which can be manipulated in the simulation program used in this study.

Simulation is the process of manipulating the parameters of the model and noting the resulting condition of the system as described by the model. The MSUSIM2 program is one implementation of the model which allows the user to experiment with the system by assigning values to certain parameters.

The process which enables the user to manipulate variables in the model is known as simulation. The mechanical means of accomplishing the manipulation is a computer program.

A System is a collection of interacting identifiable parts. A university is viewed as a system in this study.

Systems Analysis is a technique for mathematically identifying, representing, and studying the interrelationships of the parts which comprise the system. Thus, the tool employed by the specialist in this study to examine the structure of the university.

Design of the Study

Prior to the design and development of the study it was necessary to describe, in nontechnical language, the systems model, and the implementation of the model, developed by the Systems Science Group in the College of Engineering at Michigan State University. This was accomplished by reading, and discussions with participants in the research project and was essential in order to determine whether or not it was possible to gain the appropriate level of understanding necessary to undertake the study. Hare and Chorafas offered valuable sources in order to obtain a historical

perspective and understanding of systems analysis.¹⁹ Kivat, Evans, et al., Pfeiffer, and several journal articles served as basic sources for examining the application of systems analysis to engineering, physics, and socio-economic problems. The reports by Koenig, et al., served as the sources for understanding the specific model used in this study. (The discussion of the model is presented in Chapter III.)

In order to identify aims, objectives, and problems concerning the future direction of Michigan State University, interviews were conducted with thirteen administrators who generally participate in long range planning as a normal part of their administrative responsibilities. Included in the interview group was one department chairman, one dean, and eleven administrators generally identified as members of the "central administration." Individuals from the "central administrative" group were selected from the Offices of the President, Provost, Secretary, and Registrar, plus representatives from the Graduate Office, Business Office, Institutional Research, and Admissions and Scholarships. No teaching faculty members, students, or members of the Board of Trustees were included in the interview group even though their role in the future development of the University is recognized. It was reasoned

¹⁹ These and all references which served as background information are identified in the bibliography.

that the members of the interview group were more concerned with the management and operational aspects of the University as compared to the groups that were excluded.

The Interview Guide

A private, one-two hour, in-depth interview was the data gathering technique employed in the study. In developing the interview guide, primary recognition was given to the central purpose of the investigation; to discover the long range plans for Michigan State University. A semi-standardized interview guide was constructed to help answer this and related questions. The interview guide contained a minimum of structure because each individual included in the study represented a unique administrative unit in the University. Appendix A contains a copy of the interview guide.

As a result of a pretest with three administrators, not included in the study, a number of minor revisions were made in the guide. This experience also suggested more effective approaches to be used by the interviewer.

Data Collection Procedures

The interviews began June 18, and were completed September 20, 1968. A tape recorder was used for two interviews, but was discontinued because its use tended to inhibit the flow of information. During the remaining eleven interviews careful notes were taken and an immediate reconstruction of the comments was written.

Analyzing the Data

The data gathered in the interviews were classified according to categories identified by the thirteen administrators. Five categories were identified which included: (1) enrollments, (2) finances, (3) academic programs, (4) social concerns, (5) physical facilities. The information gathered from the interviews was analyzed as follows:

1. The responses which fell within the framework of the model, but could not be directly applied to the simulation program, i. e., social concerns quality of programs.
2. The responses which were found to be directly addressable to the computer simulation program.

The responses which were found to be addressable to the computer simulation program, served as the basis for the design of seven experiments to demonstrate the possible use of the model in approaching educational problems.

The experiments were carried out using a simulation program identified as MSUSIM2 and run on a Control Data 3600 Computer. The computer carried out the basic calculations according to the instructions of the program developed by the user.

The analysis of the experiments was conducted to show the effects of the parameter changes within the simulation program. Graphs and tables were prepared to assist in the display of the changes and interactions which occurred.

CHAPTER II

REVIEW OF RELATED LITERATURE

A review of related research was conducted to identify and examine studies where systems analysis has been used as a tool to approach educational problems. A limited number of investigators have used this technique for analysis of entire school systems and universities or recognized parts of these organizations. Of primary concern were those studies involved with colleges and universities, but selected studies pertaining to other school systems were also included.

The review of literature also revealed a number of studies where the term "systems" was used to describe a particular research activity, but not in the same sense as in this study. Therefore, a general criterion was developed to determine the studies that were judged as relevant to this project. The section which follows is not intended to be a comprehensive review of the "systems approach," but a framework or strategy for identifying the types of educational studies included in the review of literature.

Literature on the Systems Approach

A systems approach is not new and there is evidence which suggests that a great deal of modern systems theory has been borrowed from the past. Blaschke reports, "We have returned to the use of the scientific approach to the method developed in the days of the Greeks, refined the techniques of implementation where possible, and in twentieth-century style christened it, sometimes with too much glory, 'the systems approach.'"¹ A similar conclusion has been reached by Hare; "The system concept is as modern as ancient Egypt, where a crude form of today's system theory played a role in the construction operation of the pyramids."²

Numerous strategies have evolved for systems analysis, but there is evidence which suggests there is no single approach. Pfeiffer offers the following:

. . . there is no such thing as the systems approach, if that implies the existence of a formula or a special set of rules for handling problems. A wide range of procedures are available, and which turns out to be the most helpful depends on the nature of the problem under investigation.³

After listing seven constituents in the study of a system, Evans and others, suggest, "Naturally all studies need not conform to

¹ Charles L. Blaschke, "The DOD: Catalyst in Educational Technology," Phi Delta Kappan, XLVIII No. 5 (January, 1967), p. 211.

² Van Court Hare, Systems Analysis: A Diagnostic Approach (New York: Harcourt, Brace and World, 1967), p. 22.

³ Pfeiffer, New Look at Education, p. 12.

this organization . . . Thus, it sometimes is hard to say whether a given constituent of study plays the role of a system, a model, a method of solution, or a solution.⁴

Recognizing that there is no single systems approach and the type of problem determines what will be included in the study, it is nevertheless important to identify a generalized procedure. Figure 1 presents a flowchart which identifies a set of procedures generally involved in a systems approach. The flowchart emphasizes a number of important principles, according to Pfeiffer:⁵

1. Identification of the boundaries of a problem.
(Define the problem.)
2. Specification of the subfunctions and alternatives
in relationship to the system.
3. The use of a model to clarify and to yield information.
4. Identification of the systems approach as a cyclical
and continuing process.

The application of the technique to educational problems is outlined by Blaschke as follows:

⁴ George W. Evans, Graham F. Wallace, and Georgia L. Sutherland, Simulation Using Digital Computers (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1967), p. 3.

⁵ Pfeiffer, New Look at Education, pp. 21-32.

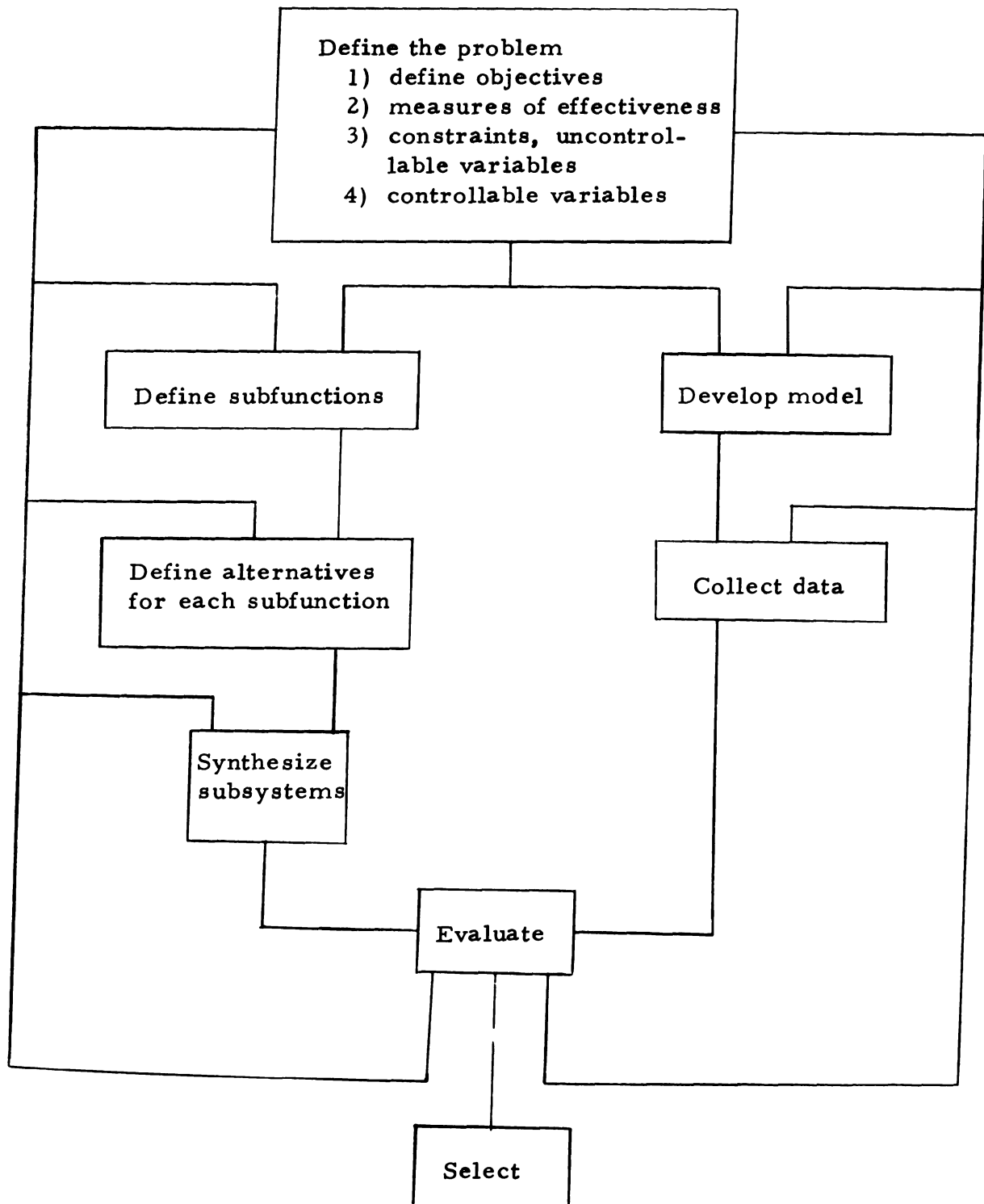


Fig. 1 -- Flowchart of a Systems Approach⁶

⁶Ibid., 32.

Its (systems approach) significance to education is that it forces the individual manager to define the problem precisely, note the alternatives available and their total costs, and choose the most efficient alternative according to performance criteria. Today its merit lies in its conceptual approach; for the future, the need to refine implementing techniques depends on our ability to define our objectives clearly, delineate our problems accurately, and develop criteria for measuring how much success we can get for how many dollars.⁷

A general systems approach for examining educational problems or other types of problems has been identified. The tools and techniques involved in implementing this systems approach is the most basic difference between research efforts related to this study and those that are not.

The model developed by the research group and used in this study is a mathematical model. Chorafas states that mathematical models "describe the equilibrium conditions among significant system variables."⁸ He further suggests that "they can be either static or dynamic. The variables themselves can be deterministic or probabilistic. Their choice and the establishment of the logical structure are of capital importance."⁹ Thus, as indicated in the flowchart, a model is meant to clarify, and to yield information. The research efforts included in this review describe studies of educational problems where the relationship of the components are expressed mathematically.

⁷ Blaschke, "D.O.D.: Catalyst in Education," p. 211.

⁸ Dimitris N. Chorafas, Systems and Simulation (New York: Academic Press, 1965), p. 21.

⁹ Ibid.

Most of the studies included in the review of literature also involved computer simulation. "Computer simulation provides a means for studying systems. It can be applied to a wide variety of systems, both real and hypothetical, and it can be employed for many different purposes."¹⁰ The following purposes are recognized by Chorafas:

- (1) for purposes of experimentation or evaluation;
- (2) as a means of learning about new systems in order to redesign or refine them;
- (3) as a tool in familiarizing personnel with a system or a situation which may, as yet, not exist in real life;
- (4) for the verification or demonstration of a new idea, system, or approach; and
- (5) as a means for projecting into the future and thus providing quantitative bases for planning and forecasting.¹¹

The research efforts listed in this review of literature tend to cut across these purposes because it is inherent in the design of the simulation model. Kiviat suggests the following reasons:

Before a simulation model is designed, two important questions must be asked and answered: (1) What use will be made of the model? (what questions will be asked); and (2) What are the requirements of accuracy and precision? Answers to these questions determine the structure of a model, as they demand that certain assumptions be made, that certain boundaries be imposed and respected, that certain types of questions can and cannot be asked, that certain territories cannot be explored, and that certain realities cannot be predicted.¹²

¹⁰ Evans, et. al., Simulation Using Digital Computers, p. 13.

¹¹ Chorafas, Systems and Simulation, p. 17.

¹² P. J. Kiviat, Digital Computer Simulation: Modeling Concepts, Memorandum RM-5378-PR (Santa Monica, Calif.: The Rand Corporation, August, 1967), p. 14.

Criteria for the inclusion of investigations related to this study have been derived. Within a generalized systems approach, those studies judged to be relevant contain elements of mathematical modeling and, where appropriate, computer simulation is used to study educational problems. A discussion of these studies follows.

Literature on the Use of Systems Analysis
in Approaching Educational Problems

The Systems Development Corporation has been active in the production of research related to instructional systems for secondary schools. Pfeiffer¹³ credits Cogswell and associates with the first modeling effort (1963) using systems analysis and computer simulation to assess the effects of educational innovations. Cogswell summarizes the intent of the project, funded in part by the U.S. Office of Education, as follows:

The purpose of the research is to find new solutions for implementing instructional media through analysis and simulation of school organization

The SDC project, which studies the use of systems analysis and computer simulation in education, should yield techniques and provide design recommendations that are more carefully conceived, that involve more pervasive and integrated changes throughout the schools, and that employ instructional media more effectively than do current methods of school design.¹⁴

¹³ Pfeiffer, *New Look at Education*, p. 119.

¹⁴ John F. Cogswell, "Systems Technology in Education," Man Machines Systems in Education, ed. by J. W. Loughary (New York and London: Harper & Row, 1966), p. 46.

Cogswell outlines the procedures in the project as follows:

- (1) survey and selection of high schools;
- (2) systems analysis of five high schools selected for study;
- (3) construction of a computer-simulation vehicle that will provide the capability of building detailed dynamic models of the schools and of hypothetical changes in the schools; and
- (4) simulation and study of the five high schools with the simulation vehicle.¹⁵

After the completion of steps (1) and (2), listed above, Cogswell developed a simulation model which described a high school in terms of instructional activities, student characteristics, and selected school activities. Yett made a major contribution to the project by expanding Cogswell's model to include the allocation of resources.

The addition of the resource allocation processor to the previously developed simulation vehicle provided for the logical flow and the capacity for control of resources, persons, places, and things by analyzing the terminations, continuation, and activation of activities according to the logical demands of the simulation vehicle and the current expression of the systems resource capabilities.¹⁶

The application of this technique was used to integrate real and simulated data for courses, counseling, the academic progress of individual students, and the exploration of a possible instructional management information system for the five schools that participated in the project.

¹⁵ Ibid.

¹⁶ Frank A. Yett, Resource Allocation Processor For the School Simulation Vehicle--Pilot Version (Santa Monica, Calif.: Systems Development Corporation, 1964), p. 30.

The final report of this project contained the following recommendations:

1. The continued development of the computer-based system to assist students and counselors in planning;
2. The continued study of the use of information processing for student instruction; and
3. The development of procedures for the management of change in schools.¹⁷

Reports of recent projects by the Systems Development Corporation indicate that present efforts are basically a continuation and extension of applications of systems analysis and computer simulation to individualized instruction at the elementary and secondary school levels, computerized instruction, and computerized counseling.

Systems analysis and computer simulation have also been used by Clark and others to model urban education. The analytical model is an aggregation of sub-models which is intended to aid in decision-making regarding school location, enrollment, facilities, organization, programs, and costs. The model has the capability to handle the introduction of known data such as available money, staff allocation, and the present school plant.

¹⁷ John F. Cogswell, New Solutions to Implementing Instructional Media Through Analysis and Simulation of School Organization--Final Report (Santa Monica, Calif.: Systems Development Corporation, 1966), p. 51.

The aggregated model consists of the following sub-models:¹⁸

1. An urban sub-model which combines pupil population, location, transportation, needs, and socio-economic characteristics of the community.
2. A school sub-model which describes the school program, site specifications, and space and equipment provisions per pupil by instructional area.
3. A cost sub-model which helps to estimate the total per pupil expenditures for remodeling existing facilities compared to new site and construction proposals.

The aggregated model then evaluates benefits and costs per pupil in relation to educational objectives.

Attempts to implement the theoretical model have been limited.

"The major constraint," according to O'Brien, "has been the limited data which are available for the estimation of parameters."¹⁹ This recognizes one of the basic necessities of implementing a theoretical model, namely, an accurate and available data base.

Another general model is the effort by Reisman to develop a mathematical model to describe the flow of students in and out of a university system and to follow the progress of students through the system. The relationships of students to the rest of the system are expressed by differential equations.

¹⁸ U.S., Department of Health, Education, and Welfare, Division of Operations Analysis for Educational Statistics, Urban Education Systems Analysis, by Stephen C. Clark, Richard J. O'Brien, and C. Marston Case, Technical Note No. 24 (Washington, D.C.: Government Printing Office, 1967) p. 10.

¹⁹ U.S., Department of Health, Education, and Welfare, Division of Operations Analysis for Educational Statistics, Cost Model for Large Urban Schools, by Richard J. O'Brien, Technical Note No. 30 (Washington, D.C.: Government Printing Office, 1967), p. 13.

This model breaks the educational sector up into four segments: undergraduate programs, master's programs, doctoral programs, and post-doctoral programs. It breaks the other sectors of society employing college-university trained people into segments according to the highest degree earned by those within the segment.²⁰

Reisman does not attempt to offer any implementation of the model; instead, he recognizes the generality of his model as follows:

Thus, we are left with a decision that most systems analysts of socio-economic systems sooner or later must face. The decision is two-fold. First, it is concerned with what portion of the universe one ought to subject to study--that is, where he should place his system boundaries. Second, it is concerned with the level of aggregation to be used both within the system's boundaries and within that portion of the remaining universe with which the system communicates.²¹

The investigations by Cogswell, Clark, and Reisman provide evidence of efforts to model large scale educational problems; other researchers have examined more specific problems. Belinski²² used systems analysis to describe the relationship between characteristics and cost elements in the procurement, installation, and operation of educational media and technology. He first identified the general system, detailed the physical and operational characteristics of the system, developed the mathematical models to describe the relationship between characteristics and costs, and

²⁰ Arnold Reisman, "A Population Flow Feedback Model," Science, 153 (July 1, 1966), p. 89.

²¹ Ibid., 91.

²² John Belinski, A Cost Study of Educational Media Systems (Washington, D. C.: General Learning Corporation, 1968).

built an aggregate model of the sub-models. The General Learning Corporation has implemented the results of this effort to assist schools in determining cost alternatives in purchasing instructional equipment aids.

Bowman has indicated that Yale University is in the process of developing a model of the operating growth budget which projects what "the University fiscal flows and structure might look like under varying conditions over an extended period, e.g., 20 years."²³

Bowman characterized the progress of this effort as follows:

We have run many simulations, adjusted the program, refined the parameter estimates, and modified the questions we have been asking. . . .

Our work with the operating growth budget has already started to influence some of the decisions of the University including the yearly operating budget, the capital funds program, and the endowment investment portfolio.²⁴

Another research effort on a specific problem was carried out by Yurkovich. He developed a computerized methodology for determining the physical facility requirements of a large university and implemented the model by using data collected for the University of Wisconsin. The results of the study indicate he was able to conduct room utilization studies, project enrollments based on fixed or expanded space needs, project staff needs, and project future

²³ Edward H. Bowman, "A Budget Model of a University," Symposium of Operations Analysis of Education (Washington, D.C.: November 19-22, 1967), p. 7.

²⁴ Ibid., 8.

physical facility requirements. "Each element, including the space classifier, the perpetual space inventory, the enrollment projector, and the staff projector, is an independent system. The integration of these elements allows for the projection of future space needs."²⁵

Few investigators have used systems analysis to produce a global model of a system. The development of a descriptive model of this type forfeits detail, but enables the educator to observe the interrelationship of several subsystems. At the present stage of development, the work of Keller, Judy, and Koenig represents the major activity in this area at the college or university level. It is perhaps misleading to suggest that these efforts are the work of one man, for each activity represents an extensive project with sizeable financial and manpower efforts.

Keller²⁶ indicated in November, 1967 that during the years 1965-1967 cost simulation models, physical plant utilization models, capital outlay models, scholarship aid models, and models of the demand for higher education, had been developed at Berkeley. Since that time real data has been implemented to examine a number of real problems. Most of these studies have been internal cost

²⁵ John V. Yurkovich, A Methodology For Determining Future Physical Facilities Requirements (Madison, Wisc.: University of Wisconsin Press, 1966), p. 154.

²⁶ John E. Keller, "The Use of Models in University Decision-Making," Symposium on Operations Analysis of Education (Washington, D.C.: November 19-22, 1967), p. 7.

studies based on the financial problems facing higher education in California. In April, 1968 the University of California at Berkeley received a \$500,000 grant from the Ford Foundation to continue its efforts to apply systems analysis techniques to university problems. "The major use of this grant will be to develop planning models to deal with academic, economic, and physical factors in relation to costs."²⁷

Judy and Levine at the University of Toronto have made an effort to communicate their modeling efforts of the entire University to educational administrators. A simulation model called C A M P U S has been built for the Faculty of Arts and Sciences to represent the implications of resource allocations as related to enrollments, resource demands, space requirements, and budgetary calculations. Judy and Levine offer the following summary of the capability of the model:

The model simulates university operations over a time period of any length. Loaded into the computer, the model accepts descriptions of the university's structure and statements of the levels of activities that the university is expected to perform. With these inputs, the model computes the resulting resource requirements of staff, space, materials, and money. These requirements are displayed by several computer-prepared reports and graphs.²⁸

The work at Toronto is no longer a pure research effort because it has been implemented as a normal part of the operations of the

²⁷ John Keller, A personal letter.

²⁸ Judy, A New Tool, p. vii.

University through the Office of Institutional Research. At the present time the University is constructing a systems simulation model for the entire University. Part of the reason for the success in implementing the effort has been the ability of the Office of Institutional Research to communicate with members of the faculty. According to Pfeiffer, "Hansen (director of the Office) has made a special effort to speak in uncluttered English, a sound and strategical policy judging by certain unfortunate experiences elsewhere."²⁹

A review of related literature located studies employing systems analysis to model global systems and specific components of schools and universities. The major research contributions in these areas were conducted by a few individuals. The results of the research efforts suggested that the use of systems analysis is in the early stage of development. Researchers who have introduced real data have produced some tangible results. The work at the University of Toronto was suggested as in the most advanced stage of development toward implementation.

As stated previously, the model to be used in this study is a description of the university as a system by Koenig and others at Michigan State University. A detailed description of the model in non-technical language is presented in Chapter III.

²⁹ Pfeiffer, New Look at Education, p. 109.

CHAPTER III

DESCRIPTION OF THE MODEL

The discussion in this section is limited to a description, in non-technical language, of a specific modeling effort, which depicts a university as a system. It is important to emphasize that the model presented in this Chapter represents the thinking of one group as developed by a series of logical steps according to the following considerations.

1. The purpose of the model.
2. The amount of detail incorporated into the model.
3. The assumptions required within the system.
4. The availability of necessary data.

Within this general framework any number of models might be developed to describe the activities of a university, depending upon the specifications of the model builders. Therefore, the model under consideration in this study should not be misinterpreted to be the model, but a single effort designed according to the purposes and objectives of a specific group.

The purpose of the model employed in this study is:

. . . . to describe quantitatively the way in which university administrators collectively allocate resources in an effort to meet the demands placed upon them by a constantly changing student body, and to provide a tool for experimenting with alternative allocation policies in the face of these changes.¹

Given this basic purpose, the model builders at Michigan State University progressed through a series of stages, outlined previously, until the details of a specific model were developed. The discussion which follows, of the structure and implementations of the model offers the necessary detail to describe the university as a system.

Structure of the Model

The total university is viewed as a system which contains a number of identifiable interrelated components called sectors. The operation of the university is described in terms of the interrelationships between and within these sectors as the university uses its resources in production. "The resource of the university are described, broadly, as personnel, space, and equipment; its 'products' are regarded as educated manpower, research, and public or technical services."² Students, faculty, office and

¹ H. E. Koenig et al., A Systems Approach to Higher Education--Interim Report No. 3, Project C-396, National Science Foundation (East Lansing, Mich.: Division of Engineering Research, Michigan State University, 1966), p. 2.

² Rita Zemach, A State-Space Model for Resource Allocation in Higher Education (East Lansing, Michigan: Division of Engineering Research, Michigan State University, 1967), p. 2.

maintenance staff are examples of personnel resources; classrooms, office space, and residence halls are examples of space resources; computers, audio-visual aids, maintenance supplies, and motor pools exemplify equipment resources. The resources at work result in the production of educated students, internal and external services, and research conducted by members of the university.

(Examples of internal services are data processing, faculty effort, counseling, and medical services; continuing education, consulting, and extension services are examples of external services.) The interactions between resources and production in the sectors and throughout the model are expressed by sets of equations. These relationships enable unit costs, units of effort, or other appropriate units to be identified and associated with the sector.

In this specific instance, the entire system is categorized into the following six components:

1. Administrative Control Sector
2. Personnel Sector
3. Physical Facilities Sector
4. Non-Academic Production Sector
5. Academic Production Sector
6. Student Sector

All sectors contain identifiable interrelated parts and therefore qualify as sub-systems of the broader university system. The relationships of all sectors except the administrative control

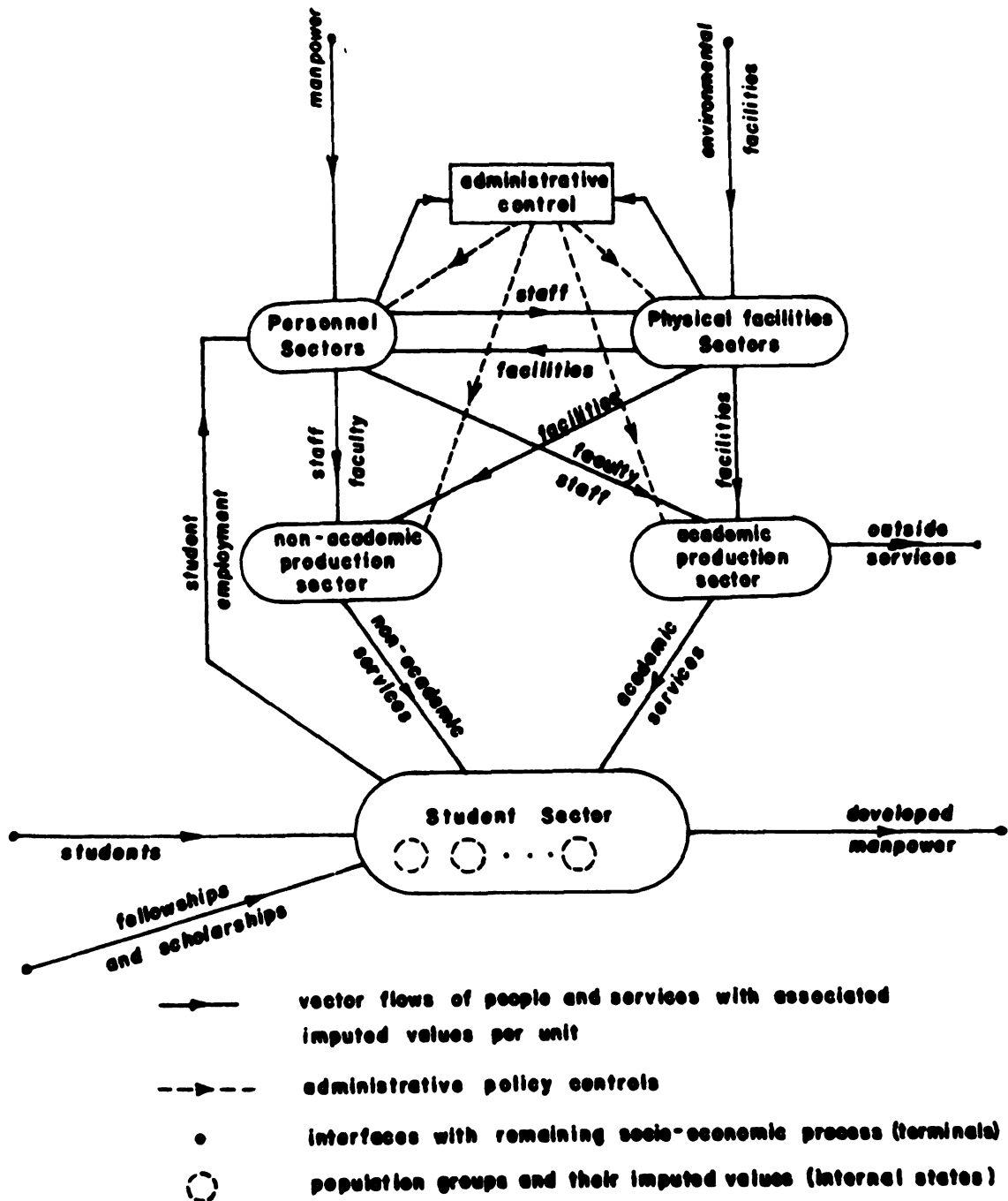


Figure 2. Structure of the System Model

Source: H. E. Koenig, M. G. Keeney, and R. Zemach, Systems Analysis and Planning in University Administration (East Lansing, Michigan: Division of Engineering Research, Michigan State University, 1967). Figure 2, p. 23.

sector, are expressed quantitatively. This means that the remaining five sectors are modeled independently and brought together through the descriptions of their interrelationships while the user functions as the administrative control as experiments are conducted. Figure 2 shows some elements of the interrelationships between the six sectors as they interact to form the university system.

Student Sector

The student sector forms the base of the schematic diagram, for it produces the internal demands of the system. This simply means that without students there would be no need for the other sectors which make up the system.

The student sector takes in students from outside the system, uses the academic and non-academic production sectors and produces developed manpower. Developed manpower includes all students who leave the university whether or not a degree has been completed. The production of developed manpower is a function of the entire system and results from the complex interrelationships of all the identified sectors.

Within the student sector a description of the distribution of all students is developed according to major fields and class levels. The description identifies factors which influence student enrollments such as the number of students by class and level the previous year, the major choices of new students, the availability

of scholarships, graduate assistantships, housing, and other factors which may be identified as attracting students to the university.

Student demand creates a pattern for courses in all fields and levels in addition to teaching and research associated with dissertation production. Demand from this sector is also evidence in the non-academic production services such as housing, counseling and medical services.

Academic Production Sector

The academic production sector consists of the relationship between the production of academic services and the faculty and graduate assistant effort, plus the environmental facilities required to produce such services. This sector therefore takes in resources from the personnel sector and physical facilities sector and produces academic services as a result of the demand from two sources;

1. The student sector which creates the demand for the production of credit hours, academic advising, dissertation direction, and other related academic services.
2. The demand from outside the university system which comes from such sources as sponsored research, adult education, and other community needs.

In order to meet the demand for academic services the effort of the faculty or graduate assistants is not enough; environmental facilities such as classrooms, instructional equipment, and library facilities are also needed.

Non-Academic Production Sector

The non-academic production sector takes in staff and faculty from the personnel sector plus additional resources from the physical facilities sector and produces non-academic services.

The production of non-academic services such as registration, housing, health services, counseling, and placement result from the demand created by the student sector. The relationships between the resources and the production within this sector are specified in terms of the efforts, facilities, and costs needed to meet the demands of the student sector.

Personnel Sector

Resources, in the form of faculty and staff manpower are received from outside the system, supplemented by student labor (including graduate assistants) from the student sector within the system. A third resource for the personnel sector consists of the environmental facilities, provided in turn by the physical facilities sector, and which are needed to support the activities of the personnel sector itself.

The resources of the personnel sector support the production sectors as well as the physical facilities sector by providing faculty, office and maintenance staff. The demand for the personnel sector is established by the academic and non-academic production sectors, administrative control sector, and the physical facilities sector. This sector therefore produces faculty and graduate

assistant effort for the academic production sector; administrative effort for the administrative control sector; maintenance and operation effort for the physical facilities sector; and student non-academic services effort for the non-academic production sector.

Physical Facilities Sector

The resources of the physical facilities sector are received from outside the system in the form of space and equipment, or dollars, which the physical facilities sector converts to space and equipment, broadly categorized as environmental facilities. A second resource from within the system is received from the personnel sector and is classified as construction, maintenance and operational staff.

The demands for this sector are established by the academic and non-academic production sectors, the personnel sector, and the administrative control sector. The physical facilities sector therefore produces the space, equipment, and staff effort required by the interacting sectors listed previously.

Administrative Control Sector

The administrative control sector produces the policy decisions which allocate the resources to the various sectors. The dotted line arrows in Figure 2 show the flow to these sectors. The changes in administrative policy are reflected in the model by changes in all the other sectors. For example, an administrative

decision to alter the enrollment of the university results in changes in the demand within the student sector. Corresponding changes then result in all other sectors as this change in administrative policy moves throughout the system. No mathematical description of the units of production are calculated within the administrative control sector, but are changed within the sectors which are effected by policy alterations. This is perhaps a subtle distinction because administrative control is specified in the model by the number of students admitted, the money available, the number of faculty, etc., but as these controls are changed the computational adjustments are carried out in all the remaining sectors.

Resources and Production

Throughout the discussion of the components which make up the entire system, several examples from the university were used to explain the flows in and out of the various sectors. Figure 3 identifies additional examples of the resources and products associated with the student sector, academic and non-academic production sectors, personnel sector, and physical facilities sector. It is the intent that the identification of resources and products associated with each sector will offer additional assistance in visualizing the components and recognizing the interrelationships which must be developed in order to describe the entire system. Just how many, which ones, and the level of detail to be selected in any given implementation, will be determined by the questions to be answered.

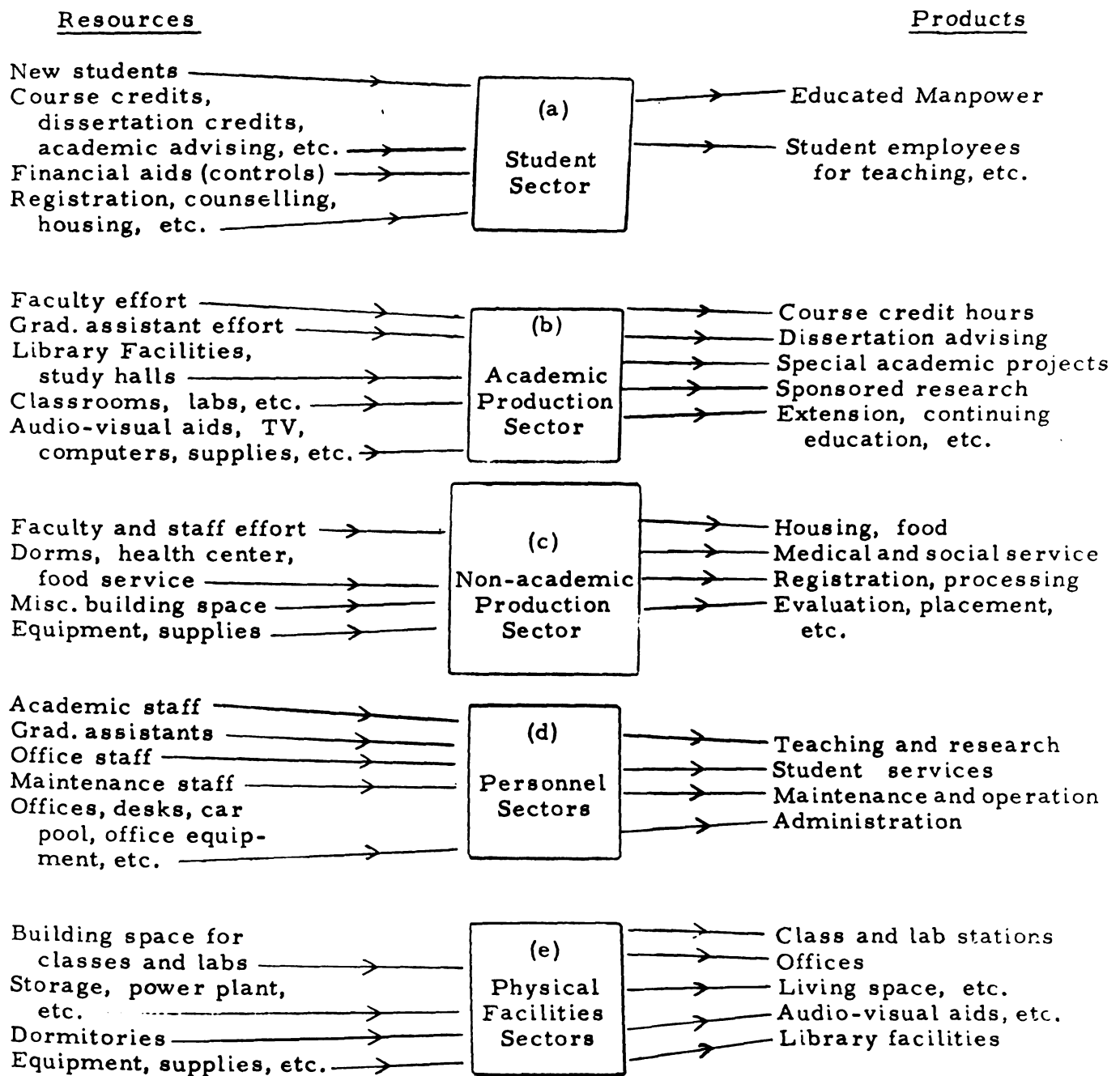


Figure 3. Sectors of the Model

Source: H. E. Koenig, M. G. Keeney, and R. Zemach, Systems Analysis and Planning in University Administration (East Lansing, Michigan: Division of Engineering Research, Michigan State University, 1967), Figure 1, p. 22.

Implementations of the Model

Implementing the model requires the insertion of real data using the relationships which have been established by the theoretical model. The model builder implementing the theoretical model is faced with some real constraints. One of the basic constraints is related to the employment of a mathematical model. The model is limited to those components and variables of an educational system for which a quantitative measure or value can be established. The administrator in making policy decisions reacts to a large number of factors; some of these factors can be expressed quantitatively and some cannot. For example, there are undoubtedly individuals on a university campus who would argue that a successful athletic program attracts students. It is not clear how anyone might identify the components and variables which would describe this effect quantitatively.

There are also mechanical constraints in the implementation process resulting from the necessity to have an accurate and available data base which is addressable by a computer system. Progress to this end has been reported by Rourke-Brooks³ and Caffrey-Mosmann,⁴ but they conclude that most universities have not yet developed extensive information systems, which are mandatory for detailed modeling using systems analysis.

³ Rourke and Brooks, The Managerial Revolution in Higher Education.

⁴ Caffrey and Mosmann, Computers on Campus.

The lack of a detailed information system is evidenced when an attempt is made to collect real data pertinent to Michigan State University. Central data files do not exist at Michigan State which identify the total production of faculty members and this is necessary to completely specify the academic production sector. Salary information for faculty members is available and computer-addressable; however, consulting activities, research involvement, publications, and service to the community and University are not collected accurately and uniformly for each individual, and the data that is collected is not coded and aggregated for computer usage. To further complicate the collection process, this information, in a variety of forms, is scattered throughout the University. This is merely one example of a constraint in developing an accurate data base which forces the analyst to develop those sectors of the model in greater detail where the most information is available. Koenig, et al. suggest an alternative for the model builder as follows:

. . . many areas remain in which an adequate data base is not currently available, and probably will not be for the next few years. In these cases it is necessary, at least for the present, to use subjective estimates or to omit them from the model.⁵

The constraints do not destroy the intent or implementation of the model, but limit the degree of detail that can be incorporated.

⁵ H. E. Koenig, M. G. Keeney, and R. Zemach, A Systems Model for Management, Planning and Resource Allocation in Institutions of Higher Education--Final Report Project C-518, National Science Foundation (East Lansing, Michigan: Division of Engineering Research, Michigan State University, 1968), p. 96.

Even with these limitations, the implementation of the model using available data at Michigan State University has been developed to a point of sophistication where it is possible to demonstrate the way that changes in allocation policies are related to the changes in production as required resources.

This development is significant, for if the theoretical model is to have any real value for the educational administrator as an aid in decision making, it must be translated into some mechanism which allows the administrator to manipulate policy changes. The process which allows experimentation in this manner is simulation.

Developing a simulation program for this model involves the establishment of values for the base year of the variables or parameters which are included in the model and assumed to accurately describe the system. These values represent the present condition or state (thus a state model) and operation of the university. It is possible to program a description of the university with these assigned values so as to reflect the operation of the university over time.

Through the efforts of M. G. Keeney and associates, a simulation program (MSUSIM2) has been written which employs a data base for the College of Engineering at Michigan State University. This is the tool used in conducting the experiments in this study. The MSUSIM2 User's Manual is included in Appendix B because it has been written so that a person with limited computer background can design and carry out experiments using this document.

As suggested previously, the policies for the allocation of resources are outputs generated from the administrative control sector. The simulation program has been written to allow the user to experiment with changes in policies or variables, and it then yields information describing the effect on related components within the system.

The simulation program using the engineering data base divides students into eight fields as follows: chemical, civil, mechanical, general, electrical and systems engineering, computer science, metallurgy, with all other fields within the University lumped into the remaining field. Students are also divided according to five levels as follows: freshmen, sophomores, juniors, seniors, and graduates.

By using this program the experimenter is able to change selected parameters, project enrollments, and calculate appropriate demands and costs. Greater detail concerning the specific application of the program will be presented in Chapter V, in the discussion of the experiments designed for purposes of this study.

CHAPTER IV

INPUT FOR THE MODEL

The theoretical model was translated into a working simulation program to provide the tool for conducting experiments to demonstrate the way a university system behaves, through the manipulation of selected parameters. Rather than the arbitrary selection of the parameters to be changed, a method was devised to incorporate the collective judgements of thirteen university administrators. Because the implementations of the model incorporated data addressable to Michigan State University, all of the administrators selected were from that institution. The method used for obtaining information from the administrators was an interview technique.

All thirteen individuals who agreed to be included in the interview group, generally participate in long-range planning as a normal part of their administrative responsibilities. The interview group consisted of one department chairman, one dean, and eleven administrators representing the "central administration" of the University. Individuals from the "central administration" were selected from the offices of the President, Provost, Secretary and Registrar, plus

representatives from the Graduate Office, Business Office, Institutional Research, and Admissions and Scholarships.

The interview guide (Appendix A) served as the means for soliciting responses from the administrators. No attempt was made to explain or interpret the workings of the model to the interview group. The purpose was to obtain input for the simulation program so that the experiments, designed to demonstrate the workings of the model, approached a realistic condition.

General Observations

The interviews yielded a broad range of responses from detailed and specific alternatives to generalized goals and objectives for Michigan State University. The range of response resulted from a combination of three factors that included the nature of the individual administrator, the open-ended structure of the interviews, and the administrative responsibilities associated with each area.

The administrators in the interview group generally interpreted long-range planning and specific aims and objectives to be the seeking of solutions to present day problems. Thus, when asked, "What long range plans have you recently considered regarding the future direction of the University?", a typical response identified a current problem associated with the entire University. Similarly, when the interview group was asked, "What are the aims and objectives of your area which have the highest priority?", a typical response identified a problem associated with a specific administrative unit.

It can also be noted from the other two questions in the interview guide concerning alternatives, that the administrators tended to respond either by outlining a specific plan the individual had considered or a series of questions which needed answers before alternatives could be identified. An example of the specific plan response was a detailed outline of a model academic budget presented by one member of the interview group. An example of a response which suggested questions as alternatives was the following discussion of financial aids for undergraduate students offered by one administrator:

Nearly 43 percent of the freshman class had some kind of financial aid last fall. Should we have an aid quota? With the sliding-scale tuition plan, 65 percent of the freshmen applied for and received a reduction in fees. What should the economic composition of our student body be?

A final general observation was the expressed realization by the administrators of the existence of external and internal pressures which influence planning and decision-making. These factors were most frequently mentioned in association with the development and expansion of various educational programs, the allocation of financial resources, and the control of enrollments. One administrator stated, "Planning at universities may truly result from expedience and opportunism rather than a strong constructive realization of aims and objectives."

Given these general observations it is next appropriate to examine the responses of the administrators according to categories

which were established to offer a structure for reporting the findings. A category was broadly defined as a major grouping of activities that appeared to fall naturally together. Five categories were established to divide the total response of the interview group as follows:

1. Enrollments
2. Finances
3. Academic programs
4. Social concerns
5. Physical facilities

The enrollment category includes interview responses associated with the admission, retention, and characteristics of undergraduate and graduate students, plus the recordkeeping activities associated with students. Finances include the cost of education, the budgeting and recordkeeping activities associated with financing, and the allocation and justification of financial resources. The academic program category includes responses concerning the procurement, retention, qualifications, and evaluation of faculty; the development of innovative educational activities and approaches; and research development for the total University. The social concern category includes those responses generally associated with the role of the University as related to the problems of society. Physical facilities includes the interview responses concerned with the allocation of space, justification for new construction, and the use of existing facilities. The analysis of each of these categories identifies the general and specific responses associated with each area

and the potential appropriateness and application of this information to the theoretical model and the simulation program. The following table gives the number of administrators who provided information, interpreted to be within the five categories.

TABLE 2
INTERVIEW RESPONSES OF 13 ADMINISTRATORS
ACCORDING TO SELECTED CATEGORIES

Category	Number
Enrollment	13
Finances	13
Academic Program	10
Social Concerns	5
Physical Facilities	4

Enrollments

The enrollment category, consisting of interview responses associated with admission, retention, and characteristics of graduate and undergraduate students, plus recordkeeping activities for students, received the greatest attention from the thirteen administrators included in the study. It was perhaps not surprising for administrators concerned with long range planning at an institution which has experienced dramatic enrollment growth in recent years, to express a variety of concerns about the enrollment of students at all levels. The interviews clearly identified the need for greater

control and better projections of enrollments as aids in the management of enrollments.

Control of Enrollments

The control of enrollments was specified as a desirable goal by nearly all administrators included in the study; however, the complexity of exercising controls to accomplish this end was also recognized.

What policies can be developed to control enrollments ?
How can we stabilize enrollments when we can control the number of new freshmen and transfer students, but departments admit graduate students, colleges readmit undergraduates, and sophomores, juniors, and seniors return at their own free choice ?

The administrators responsible for the admission of new students were reluctant to identify a detailed plan for controlling enrollments. However, by "piecing together" a number of comments, it appeared that the number of new freshmen might be reduced from 2-4 percent in future years, accompanied by an increase in the number of transfer students. Several administrators expressed interest in controlling enrollments by admitting students at the undergraduate and graduate levels where there is room because of existing staff, facilities, and financial support. One administrator stated, "Departments must make a decision as to how big they are going to be; quotas to limit enrollment cannot be established by the central administration." No specific plan was offered as to how departments might make this determination but a number of other factors were suggested which contribute to the complexity of controlling enrollments.

The interview group identified a number of internal (within the institution) and external factors associated with the control of enrollments. The internal factors generally included descriptive characteristics pertaining to students and policy decisions which influence enrollments. The external factors were exclusively policy alternatives over which the administrators felt they had little control.

One of the internal factors dealt with the transition of students from one major to another. Some areas on the campus, particularly in the sciences and engineering, were identified as big suppliers to other majors on campus. "We need better information concerning the mobility of students from one department to another," suggested one administrator. Another administrator said, "to admit students where room is available at the undergraduate level, may lead to an overflow of students in other departments after they begin to change majors."

Internal policy decisions which effect enrollments were also discussed by some administrators. Those responsible for the construction on new residence halls expressed the need for and reliance of enrollment projections. These administrators also expressed concern regarding internal policy changes which influence their expected needs:

Based on past experience we have made projections for the construction of residence halls to house new students. Virtually overnight a policy to liberalize requirements to live in these units was adopted. We are faced with the critical decision of whether or not to convert existing residence hall buildings for other purposes or keep the present number of housing

units. We don't have enough experience to determine what might happen.

The grading report, adopted for implementation in Fall, 1968, was suggested as an additional ramification for the control of enrollments. This report, primarily designed to change the system of grading from a letter scale to a numerical scale, also contained a provision calling for the development of a four year academic progress scale. The specific policy provided for the elimination of a 2.00 grade point average requirement for undergraduate students at the time they reached junior standing and substituted a lesser requirement. One administrator suggested that the academic progress scale might enable a greater number of students to remain in school longer and therefore affect class size and teaching loads. The number of services required by students as a result of this policy might also be expanded.

The policy allowing a College or Department to substitute other course requirements for the University College sequence closest to the student's major, offered another example of an internal policy which might affect enrollments. The flexibility for students in the College of Social Science, for example, to waive the University College Social Science series and replace these courses with credits inside or outside the College, might result in substantial changes in selected areas.

External pressures were also identified by the interview group concerning the control of enrollments. The control exercised by the

State Legislature in limiting the number of students from outside the State of Michigan to 20 percent of the entire student population, was suggested as a specific example of an external pressure. A second example was the expressed concern for admitting more black students to the University. A final external control was the concern about the effects of the draft policy on the enrollment of graduate students. As one administrator stated, "it is indeed difficult to determine what effect the present policy of not allowing deferments to graduate students will have on the total enrollment of the graduate school."

Thus, the problem of controlling enrollments was recognized by the interview group as an important ingredient in planning. Enrollment controls were suggested as desirable, but the methods to accomplish this task are complicated by internal and external factors. Present admission policy calls for a reduction in numbers of new freshmen and an increase in new transfer students, but it was suggested that for these enrollment controls to be effective, departmental quotas are needed.

Student Characteristics

A second element included in the enrollment category was the discussion of student characteristics. Those administrators primarily responsible for the admission of students were most concerned about the quality and general composition of the student body. The responses received in this area were largely in the form of questions and reflected a need for greater descriptive information about

enrollments. Some of the specific questions were as follows:

1. "There has been a greater increase in the past two years of the number of females than of males being admitted at the freshmen level. What implications does this have? What does this mean about the image of M.S. U. ? What if we control this to provide a 60-40 ratio of males to females?"
2. "What should the economic composition of our student body be?"
3. "As we move ahead with better quality students, what does this do to marginal admission students?"
4. "What kind of student successfully completes a B.S. degree? Where does he go upon completion of his degree?"
5. "What kind of student body do we want?"

One administrator expressed concern over the increased number of foreign students in certain departments on the campus. It was suggested that the number of graduate students had not declined in those areas but the ratio of American to Foreign students had decreased compared to previous years. A study of successful foreign students was offered as a method of determining what foreign students might be admitted. The same individual recognized the role of the University has played in International Education, but was concerned about the prospects of the State Legislature examining the number of foreign graduate students.

The identification of specific student characteristics was suggested by some administrators as an important element for long range planning. Generally, the major emphasis pertained to the admission of students as alternatives to the composition of the student body.

Student Records

A final element in the enrollment category was the response associated with the recordkeeping activities for students. A centralized recordkeeping system was judged to be desirable by one administrator, but the problem of volume and the demand for services was recognized as follows:

In 1962, there were 27,000 current records for students while in 1967 there were 42,000. The average number of current records per staff member has increased from 386 to 512 during the same period. The demand for services such as providing transcripts has reached a point where 196,231 pages of transcripts were produced in 1967.

Additional demands for services such as the certification of an increasing number of teachers were also suggested as contributing to this problem. The basic concern outlined by the Registrar was how to keep pace with the increased volume and whether or not certain services should be cut out.

The hope for future planning rests in a sophisticated recordkeeping system using an advanced computer system. One of the most promising alternatives suggested was a number of teletypewriters connected to a centralized data system which would provide offices throughout the campus with accurate information about students.

Another administrator expressed interest in the desirability of an automated information system to process changes of major and a general updating of students records as follows:

"The amount of paper work that shuffles in and out of my office pertaining to the enrollment and status of students is ridiculous. Certainly some system could be developed to cut down on this activity."

A final comment concerning the records of students was the recognized need for a common coding system which would unify the recordkeeping procedures for Institutional Research, the Registrar, and the Business Office. One administrator listed several problems connected with the lack of a single system to serve all areas. Apparently the problem has been the failure to designate some office to assume a leadership role in this area.

Those administrators who expressed concerns about students' records were from specific administrative units assigned to carry out those tasks. The problems of volume, complexity, and continuity were generally identified by the group. The solution to the problems appeared to be a uniform centralized information system which would serve all areas of the campus.

Finances

There was considerable discussion by the interview group regarding the justification, allocation, and budgeting of financial resources to support both academic and non-academic functions of the University. Most of the discussions centered around the academic budget since the competition for finances was recognized as an important element in planning as a "means to an end." This point of view was exemplified as follows: "If we are to attract and retain faculty to conduct research and develop quality educational programs, money is an extremely important consideration to carry out this end."

Academic Finances

Concern was expressed by some administrators about the need to justify expenditures to "outsiders" on the basis of something other than enrollment. It was clear from the interviews that in the past Michigan State University has based its justification for appropriations from the State Legislature on an anticipated increase in enrollments. "If enrollments become stablized," as was suggested earlier," then the University must seek ways of communicating the value of quality educational programs at the undergraduate and graduate levels."

Justification for resources was also suggested as an important consideration for areas within the University. This general area was discussed by one administrator as related to the academic budget. "What are we buying for our money in terms of instruction, research, and service?" Further, "What are the meaningful programs in terms of resources and other considerations?" It was pointed out, historically, allocations have been examined over a period of time as related to the number of faculty, students, and graduate programs. This has been done primarily through an examination of load and section size, sometimes resulting in reduced expense through the comparison of costs per student credit hour in relation to full-time equivalent faculty, but not necessarily without some cost in terms of quality.

It was revealed that there has been little attempt to justify departmental budgets. The services and supplies category in the departmental budget was offered as a specific example where there

has been an absence of planning. An alternative to justify departmental expenditures was offered to include the development of a formula for each department based on the number of faculty, faculty efforts, secretarial costs, etc. This would involve the development of staff and instructional needs in relation to costs and would include the development of common criteria to cut across various college lines. The possibility of a model academic budget has been considered to develop averages across departmental lines to include a staff ratio, faculty travel ratio, equipment and supply ratio, which would be aggregated. The ultimate goal would be to produce a realistic and defensible academic budget. If differential treatment were necessary, then this would provide a means of explaining why this might be the case.

Some discussion was focused on the amount of research money that flows into the University. Concern was expressed by some over the prospects of a curtailment of funding in certain areas by the Federal Government. Commitments have been made on the basis that a certain amount of research money would flow in from the outside, but if a serious cut-back occurs the University would have to pick up a greater share of the cost. Some questions were also raised related to research finding:

1. "What is the real commitment by the University when we agree to participate in a matching grant?"
2. "Overhead charges are accepted, but where does the money flow and are these charges realistic?"

3. "What resources and facilities are being provided to support consulting and other outside research efforts?"

A final concern expressed by a few administrators was the increased money needed to attract and hold faculty and graduate students. Financial incentives were recognized as important to the total development of the University.

Non-Academic Finances

The responsibility for the financing and prioritizing of resources for the non-academic area was recognized as clearly in the hands of a few administrators at Michigan State University. Apparently most of the administrators included in this study assumed in their planning that buildings, classrooms, residence halls, laboratories, equipment, and other auxiliary facilities and supportive programs would be available.

Two administrators identified a number of financial problems associated with non-academic financing, but no clear alternatives. Foremost in the minds of these people were the rising costs of labor, primarily for maintenance, service, and construction. An example of this concern was the following:

"A need is determined for a building and a dollar value is placed on it. Long before working drawings are prepared and the plans are finalized, the cost may increase nearly 20%. As the bids are finally let for the actual construction the building cost may have increased as high as an additional 20%."

A need was expressed to justify expenditures for non-academic areas to external sources. Externally, the importance of justifying needed construction projects to the State Legislature and outside agencies was offered as an important element for planning. A need was expressed for all types of information to support requests for construction. As one administrator noted, "It is of paramount importance that we build a careful case for new construction because legislators are extremely sensitive to buildings that always visually remind them of expenditures they have allocated."

Academic Program

Academic programs were discussed by ten administrators and contained a great deal of overlap with the other categories. The elements included in this section were those pertaining to faculty, new educational approaches, and research development for the entire University.

Faculty

Several administrators suggested that the faculty is a very important ingredient in long range planning. There was a great deal of interest in attempting a variety of approaches to obtain quality faculty. The basic suggestion was more money, but secretarial and research support were also mentioned as important factors not only to attract faculty, but retain them as well. One administrator asked, "What are the implications of faculty mobility? Where do faculty members go and do they leave for more money, or other reasons?"

It was suggested that faculty needed to be evaluated critically, particularly in their early years. One member of the interview group noted that each position should be treated as "sacred" and the individual in that spot be evaluated critically.

Innovative Educational Activities and Programs

The major interest concerning educational activities and programs was the evaluation of existing approaches and the development of new ones. Specifically, it was suggested that the new Residential Colleges needed to be evaluated to determine whether this movement should be expanded, disregarded, or continued. It was recognized that these Colleges were established as experimental but there has been little evidence to date of evaluation. Related to this concern was the question as to whether Michigan State should attempt to organize more diversified colleges such as an Antioch or an "Ivy League" selective college approach.

There was considerable interest in the development of innovative teaching methods. It was suggested that little is being done with computer-assisted instruction and other innovative techniques which many public schools have attempted. Broadly, one administrator stated, "Are there alternatives to the lecture method of instruction?" The use of graduate assistants was applauded by one administrator and criticized by another. The general need for in-service training for the new instructor was emphasized as a possibility for upgrading teaching.

The need was suggested for flexible curriculums cutting across traditional departmental lines that would allow students the opportunity to be free to choose, with proper direction, the courses and competencies they desired to achieve. Experimentation with curricular offerings, grades, independent study, etc., coupled with proper evaluation was suggested as an important alternative to present practice.

One administrator inquired about the development of new programs and the elimination of others.

"Is M. S. U. a complete University? What fields are we not covering that have appreciable enrollment at other institutions? Are these areas we are missing? Are there areas in the University we should get rid of based on enrollments, research, and other activities?"

The development of new programs, the strengthening of existing programs, and the abandonment or reduction of others were mentioned. It was generally agreed that one of the most important areas that should be strengthened was the graduate school. It was noted that Michigan State has reached a high point in the development of undergraduate education, but a genuine effort to improve all phases of the graduate school was needed. One administrator noted the need to analyze the emphasis on agriculture with the hope that it would be brought into a realistic perspective with the rest of the University.

Social Concerns

Social concerns refer to requirements of the University to be sensitive to societal needs in planning for present and future direction. The greatest attention was directed toward minority groups, but concern with student dissatisfaction was also identified.

The need for a variety of equal opportunity programs on the campus was identified as an important first step. The following definition of equal opportunity programs was offered:

Equal opportunity programs are those directed at assuring non-discriminatory access of minority representatives to the student body, administrative staff, teaching faculty, and supporting staff of this University. Equal opportunity programs should be further concerned with the articulation of policies and the inauguration of projects that establish a body of legalistic and quasi-legalistic statements against which equal opportunity issues can be analyzed and judged, and which will preclude Michigan State University support of discriminatory practices by organizations and individuals doing business with the University, its students and employees.

A number of objectives were identified by some administrators within the framework of the above definition which included: an increase in the number of entering and graduating undergraduate and graduate minority students; an increase in the proportion of minority faculty members, administrators, and staff and supportive personnel; and the development and enforcement of regulations against discriminatory practices in University involvements.

The four recommendations for curricula, research, community action, and experimental functions, outlined by the committee of sixteen at Michigan State University, were identified by one member of

the study as important areas for social concern. Some of the objectives in these four areas were as follows: the coordinated development of socially relevant curricula; the need to conduct and coordinate urban related research; the development and coordination of degree programs in Afro-American Studies and urban affairs; the initiation and coordination of University participation in community action programs; and the dissemination of research findings and other information.

A second element in the social concern category was the discussion of student unrest. Three administrators indicated that future planning should include provision for the orderly involvement of students in the affairs of the University. One administrator pointed to the "Academic Freedom Report" as an important guide and foundation block. "If procedures and policies need revision, the mechanism is provided for in that document." It was emphasized that students are concerned about the excellence of teaching, courses that are relevant to the problems of society, and programs where they can be actively involved in assisting others. The direction that student dissatisfaction will take in the future, was identified as an unknown quantity. One administrator summarized the problem as follows, "I am not willing to turn over the reins of leadership to students, but I welcome the opportunity to listen and to establish mechanisms and procedures for their participation."

Physical Facilities

The finance category included a discussion of the financial consideration and justification for the construction of new facilities. In addition to the problem of financing, some administrators, responsible for specific administrative areas, identified problems and alternatives associated with the use and allocation of existing facilities.

Present policy identifies classroom space as belonging to the University. Departmental offices, laboratories, libraries, and special space needs belong to the University, but are assigned and designated to certain areas.

The problems associated with classroom scheduling are largely due to the increase in the number of large sections. As enrollments have expanded one of the most common ways to handle this growth has been by increasing class size. The need for large classrooms at popular times during any given term was identified as critical. During Fall term the demands for classrooms peak because enrollments and course offerings are the highest. A 50 percent classroom utilization figure is judged to be nearly optimal. (This percentage is obtained by assuming that a classroom will be used every day, during all periods between 8:00 a.m. and 5:00 p.m., five days per week.)

Alternatives to reduce the use of space included greater controls for forcing departments to spread out course offerings throughout the day; a better use of classroom facilities at night;

and greater imagination for the scheduling of courses at times other than normal patterns. (For example, the question was raised, "Why must nearly all three credit courses be offered on Monday, Wednesday, and Friday?")

The increase in the number of graduate students and faculty has also presented critical space problems. Classrooms can be moved throughout the campus, but departments do not want their faculty to be split into small divisions at various locations. The office space problem is further complicated by differences that exist between departments and colleges. In some departments graduate students may have private offices, while in others professors may share a common facility.

Alternatives for the use of office space were; the grouping of graduate students together in large "bull-pen" type areas, the elimination of two offices for faculty on dual appointments, and greater uniform policies for the assignment of office space which cut across departmental lines.

Research grants calling for the development of specialized equipment and facilities often cause space problems. The contract may be written, but space considerations for the development of hardware may be a minor consideration. A similar problem was suggested for the development of new programs. If new programs and activities are established and grow, too often space facilities are needed as a result of this expansion. It was suggested that space considerations are not generally involved in the original planning and become important at a later date. Departments and administrative areas are

reluctant to release space once it has been assigned. The end result may be the development of new construction when consolidation may have provided wiser alternatives.

Analysis of the Interview Input as Related to the Model

The interview results generally revealed a range of problems associated with present University policies and practices. It was clear that several administrative units in the University have independently considered future planning, but not within a centralized framework or strategy for development. There was little evidence reported, for example, that much centralized direction has been given to the problem of control of enrollments, even though this concern was identified by all administrators as a critical problem.

The administrators expressed a desire for more descriptive information as an aid in planning. The discussions of the characteristics and transitions of students, and the distribution of finances exemplify this generalized conclusion.

The significance of enrollments and the importance of finances were recognized by all administrators as critical elements in planning. The administrators tended to discuss these as interrelated factors whether they had concerns about the quality of faculty, the development of innovative programs, the construction of physical facilities, or other concerns about the University.

There was concern expressed by administrators that policy decisions have been made in isolation without an awareness of other

areas on campus. The reduction of requirements for living in residence halls, the redistribution of student credit hours, and the change in academic standards were suggested as specific examples of isolated policy decisions.

The need for evaluation of existing programs and personnel was suggested as an important need by administrators. The evaluation of faculty, curricula, social needs, and educational programs and approaches were some of the identified concerns in this area.

Three of the four generalized concerns identified by the administrators are judged to be directly addressable to the specific model employed in this study. The need for more information can be approached by using the model as a descriptive tool; the inter-relationship of enrollments and finances, and the problem of isolated decisions can be approached by using the model as an aid in examining the effects of alternative policies. The need for evaluation of existing programs and personnel would require greater refinement before these questions are directly addressable to this specific model. As emphasized in Chapter III, the model used in this study is limited to those aspects of the educational system that can be measured. As a result, many problems related to broad goals and objectives would need further clarification in order to be addressable to the model. The less tangible aspects of the educational system that influence decisions, such as social concerns and political influences, are not directly included in the model. This type of influence must be translated into some tangible measure.

An adequate and accurate data base enables the administrator to obtain information about the present operations of the University. Because each sector in the model has been modeled as an independent system and these sub-systems interconnected to form the total system, it is possible for the administrator to examine a particular segment of the system. For example, it is possible to examine the number of new students, the transition of students, the cost of faculty by rank, the faculty effort for teaching, the cost of equipment and/or supplies and services, or the number of credit hours produced, etc., all of these yield descriptive information which the administrator may desire to have about the present operation of the university. A great deal of this information is available in the present model and the capability to enlarge the data base is present. Expanding the data base of the model is obviously contingent upon the availability of information and the capability to categorize it in quantitative units.

The transition of students from one area to another was identified as a specific concern by one administrator in the interviews and this information is directly available in the present model. Depending upon the specifications of the administrator, it would be possible to expand the data base to include additional student characteristics which were suggested in the interviews. For example, the identification of students by sex, race, economic backgrounds, and geographical locations are not included in the present model, but could be included.

Thus, the concern by the interview group for more descriptive information can be approached by the use of the model as a descriptive tool. This is the simplest use of the model because the segments of the model are examined in isolation and not as they interact with the rest of the system.

The Model as an Aid to Examining Alternatives

Several alternatives to present University practices and policies were suggested in the interviews. While it is not the intent to examine how each alternative might be answered by the model, two examples have been selected to illustrate the use of the model in this manner. Again, it must be emphasized that the alternatives must be reduced to measurable quantities.

One administrator suggested that the graduate school should be expanded. To consider this alternative a number of questions need answers:

1. What areas will the new students enter ?
2. Will this increase require additional faculty ?
3. Will the students receive graduate assistantships ?
4. What kinds of demands will they place on the entire university for courses, equipment, space, and services ?
5. If these students are graduate assistants will they provide a source of manpower for teaching undergraduates ?
6. Will any of these students be working on research projects ? If so, can research projects help to carry the financial load ?

7. Where will these students live? Will they create increased demands for married housing or graduate dormitories?

These questions could be carried further, but they do illustrate the interrelationship between enrollment, costs, faculty effort, and physical facilities, which is one intent of the model in this study.

To the extent that the data base and the interrelationships expressed in the simulation are realistic, the administrator can experiment with alternatives to existing conditions.

A second example is the concern about policies being developed in isolation. Specifically, the question of the redistribution of course hours because students are no longer required to take the University College sequence in social science, can be examined. Again, a number of questions surround the policy change:

1. What will be the reduction in the faculty effort for teaching in the Department of Social Science as a result of the policy change?
2. Will the faculty members be available to do other activities in the department or shifted to new areas?
3. What is the associated cost of this shift?
4. Will new faculty positions be available to the areas receiving the students?

This example suggests that policy decisions affect the operation of the entire university. The model can be used as a tool to examine policy alternatives before they are enacted, by using simulation.

The process of simulation requires the development of a series of computer programs to establish a data base and carry out the computations which represent interactions of the sectors of the model.

A simulation program has been developed using the College of Engineering as an example of how policy alternatives affect the operation of the system. Experiments have been designed to demonstrate how the system behaves when subjected to changes in present policy. The experiments and the resultant interactions are reported in Chapter V.

CHAPTER V

ANALYSIS OF THE EXPERIMENTS

The analysis of the interview data plus the intent to communicate the use of the model, led to the design of seven experiments to demonstrate the use of a simulation model as a potential aid for educational decision-makers.

Due to the concern by administrators in the interview group regarding the management and control of enrollments, four experiments were designed to simulate the magnitude of changes and the sensitivity of the system to the admission of new students. Two specific enrollment changes were identified by administrators as possible alternatives for the future direction of Michigan State University. A trend was identified to increase the number of transfer students admitted at the upper levels to the University. The expansion of the number of community colleges in the State of Michigan was suggested as the basic reason for this projected increase. Therefore, experiments I and II were designed to reflect varying percentage increases in the number of new sophomores, juniors, and seniors admitted to Michigan State University. Transfer students from other institutions are not specifically identified

in the simulation model used in this study; the new student category in the model includes transfer students and students readmitted to the University. Because transfer students comprise the largest number in the new student category, it was expanded.

Administrators also expressed considerable interest in limiting the number of new freshmen admitted to the system. The rationale for this judgement was generally that quality should be emphasized at the first year level and one of the means to insure quality was to establish selective admission policies.

Thus, experiments I, II, III, and IV reflect the response of the system to increases in the number of sophomores, juniors, and seniors, and decreases in the number of freshmen admitted as new students.

The concern by the administrators about the effects of changes in graduation requirements for students in one area on supporting departments, provided the background for experiment V. Administrators in the interview group indicated that policies of this type were often made in isolation. The design of experiment V was an attempt to show the effects on the system due to a change in the curriculum for students in a representative department.

The remaining experiments were included to demonstrate the working of the simulation model and to emphasize the notion that decisions are rarely made independent of one another. Experiment VI combined the effects of the policy changes incorporated in

experiments I and III. The intent of this experiment was to demonstrate the effects of two policy changes operating at the same time. It was primarily related to financial considerations because of the reactions by the administrators regarding the importance of the allocation of resources.

Four simulated policy changes were made simultaneously in experiment VII. The purpose of this experiment was to illustrate a more realistic situation where several changes are operating at one time. The complexity of the interaction of the changes result from differing time constants and unclear relationships between effects that augment or cancel one another. Calculating the net change on the entire system is so complex that a computer is required if the interactions are to be evaluated in a reasonable amount of time for a variety of conditions. In particular, an illustration of the effect of a decrease in freshmen enrollments, an increase in the number of new students at the upper levels, an increase in salaries and projected costs, and curriculum changes in one department, in combination, was exhibited for the College of Engineering.

The College of Engineering is the basic administrative unit used to demonstrate the workings of the simulation model. However, in selected instances, it is possible to demonstrate the relationship of the College to the rest of the University. The extent to which this type of detail can be examined is directly dependent upon the information detail incorporated in the simulation program. Only

enrollment information is included for the entire University in the simulation program used in this study, while additional detail from other sectors is incorporated for the College of Engineering. This is because student records are available and computer addressable for the entire University, but cost information and faculty records are generally not accessible in this form and so were calculated for only one College.

The presentation of the experiments in this section represent a gradual movement from the simple to the complex through the manipulation of selected parameters in the simulation program. The suggested policy changes by the administrators become the parameter changes in the administrative sector when applied to the simulation model. Experiments I, II, III, IV, and V present a single parameter change where the results of the manipulation are clearly visible and can be traced directly to the change. The discussion of experiment I is presented in greater detail than the rest of the experiments because of the necessity to clarify terminology and show the step by step procedures carried out by the simulation program. Experiment VI reflects two parameter changes where the alterations are visible, but the identification of the changes result from the interactions of two variables instead of one. Experiment VII demonstrates the resulting interactions of four parameter changes and exemplifies the complexity of a University system.

Before examining the experiments, it is important to introduce two concepts which underlie experimentation with the simulation

model. The consistency of the data in the simulation program used in this study has been tested and carried out to a point in time where the calculations performed in the program do not alter the numbers or the results.¹ This status is identified as the steady state condition and serves as the base year of the simulation model. The base year, labeled 1967, represents conditions prior to the introduction of any parameter changes. It is not practical to display all the base year information supplied by the simulation program because of the detail incorporated in the model. Instead, only the base year quantities are presented which are pertinent to the experiments conducted in this study.

It is important in these experiments to emphasize that the actual numbers are not to be interpreted too literally because the available records were not necessarily coordinated but trends and orders of magnitude do approximate realistic conditions.

Experiment I

The interviews with administrators at Michigan State University revealed an interest in expanding the number of transfer students from community colleges in the State by 25-33 percent. As explained earlier, it is not possible to single out transfer students

¹ Documented on October 20, 1968 by the creation of Data File 6. Data File 5 in the simulation program was projected 10 years to a point where the data base did not change.

in this particular program, but the number of new students admitted to the University can be changed. Therefore, experiment I considers the following questions: What are the implications of a 25 percent increase in the number of new sophomores, juniors, and seniors admitted to Michigan State University? How many additional student credit hours will be produced? What are the associated costs, enrollments, faculty additions, and student credit hours for the College of Engineering as a result of this increase?

The answers to these questions can be displayed by a comparison between quantities which result from present administrative policy and the quantities which result from a simulated policy change which alters the number of new students. New students are defined as those students new to the University for a given year and includes freshmen, transfer, graduate, and all readmitted students.

Table 3 presents the changes in enrollments as a result of a simulated increase of 25 percent in the number of new sophomore, junior, and senior students admitted to the College of Engineering. The number of new students and the total number of students by class levels are identified. It is significant to note that the enrollment figures at the freshman level do not change because the new administrative policy affects only three class levels.

The base year (1967) shows 129 new students presently being admitted at the sophomore, junior, and senior levels. A change in that policy is introduced which allows an additional 32

TABLE 3
SIMULATED ENROLLMENT INCREASES 1967-1971
COLLEGE OF ENGINEERING
EXPERIMENT I

	Freshmen	Sophomores	Juniors	Seniors	Grads	Total
<u>1967</u>						
New Students	672	35	80	14	106	907
Total Students	687	382	310	343	287	2009
<u>1968</u>						
New Students	672	43	101	17	106	939
Total Students	687	390	331	346	287	2041
<u>1969</u>						
New Students	672	43	101	17	106	939
Total Students	687	392	337	361	287	2064
<u>1970</u>						
New Students	672	43	101	17	106	939
Total Students	687	392	337	371	288	2075
<u>1971</u>						
New Students	672	43	101	17	106	939
Total Students	687	392	337	373	291	2080

new students to be admitted to the system. The changes can be observed by increases in the new students, at the three middle levels, and the total number of students for the year 1968. The enrollment data reported for 1968 reflect the new policy.

The movement of the students through the system for subsequent years is also evidenced in Table 3, but the effects cannot be isolated. For example, the increase in the number of juniors in

1968 ($331 - 310 = 21$) partially accounts for the increase in the number of seniors in 1969; however, the increase may also partially account for the increase in juniors in 1969 because some may be retained at the same level.

The increase in graduate students which first appears in 1970 and again in 1971, demonstrates two factors which contribute to the growth of graduate enrollments. First, the undergraduate enrollment increases create demands for graduate assistants who are used in instruction; second, an increase in undergraduate enrollments produces students who continue in the College of Engineering upon completion of the B.S. degree. The effects of the new policy are virtually stabilized by 1971, for only the total enrollment at the senior and graduate levels increased slightly over 1970. It can be noted that the aggregated enrollment effects would produce a total of ($2080 - 2009 = 71$) additional students three years following the initiation of the new policy.

It is also possible to observe similar effects for the rest of the University by an examination of the data reported in Table 4. As a result of the policy change introduced in 1968, a total of ($14,107 - 13,403 = 704$) additional students are initially admitted to the University. The comparable figure for the College of Engineering is 32. The enrollment increases resulting from the policy change do not stabilize as quickly as reported for the College of Engineering. For example, 62 more seniors appear in 1971 than were present in 1970. In spite of this limitation it is possible to state that the system has

returned to a relatively stable condition. A comparison between the total enrollment in 1967 and 1971 shows the net effects of the change in enrollment policy. The total enrollment in 1971 is 1,539 students higher than the figure reported for 1967. The effect of an increase in undergraduate enrollment over graduate enrollment is evidenced earlier in Table 4 than in Table 3. The need for 10 graduate assistants to teach the additional undergraduate students accounts for the increase in graduate enrollments for 1969. The additional increases in graduate enrollments can be observed in the remaining two years.

The enrollment increases produce greater demands for services and instruction which results in greater costs. Examples of the effects of enrollment increases in instruction are the increases in the number of faculty and student credit hours.

Student credit hours are determined by multiplying the number of students enrolled in a particular course by the credit weight assigned to each course. Thus, a 3 credit course with an enrollment of 30 students yields a total of 90 student credit hours. Table 5 shows the increase in the number of student credit hours, by levels, resulting from the simulated enrollment increase. The five levels associated with student credit hours are different than the enrollment levels for students. The following shows the grouping of courses used to determine the level of student credit hours:

TABLE 4
SIMULATED UNIVERSITY ENROLLMENT INCREASES 1967-1971
(NOT ENGINEERING)
EXPERIMENT I

	Freshmen	Sophomores	Juniors	Seniors	Grads	Totals
<u>1967</u>						
New Students	7,438	783	1,432	599	3,151	13,403
Total Students	7,812	6,615	6,549	7,757	7,564	36,297
<u>1968</u>						
New Students	7,438	979	1,790	749	3,151	14,107
Total Students	7,812	6,811	6,907	7,907	7,564	37,001
<u>1969</u>						
New Students	7,438	979	1,790	749	3,151	14,107
Total Students	7,812	6,825	7,066	8,222	7,574	37,499
<u>1970</u>						
New Students	7,438	979	1,790	749	3,151	14,107
Total Students	7,812	6,828	7,087	8,416	7,602	37,745
<u>1971</u>						
New Students	7,438	979	1,790	749	3,151	14,107
Total Students	7,812	6,828	7,090	8,478	7,628	37,836

Courses numbered:

100 - 199
200 - 299
300 - 399
400 - 499
800 - 999

Level

Freshmen
Sophomore
Junior
Senior
Graduate

Students at all enrollment levels register for a variety of courses with designated course levels. It is not uncommon for some graduate programs to require collateral work in 400 (senior) level courses.

The increase in the number of student credit hours at the freshmen level reported in Table 5, offers an appropriate example. Even though the policy change to increase enrollment did not involve freshmen students, the student credit hours required at the freshmen level increases. The admission of new students at some levels, then, may create needs in the total system for the production of greater numbers of student credit hours at all levels.

Three years following the initial policy change (1971), the net effect for the College of Engineering is that an additional (13, 049-12, 321 = 728) student credit hours would be needed. It is important to emphasize that the majority of the demand would come from within the College, but increased demand from areas outside the College could also contribute. The net effect for the remainder of the University during this same period would be the production of 22, 226 additional student credit hours.

In addition to student credit hours, the effects of the enrollment increase on instruction can be identified with the need for additional faculty. The simulation program has the capability to calculate faculty and graduate assistant needs for all departments in the College of Engineering from student credit hour demands. The changes in faculty and graduate assistant needs from 1967-1970 are shown in Table 6. The increase column refers to the differences between faculty and graduate assistant needs in 1967 and those that would be required in 1970.

TABLE 5
STUDENT CREDIT HOUR INCREASES 1967-1971
EXPERIMENT I

	Fresh- men	Sopho- mores	Juniors	Seniors	Grads	Totals
<u>1967</u>						
Engineering	2,236	2,060	3,318	2,835	1,872	12,321
Not Engineering	138,916	142,960	84,732	51,589	51,589	497,394
<u>1968</u>						
Engineering	2,277	2,142	3,380	2,874	1,872	12,545
Not Engineering	140,514	147,278	87,563	80,999	51,624	507,978
<u>1969</u>						
Engineering	2,299	2,181	3,541	2,995	1,878	12,894
Not Engineering	141,254	148,972	89,879	83,237	51,755	515,097
<u>1970</u>						
Engineering	2,308	2,192	3,564	3,057	1,890	13,011
Not Engineering	141,541	149,531	90,915	84,472	51,968	518,427
<u>1971</u>						
Engineering	2,311	2,197	3,571	3,073	1,897	13,049
Not Engineering	141,638	149,706	91,233	84,888	52,155	519,620

TABLE 6

INCREASES IN FACULTY AND GRADUATE ASSISTANT
REQUIREMENTS FOR ENGINEERING DEPARTMENTS 1967-1970^b
EXPERIMENT I

	1967	1968	1969	1970	Increase
<u>Chem. Engr.</u>					
Faculty	7.2	7.2	7.3	7.3	.1
Grad. Asst.	2.5	2.5	2.6	2.6	.1
<u>Civil Engr.</u>					
Faculty	8.9	9.0	9.1	9.2	.3
Grad. Asst.	9.0	9.3	9.5	9.7	.7
<u>Mech. Engr.</u>					
Faculty	14.6	14.9	15.2	15.4	.8
Grad. Asst.	13.4	13.8	14.3	14.4	1.0
<u>Gen. Engr.</u>					
Faculty	5.8	5.9	6.0	6.0	.2
Grad. Asst.	1.9	2.0	2.0	2.0	.1
<u>Elec. Engr.</u>					
Faculty	19.3	19.6	20.0	20.2	.9
Grad. Asst.	24.9	25.8	26.6	27.0	2.1
<u>M. M. M.^a</u>					
Faculty	14.5	14.8	14.9	15.0	.5
Grad. Asst.	11.4	11.9	12.2	12.3	.9
<u>Computer Sci.</u>					
Faculty	10.9	11.1	11.3	11.3	.4
Grad. Asst.	5.4	5.5	5.6	5.6	.2

^a M. M. M. refers to the Department of Metallurgy, Mechanics, and Materials Science.

^b The figures are expressed in terms of full-time-equivalent faculty.

The collective faculty and graduate assistant needs of the College of Engineering provide a means of comparison with other data expressed in experiment I. The aggregated need for the College would be an additional 3.2 full-time-equivalent faculty members and 5.1 graduate assistants. It is questionable, however, particularly for faculty members, that the total College needs could be met in this aggregated manner. It is more realistic to observe that mechanical and electrical engineering by 1970 would be approaching the point where an additional faculty member would be needed. A similar observation can be made with reference to graduate assistants, but a part-time graduate assistant is a more realistic consideration than a part-time faculty member.

An examination of the effects of the simulated enrollment increase on costs is the next step in analysis. No cost data is available for the entire University, but detailed cost information is available for all departments in the College of Engineering. No changes in cost parameters have been introduced in this experiment, therefore, the changes in costs are a result of the interactions among the enrollments resulting from the policy change. It is possible to examine the changes in total costs for the College of Engineering from 1967-1970, as presented in Table 7. Numerous calculations are performed in the computer program to reach the total distributions reported in this table. Total Undergraduate Costs includes the cost of undergraduate instruction by faculty and graduate assistants and the

TABLE 7
 INCREASES IN TOTAL COSTS - COLLEGE OF ENGINEERING
 1967-1970
 (IN DOLLARS)
 EXPERIMENT I

	1967	1968	1969	1970	Increases
Total Undergraduate Costs	\$ 841,263	\$ 863,519	\$ 882,572	\$ 890,328	\$49,065
Total Graduate Costs	306,408	306,965	308,197	309,738	3,330
Total Thesis & Research Costs	355,658	355,648	355,699	355,921	263
Total Costs, Other Activities	159,112	161,611	163,722	164,763	5,651
Total Costs	\$1,662,441	\$1,687,743	\$1,710,190	\$1,720,750	\$58,309

equipment and supplies required to carry out that instruction. Total Graduate Costs includes the cost of instruction by faculty and the equipment and supplies required to carry out that instruction. Total Thesis and Research Costs includes the faculty and graduate research assistants, equipment and supplies required to conduct research and direct dissertations. Total Costs, Other Activities includes secretarial services, special equipment and supportive services which cannot be directly attributed to any of the other categories.

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The greatest increase in costs during the three year period is logically in Total Undergraduate Costs. The Total Costs of \$58,309 represent the net effects of the enrollment policy change after three years.

Thus, Experiment I shows the net effects of introducing a single parameter change. The 25 percent increase in the number of new students produced enrollment changes for the College of Engineering and the remainder of the University. The new students create demands for the production of additional student credit hours, and faculty and graduate assistants to carry out that instruction. Finally, the effects of the increases are translated into the total dollar costs, illustrated by using the College of Engineering as an example.

Experiment II

Experiment II is designed to show a different magnitude of the enrollment policy change introduced in experiment I. The only difference between experiment I and II is that the simulated percentage increase in the number of new sophomore, junior, and senior students admitted to the University is 33 percent instead of 25 percent.

It is possible to develop user confidence in the model in that calculations can be manually carried out from the results of experiment I. Table 8 shows the enrollment comparisons for the differences between the two experiments. Thus, $\frac{33}{25} = 1.333$ which is the ratio between the 33 and 25 percent enrollment changes. If a 25 percent increase causes a change of $(939-907 = 32)$ additional new students,

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Experiment II

Experiment II is designed to show a different magnitude of the enrollment policy change introduced in experiment I. The only difference between experiment I and II is that the simulated percentage increase in the number of new sophomore, junior, and senior students admitted to the University is 33 percent instead of 25 percent.

It is possible to develop user confidence in the model in that calculations can be manually carried out from the results of experiment I. Table 8 shows the enrollment comparisons for the differences between the two experiments. Thus, $\frac{33}{25} = 1.333$ which is the ratio between the 33 and 25 percent enrollment changes. If a 25 percent increase causes a change of $(939-907 = 32)$ additional new students,

TABLE 8
NET EFFECTS ON ENROLLMENT FOR ENGINEERING
AND THE REMAINDER OF THE UNIVERSITY
RESULTING FROM TWO PARAMETER CHANGES
EXPERIMENT II

	1967	1968		1969		Difference	
		25 percent	33 percent	25 percent	33 percent	25 percent	33 percent
New Students- Engr.	907	939	950	939	950	+32	+43
Total Students- Engr.	2,009	2,041	2,052	2,080	2,103	+71	+94
New Students- Non Engr.	13,403	14,107	14,341	14,107	14,341	+704	+938
Total Students- Non Engr.	36,297	37,001	37,135	37,836	38,356	+1,539	+2,059

then the expected number of new students according to the 33 percent increase should be $(1.33 \times 32 = 43)$. As recorded in Table 8, the increase is $(950 - 907 = 43)$. Similar calculations can be made with reference to Tables 9 and 10.

Table 9 reports an increase of $(13,049 - 12,321 = 728)$ additional student credit hours as a result of the 25 percent enrollment change. The expected number of student credit hours for a 33 percent change would be $(1.333 \times 728 = 970)$. The increase reported in Table 9 for the 33 percent change is $(13,294 - 12,321 = 973)$. Table 10 presents the differences between the 25 and 33 percent enrollment increase for the College of Engineering as they apply to teaching

TABLE 9
DIFFERENCES IN THE PRODUCTION OF STUDENT CREDIT
HOURS FOR ENGINEERING AND THE REMAINDER OF
THE UNIVERSITY AS A RESULT OF TWO
PARAMETER CHANGES
EXPERIMENT II

	1967	1968		1971		Difference	
		25 percent	33 percent	25 percent	33 percent	25 percent	33 percent
Engr.	12, 321	12, 545	12, 737	13, 049	13, 294	728	973
Non Engr.	497, 394	507, 178	511, 506	519, 620	527, 032	22, 226	29, 638

TABLE 10
DIFFERENCES IN FACULTY INCREASES AND GRADUATE
ASSISTANTS FOR ENGINEERING AS A RESULT OF
TWO PARAMETER CHANGES^a

	1967	1968		1970		Difference	
		25 percent	33 percent	25 percent	33 percent	25 percent	33 percent
Engr. Faculty	81.2	82.5	84.7	84.4	85.5	3.2	4.3
Grad. Asst.	68.5	70.8	74.3	73.6	75.5	5.1	7.0

^aExpressed in full-time-equivalent faculty

requirements. The 25 percent enrollment change shows the difference to be $(84.4 - 81.2 = 3.2)$ additional engineering faculty members. The expected number of engineering faculty members for a 33 percent enrollment increase would be $(1.333 \times 3.2 = 4.3)$. The difference noted in Table 10 is $(85.5 - 81.2 = 4.3)$.

It would now be possible to manually calculate the change in any of the tables for any percentage change simply by the ratio $\frac{a}{25} \times (\text{change due to } 25\%)$. This is due to the linearity of the relationships used in the model. This means a model is probably valid over only a limited range because actual relationships are non-linear. If other (non-linear) relationships were incorporated in the model, this simple linear relationship would not hold.

The illustrations show that the model does give expected answers which are easy to verify for this simple change. Later, more complex changes are made which are not easy to verify manually. It points to one advantage of simulation, that is, it allows a large amount of calculations to be carried out more rapidly and accurately than can be done manually.

Experiments III and IV

Experiments III and IV are designed to simulate reductions in the number of freshmen admitted to the University. The members of the interview group expressed interest in reducing the number of students admitted at this level in an effort to increase the quality

of students attracted to Michigan State University. It is not possible to simulate possible quality changes in the nature of the first year population, but it is possible to reduce the number of new students admitted at this level.

In particular, experiments III and IV are concerned with the changes in dollar costs resulting from two and four percent reductions in the number of new freshmen admitted to Michigan State University. Cost variations in the College of Engineering due to the enrollment change are studied. Experiment III provides for a two percent reduction in the number of new freshmen admitted to the system while in experiment IV a four percent reduction is simulated. The results of the two experiments are presented together for comparison of the two alternatives.

It is important to emphasize that no other parameter changes such as faculty salary or load adjustment are introduced. The cost differentials can only be attributed to the reduction in the number of new freshmen. The primary purpose of this experiment is to examine cost information; however, it is important, for background information, to show the effects of the policy change on enrollments. Instead of a detailed presentation of enrollment changes by year and level, only the total enrollment change is presented in Table 11.

The net change in enrollments by 1971 would result in 29 fewer engineering students and 420 fewer non-engineering students in the system due to the two percent reduction would be double these figures, or 58 fewer engineers and 839 fewer students in the rest of the University.

TABLE 11

TOTAL ENROLLMENT CHANGE FOR THE COLLEGE OF
ENGINEERING AND THE REMAINDER OF THE
UNIVERSITY RESULTING FROM A REDUCTION
IN THE NUMBER OF NEW FRESHMEN

	1967	1968		1971		Change	
		2 percent	4 percent	2 percent	4 percent	2 percent	4 percent
Total Students- Engr.	2,009	1,994	1,980	1,980	1,951	-29	-58
Total Students- Non Engr.	36,297	36,149	36,001	35,877	35,458	-420	-839

Table 12 presents the computation of the freshmen enrollment reductions into cost information for the College of Engineering. The differences in costs are caused by the two percent and four percent reductions in freshmen enrollment for the period 1967-1970.

The slight reduction in costs during 1968 shows the limited number of freshmen who take courses in the College of Engineering. The largest producer of freshmen credit hours for engineering students is the computer science area and nearly all decreases for the College occur there. A larger reduction in costs begins to appear in 1970 because engineering students have completed the first full year of engineering courses. The full effects of the enrollment change on costs would not appear until 1971. The significance here is not so much the actual numbers, but the trends and the cost areas that would be reduced by the enrollment change.

TABLE 12

COMPARATIVE COST REDUCTIONS FOR THE COLLEGE OF ENGINEERING

ACCORDING TO TWO PERCENT AND FOUR PERCENT

DECREASES IN FRESHMAN ENROLLMENTS 1967-1970

(IN DOLLARS)

	1967	1968		1969		1970		Net Difference	
		2 percent	4 percent	2 percent	4 percent	2 percent	4 percent	2 percent	4 percent
Total Undergraduate Costs	\$ 841,263	840,337	839,414	838,498	835,739	835,372	829,491	\$-5,891	\$-11,772
Total Graduate Costs	306,408	306,309	306,238	306,225	306,084	306,116	305,872	-292	536
Total Thesis & Research Costs	355,658	355,658	355,658	355,639	355,630	355,631	355,617	-27	-41
Total Costs (Other Activities)	159,292	159,197	159,108	159,003	158,721	158,669	158,057	-623	-1,235
Total Costs	\$1,662,621	1,661,501	1,660,418	1,659,365	1,656,174	1,655,788	1,649,037	\$-6,833	\$-13,584

The reduction in total undergraduate costs is the largest cost difference between present policy and simulated change in enrollment policy. The largest factor contributing to the reduction in this category is the decrease in faculty required to teach fewer students. Total graduate costs show a slight reduction because fewer graduate assistants would be needed to teach undergraduates and this reduction in turn results in a reduced demand for graduate instruction. The decrease in total costs for other activities is because of reduced requirements for supportive services at the undergraduate level. The net difference column in Table 12 shows the cost reductions due to each of the parameter changes as compared to the continuation of present policy.

It is also possible in this experiment to offer a more detailed cost breakdown for a department. Assume that the chairman of the Mechanical Engineering Department wanted to know the effects of decreases in freshmen enrollment on anticipated costs for the next three years. Table 13 presents detailed cost information for the Mechanical Engineering Department for the given time period.

Because the enrollment change for a single administrative unit is small, cost changes are also small. However, a few important principles can be identified from the data presented in Table 13. Overhead costs do not change over time as enrollment decreases in the simulation model. Slight decreases can be observed by the end of the third year (1970) in the costs of graduate teaching assistants. The reduction in undergraduate teaching assistants

contributes most of the reduction in total undergraduate costs. A slight reduction also occurs in total costs of other activities. As described in experiment I, the cost of other activities includes those costs which are generally supportive to the efforts for teaching, research, and service, but can not be directly identified with any specific category.

Experiments III and IV also show the linear relationship of the model explained in experiment II. The anticipated differences in costs would generally be double for the four percent decrease when compared to the two percent decrease. Thus, the total cost information as reported in Table 13 for the Mechanical Engineering Department is ($\$920 \times 2 = \$1,840$). This further supports the degree of confidence that the user may develop in using the model.

The comparative results of experiments III and IV have been presented to demonstrate the effects of enrollment changes on educational costs. Cost differences were identified as a result of a reduction in the number of new freshmen. As fewer freshmen students moved through the system, reductions were observed primarily in the cost of undergraduate education, although additional cost reductions were present in related categories.

TABLE 13
COMPARATIVE COST REDUCTIONS FOR THE MECHANICAL
ENGINEERING DEPARTMENT ACCORDING TO TWO PERCENT
AND FOUR PERCENT DECREASES IN FRESHMEN ENROLLMENTS
1967-1970
(IN DOLLARS)

	1967	1968		1969		1970		Net Changes	
		2	4	2	4	2	4	2	4
		percent	percent	percent	percent	percent	percent	percent	percent
Partial Cost Data									
Undergraduate Overhead	\$ 18,158	18,158	18,158	18,158	18,158	18,158	18,158	0	0
Graduate Overhead	6,288	6,288	6,288	6,288	6,288	6,288	6,288	0	0
Thesis & Research Overhead	19,696	19,696	19,696	19,696	19,696	19,696	19,696	0	0
Overhead for Other Activities	8,808	8,808	8,808	8,808	8,808	8,808	8,808	0	0
Graduate Teaching Asst. Costs	37,448	37,448	37,448	37,388	37,329	37,231	37,014	-217	-434
Graduate Research Asst. Costs	16,800	16,800	16,800	16,800	16,800	16,800	16,800	0	0
Total Cost Data									
Total Undergraduate Costs	158,163	158,163	158,163	157,925	157,688	157,356	156,550	-807	-1,613
Total Graduate Costs	48,156	48,156	48,156	48,156	48,156	48,141	48,125	-15	-31
Total Thesis & Research Costs	60,651	60,651	60,651	60,651	60,651	60,651	60,651	0	0
Total Costs, Other Activities	36,116	36,116	36,116	36,086	36,057	36,018	35,920	-98	-196
Total Costs	\$303,086	303,086	303,086	302,818	302,552	302,166	301,246	\$-920	\$-1,840

Experiment V

The administrators in the interview group suggested that policy decisions are often made in isolation and without regard for other areas in the University. The group stressed the need for decisions to be made with a greater awareness of how they may affect others.

The purpose of experiment V is to determine the effect on a department of altering the curriculum requirement for its majors so as to demonstrate the implications for the department, and also to suggest the relationship to other areas. Some course requirements previously fulfilled by taking courses offered by outside departments will be satisfied by taking equivalent courses in the department. The Electrical Engineering Department is used to show the effects of requiring 13 credits per year for each electrical engineering major which were previously taken in mathematics and statistics. The effects of the simulated change are examined over a four year period.

The change in student credit hours is the area most directly effected by this policy change. The shift in the number of student credit hours from present policy for the Electrical Engineering Department is presented in Table 14. Present policy is exhibited in 1967, the parameter change is introduced in 1968, and the new policy is carried out for the remainder of the simulated time period. The new policy requires the production of an additional 421 student credit hours in the department by 1970.

TABLE 14

CHANGES IN THE PRODUCTION OF STUDENT CREDIT
HOURS IN THE ELECTRICAL ENGINEERING
DEPARTMENT RESULTING FROM AN INCREASE
OF THIRTEEN CREDIT HOURS PER MAJOR
1967-1970

Level	1967	1968	1969	1970	Change
E.E. Fresh.	0	0	0	0	
E.E. Soph.	0	0	0	0	
E.E. Junior	985	1, 274	1, 274	1, 274	+289
E.E. Senior	941	1, 073	1, 073	1, 073	+132
E.E. Grad	518	518	518	518	
Totals	2, 444	2, 865	2, 865	2, 865	+421

What are the changes in teaching faculty that accompany the increase in student credit hours? Table 15 gives the required number of faculty members and teaching graduate assistants as a result of the policy change. To meet the additional student credit hours, two new faculty members and five new graduate teaching assistants would be needed. This assumes there would be no increase in teaching loads or any effort to absorb the required teaching effort among existing staff.

The translation of the change in the production of student credit hours by the Electrical Engineering Department into teaching costs can be shown by the increases in faculty and graduate assistant costs and total undergraduate costs. Table 16 shows a total increase

TABLE 15

CHANGES IN THE NUMBER OF FACULTY AND
TEACHING GRADUATE ASSISTANTS IN THE
ELECTRICAL ENGINEERING DEPARTMENT
RESULTING FROM AN INCREASE OF THIRTEEN
CREDIT HOURS PER MAJOR
1967-1970

	1967	1968	1969	1970	Change
Faculty	19.3	21.4	21.4	21.4	+2.1
Teaching Grad. Asst.	24.9	30.3	30.3	30.3	+5.4
Totals	44.2	51.7	51.7	51.7	+7.5

in costs of \$39,883 which would result from the additional staffing requirements.

TABLE 16

CHANGES IN TEACHING COSTS FOR THE ELECTRICAL
ENGINEERING DEPARTMENT RESULTING FROM AN
INCREASE OF THIRTEEN CREDIT HOURS PER MAJOR
(IN DOLLARS)

	1967	1968	1969	1970	Change
Direct Under-graduate Costs for Faculty Salaries	\$120,521	145,203	145,203	145,203	+\$24,682
Graduate Teaching Asst. Costs	69,597	84,798	84,798	84,798	+ 1,520
Undergraduate Overhead	43,503	43,503	43,503	43,503	0
Total Undergraduate Costs	\$233,621	273,504	273,504	273,504	+\$39,883

The simulated change has been presented as it would affect the Department of Electrical Engineering. This specific model cannot examine the corresponding effects for the Departments of Mathematics or Statistics, but obviously the students would no longer place demands for instruction on these two departments. It is only possible to speculate about the effects; however, the reduction in demand might cause the elimination of a course or a reduction in the number of sections to be offered.

Experiment V translates a change in curriculum requirements into a need for additional teaching staff and the subsequent cost of new staff. The additional 421 student credit hours would require two new faculty members and more than five graduate assistants. The cost of this simulated change would be nearly \$40,000 per year.

Experiment VI

Experiment VI combines the interactions of policy changes introduced in experiments I and III. Experiment I increased the number of sophomore, junior, and senior students admitted to the University, and experiment III decreased the number of new freshmen admitted to the system. What are the combined enrollment implications of a 25 percent increase in the number of new students admitted at the sophomore, junior, and senior levels and a reduction of two percent in the number of new freshmen? What are the changes in the number of student credit hours produced? What are

the associated costs, enrollments, faculty requirements, and student credit hours for the College of Engineering as a result of these combined changes ?

The enrollment changes resulting from the two parameter changes for the College of Engineering are presented in Table 17. The year 1967 corresponds to present policy and the new policies are introduced in 1968. The interactions of the two policy changes result in $(926-907 = 19)$ additional students. The reduction in the number of freshmen and the increase in sophomores, juniors, and seniors can be observed in 1968. The results of the interactions of the two changes stabilize rather quickly and by 1971 the College would have an additional $(2,052-2,009 = 43)$ students. In experiment I a single parameter change to increase the number of new sophomore, junior, and senior students resulted in an increase of 71 students for the College of Engineering by 1971. The added variable in experiment VI, calling for a two percent reduction in the number of new freshmen, decreases the total number of new students from 939, as reported in experiment I, to 926.

The enrollment changes for the College of Engineering are small, but reflect the interaction of the two policy changes. However, enrollment effects on the rest of the University are larger and perhaps more visible, as presented in Table 18. The net effects of the two policy changes on the rest of the University would be $(37,432-36,297 = 1,135)$ more students than enrolled under present

TABLE 17

ENROLLMENT CHANGES FOR THE COLLEGE OF
ENGINEERING RESULTING FROM TWO PARAMETER CHANGES
1967-1971

	Fresh- men	Sopho- mores	Juniors	Seniors	Graduates	Totals
<u>1967</u>						
New Students	672	35	80	14	196	907
Total Students	687	382	310	343	287	2,009
<u>1968</u>						
New Students	659	43	101	17	106	926
Total Students	672	390	337	346	287	2,032
<u>1969</u>						
New Students	659	43	101	17	106	926
Total Students	672	384	337	361	287	2,041
<u>1970</u>						
New Students	659	43	101	17	106	926
Total Students	672	384	333	370	288	2,047
<u>1971</u>						
New Students	659	43	101	17	106	926
Total Students	672	384	336	369	291	2,052

TABLE 18
ENROLLMENT CHANGES FOR THE REMAINDER OF THE
UNIVERSITY RESULTING FROM TWO PARAMETER CHANGES
1967-1971

	Fresh- men	Sopho- mores	Juniors	Seniors	Graduates	Totals
<u>1967</u>						
New Students	7,438	783	1,432	599	3,151	12,403
Total Students	7,812	6,615	6,549	7,757	7,564	36,297
<u>1968</u>						
New Students	7,289	979	1,790	749	3,151	13,958
Total Students	7,664	6,811	6,907	7,907	7,564	36,853
<u>1969</u>						
New Students	7,289	979	1,790	749	3,151	13,958
Total Students	7,661	6,723	7,066	8,222	7,574	37,246
<u>1970</u>						
New Students	7,289	979	1,790	749	3,151	13,958
Total Students	7,664	6,715	7,014	8,408	7,600	37,401
<u>1971</u>						
New Students	7,289	979	1,790	749	3,151	13,958
Total Students	7,664	6,715	7,005	8,409	7,639	37,432

policy. Experiment I indicated an additional 1,539 students for the same period, resulting from a 25 percent increase in the number of new sophomores, juniors, and seniors. Therefore, after four years the two percent reduction in the number of new freshmen would offset the enrollment increase by $(1,539 - 1,135 = 404)$ total students.

The interactions of two policy changes imposed simultaneously on enrollments for the University have been exhibited. As indicated

in previous experiments, these changes can be translated into student credit hours, teaching requirements, and costs in whatever detail may be necessary. However, these detailed results for experiment VI contribute nothing more to the purpose here, so Table 19 simply summarizes the totals and the net effects, which are the differences between simulated policy changes and present policy.

The net effects of the two parameter changes for the College of Engineering would result in the demand for 599 additional student credit hours. This demand would come from greater numbers of students within the College and others throughout the University taking engineering courses. The requirement for additional faculty members and graduate teaching assistants would approach three more than presently required. The total costs of these changes would be approximately \$51,000 per year by the end of the four year period.

Experiment VI exhibited two policy changes, (a) the number of new freshmen were reduced 2 percent, and (b) the number of new sophomores, juniors, and seniors were increased 25 percent. Experiment VI differed from previous experiments by carrying out two changes simultaneously and so effects of the policy changes cannot be traced directly to a single variable. To this end, experiment VI provides a logical introduction to the last experiment where several parameter changes are imposed simultaneously.

TABLE 19
NET EFFECTS ON STUDENT CREDIT HOURS,
TEACHING REQUIREMENTS, AND TOTAL
COSTS FOR THE COLLEGE OF ENGINEERING
RESULTING FROM TWO PARAMETER CHANGES

	1967	1971	Net Effects
Student Credit Hours	12, 321	12, 920	+599
Teaching Faculty	81.2	84.0	+2.8
Teaching Graduate Assistants	68.5	71.2	+2.7
Total Costs	\$1, 662, 441	\$1, 713, 993	\$+51, 552

Experiment VII

Given the knowledge of how the model reacts to rather simple parameter changes, it is possible to manipulate the model with more confidence to simulate four changes operating simultaneously over varying time periods. The variables to be changed were selected to provide a composite of previous experiments plus projected increases of selected costs, thus representing a more realistic situation in the way an educational system behaves.

Experiment VII combines the following parameter changes:

1. An increase of 33 percent in the number of new sophomore, junior, and senior students;

2. A decrease in freshmen enrollment of four percent;
3. A shift to teaching some courses for Electrical Engineering majors into the Electrical Engineering Department instead of outside departments; and
4. A three percent salary increase for all faculty and graduate assistants.

The purpose of this experiment is to demonstrate the interactions of all the above parameters as they effect the total operation of the College. The net results of the total changes over a four year period are presented according to the effects on enrollment, student credit hours, teaching requirements, and costs. In each instance the results of all the policy changes are a comparison between present conditions and simulated future conditions.

The enrollment changes resulting from the policy changes are shown in Table 20. The effects of the policy changes on

TABLE 20
ENROLLMENT CHANGES FOR THE COLLEGE OF
ENGINEERING RESULTING FROM SEVERAL
PARAMETER CHANGES
1967-1971

	1967	1971	Change
New Students	907	925	+18
Number Graduated	285	302	+17
Total Students	2,009	2,041	+32

enrollments after four years would mean that 18 more new students would be introduced into the College at various levels, an additional 17 seniors and graduate students would complete degrees by 1971, and total enrollment for the College would be increased by 32 more students than provided for by an extension of present policy.

The effects of all parameter changes on the production of student credit hours are shown in Table 21. The additional

TABLE 21
NET EFFORTS OF SEVERAL PARAMETER CHANGES
ON STUDENT CREDIT HOURS FOR ENGINEERING

Total Student Credit Hours 1967	Total Student Credit Hours 1971	Change
12,321	13,479	+1,158

student credit hour requirements generally come from three sources: (1) increases in University enrollment, (2) increases in College enrollment, (3) Electrical Engineering Department curriculum changes. This experiment exemplifies the difficulty of tracing parameter relationships when several changes are involved. Nevertheless, the policy interactions would produce the need for an additional 1,158 student credit hours. The user must now rely on confidence in the model because the calculations cannot be validated manually as conducted in earlier experiments.

The student credit hours are also reflected in total graduate assistant and faculty requirements for the College. The combined effects for the College are given in Table 22. The increased number of faculty and graduate assistants stems from the enrollment

TABLE 22
EFFECTS OF SEVERAL PARAMETER CHANGES
ON FACULTY AND GRADUATE ASSISTANT
REQUIREMENTS FOR ENGINEERING^a

	1967	1970	Change
Total Faculty	81.2	86.3	+5.1
Graduate Assistants	68.5	79.0	+10.5

^aFigures expressed in full-time-equivalent faculty.

increases and the departmental curriculum change. The aggregation of faculty members for the College is misleading, for the specialities of individuals must be recognized. However, the gross comparison does translate the total needs of the College into increased faculty and graduate assistant needs.

The identification of increases in costs is important for this experiment. The increases in faculty and graduate assistant costs are shown separately because a parameter change was introduced to provide for salary increases. In addition to salary increases, the number of new faculty members and graduate assistants required to meet additional demands of the system would contribute to increases

in costs. Cost information is presented in Table 23. The net effect of all policy changes introduced in experiment VII would cost the College of Engineering an additional \$143,951 per year by the end of four years.

TABLE 23
EFFECTS OF SEVERAL PARAMETER CHANGES
ON COSTS FOR ENGINEERING
(IN DOLLARS)

	1967	1970	Change
Total Faculty Salaries	\$1,076,066	1,179,839	\$+103,773
Total Graduate Assistant Salaries	326,236	366,146	+39,910
Other Costs	260,139	260,407	+268
Total Costs	\$1,662,441	1,806,392	\$+143,951

Thus, experiment VII identifies the results of the interactions of four parameter changes introduced in the simulation program. The interactions of the parameters cannot be traced to specific manipulations, but form a composite of total effects. Experiment VII is a more realistic reflection of the behavior of a University system than the single parameter changes presented earlier. The use of the simulation model in this manner offers the educational administrator an opportunity to view the aggregated results of changes and provides a potential tool as an aid in

long range planning. The experiment further emphasizes that even though decisions may be made in isolation, the effects of those decisions are not isolated.

Summary of the Experiments

The seven experiments were designed to reflect the thinking and questions of a selected group of educational administrators at Michigan State University, and to demonstrate the way a specific simulation program can be manipulated according to instructions by the user to assist in providing some of the answers. The manipulations were basically identified as changes in current operating conditions for the College of Engineering. The base year (1967) identified conditions before the introduction of any administrative policy changes. As changes in the system were introduced, an attempt was made to observe how the various components in the system responded to these changes.

The results of the single parameter changes initiated in experiments I-V were discussed in detail since the effects of the changes were more visible here. It was possible to manually calculate the anticipated changes in the system, given the results of calculations performed by the instructions of the simulation program. This validation effort was an attempt to build confidence in the calculations performed by the computer. The more complicated experiments were included to demonstrate a broader range of capability of the simulation program and to be more realistic about the operations of a complex university system.

CHAPTER VI

SUMMARY, CONCLUSIONS, AND THEORETICAL CONSIDERATIONS

Evidence was located in the literature which suggested that educational administrators should begin to become aware of analytical tools and techniques which may assist them in decision-making concerning the present and future direction of colleges and universities--specifically, in logistical decisions. A means was sought in this study of demonstrating how a specific model might be employed to describe the operations of a university so that educational administrators can become aware of the potential of a systems approach to aid rational decision-making.

It was the purpose of this study to: (1) describe in non-technical language a systems model and an implementation of the model using data descriptive of Michigan State University as developed by a research group in the College of Engineering; (2) identify aims, objectives, and problems concerning the future direction of Michigan State University as suggested by a selected group of educational administrators responsible for policy decisions in this institution; and (3) show how some of these identified concerns

and objectives were addressable to a specific computer simulation program which is an implementation of the theoretical model describing the university as a system.

A review of related literature identified studies employing systems analysis to model global systems and specific components of schools and universities. The major research contributions in these areas were conducted by a few individuals. The results of the research efforts suggested that the use of systems analysis is in the early stage of development. Researchers who have introduced real data have produced some tangible results.

The theoretical model used in this study identifies the university as a total system composed of interacting sub-systems or components. Mathematical models have been constructed for selected representative components of the system and the interconnection pattern among components. Each component defines a specific operation or function of the university. The total model of the system, which incorporates all components, describes the relationship of inputs and outputs in the university to the overall educational process and the associated units of production. It delineates how the university uses its resources--personnel, space, and equipment--in the production of educated manpower and other services.

The development of a simulation computer program (MSUSIM2) which includes data for the College of Engineering was the tool used

to conduct experiments. By using this program it was possible to vary selected parameters to reflect conditions and policies of Michigan State University as recognized by a selected group of educational administrators.

Interviews were conducted with thirteen administrators at Michigan State University to offer input for the experiments according to aims, objectives, and problems regarding the future direction of this Institution. The interviews yielded a broad range of response from detailed and specific alternatives to generalized goals and objectives.

The group generally interpreted long-range planning and specific aims and objectives to be the seeking of solutions to present day problems. Evidence was reported that some administrative units have considered future planning, but not within a centralized framework or strategy for development.

The existence of external and internal pressures which influence planning and decision-making was identified as a significant factor by many administrators.

The responses of the administrators were grouped according to five categories: enrollments, finances, academic programs, social concerns, and physical facilities. The interview group was most concerned about the control and management of enrollments and clearly recognized the need for greater control and better projections of enrollments. There was considerable discussion about the justification, allocation, and budgeting of financial resources to

support both academic and non-academic functions of the University. Ten administrators discussed plans and alternatives pertaining to the academic program which were related to faculty, and innovative educational activities and programs. The concern for the University to be sensitive to societal needs was discussed by five administrators. The greatest attention was directed toward minority groups, but student dissatisfaction was also mentioned. Four members of the group suggested that the use and allocation of physical facilities offered particular concern for planning.

As a result of the interviews the following conclusions were drawn. Administrators desire more descriptive information as an aid in planning and decision-making. The significance of enrollments and the importance of finances were recognized as critical elements in planning. Policy decisions are made in isolation without an awareness of other areas on campus. A need exists for evaluation of present programs and personnel before the development or expansion of innovations.

Seven experiments were designed which were addressable to the conclusions drawn from the interviews. The parameters which were manipulated in the simulation program reflected changes in enrollments, finances, and policies as suggested by the administrators. Experiments were conducted that reduced the number of new freshmen and increased the number of new sophomores, juniors, and seniors admitted to the University. One experiment was conducted to examine the effects of a change in graduate requirements

for students in a specific major. The final experiment was a composite of changes plus simulated salary increases for faculty members in the College of Engineering.

Throughout the analysis of all experiments it was possible to demonstrate two uses of the model: (1) the use of the model to provide descriptive information about the condition of the system; (2) the use of the model to examine changes in the condition of the system.

The following conclusions can be drawn as a result of the experiments. A reasonable confidence in the calculations performed by the computer was developed by manual calculations of anticipated changes. The user of this simulation program can then be reasonably sure that the calculations are accurate and express reasonable relationships. The specific model used in this study can be used to simulate enrollment projections, calculate appropriate demands and costs, and change selected parameters. As changes are introduced it is possible to trace some interrelationships of the results of the changes. The interaction of the variables made it possible to observe that when policy changes are made in isolation the results of these changes affect the total operations of the University. To the extent that an accurate data base exists, the simulation program provides a tool for administrators in the College of Engineering to conduct a number of experiments concerning the present and future direction of the College.

The development of management information systems to aid administrators can only be effective if accompanied by an organizational structure to insure communications in the system. This communication linkage must be recognized as an important mechanism for decision-making in order for the administrator to make maximum use of the analytical tools in carrying out management functions. The accumulation of information about the system must therefore be viewed as a supportive component to a sound organizational pattern.

Theoretical Considerations

What considerations must be weighed if analytical tools and techniques are implemented in a university system? The employment of these techniques may introduce some unanticipated changes in the behavior of the system. When model builders, in cooperation with educators, are able to quantify more variables and thereby produce more sophisticated models, then it would be possible for greater controls to be exercised by administrators. Where is the delicate balance between a "free-wheeling" system with a minimum of controls and a system characterized by a number of controls? Certainly, as evidenced in this study, there is a level of control beyond present conditions, but what point approaches an optimum arrangement? It would appear that institutions would need to assess carefully this critical level depending upon the goals of the institution.

Greater control and management of enrollments, for example, might freeze the transition of students from one major to another. These constraints might also result in greater departmental autonomy which could lead to the elimination of service courses or a complete disregard for the needs of other departments in the system. Changing the behavior of an existing system by decisions supported by sophisticated models does not reduce the role of the administrator; instead, his role is changed to expand his importance in providing leadership for the future direction of the organization.

Analytical techniques are no panacea for the ills of education and should not be interpreted in this way. The administrator has the potential for a new capability to aid in the decision-making process. The development of this capability does not produce a system run by a computer, but a system where decisions are made on a sound basis with an awareness of available data. The concept of weighing alternatives before making decisions is not new, however, the opportunity for using sophisticated analytical tools is nearly revolutionary.

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APPENDIX A

THE INTERVIEW GUIDE

INTERVIEW GUIDE:**INTRODUCTION:**

I am involved in a project which is in the process of developing a mathematical description of the university. Through the cooperation of the Office of Institutional Research a great deal of information has been gathered about Michigan State University and we are now ready to simulate the activities of the University through the use of a computer program. Your assistance is needed at this point because if possible we would like to have the value of your thinking concerning long-range planning at M.S. U.

- Question 1. What long-range plans have you recently considered regarding the future direction of the University?
- Question 2. What are the alternative policies which might come about as a result of these plans?
- Question 3. What are the aims and objectives of your area which have the highest priority?
- Question 4. What are the possible alternatives for carrying out these aims and objectives?

(Note: Follow-up questions pertaining to these four general areas were asked depending upon the initial responses of the administrators.)

APPENDIX B

MSUSIM2 USER'S MANUAL

MSUSIM2

User's Manual

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1. Introduction

MSUSIM2 divides the university into up to 8 fields, each of which is an aggregation of one or more departments. It divides students and courses into levels, which may be arbitrary groupings of class codes (for students) and class levels (courses). Faculty are divided into ranks, which may be specified arbitrarily; MSUSIM2 does not require any information about how the divisions are made; it assumes that all data given is grouped properly and consistently.

The user's instructions to MSUSIM2 consist of commands to change selected parameters, commands to project enrollments, demands, or costs, and commands which maintain a file of data for use in the simulations. These commands begin with a call for input, output or modification of parameters, followed by the commands which cause calculations to be performed, commands which employ the data tape, and miscellaneous other commands.

The design of the MSUSIM2 system is such that it may be used for quite a wide variety of purposes. The user may wish to (1) predict future trends in enrollment, (2) calculate the effect of curriculum changes on the teaching faculty required or to determine cost estimates on two alternative courses of action, (3) study the manipulation of enrollment using certain control variables, perhaps to achieve some particular distribution of students among various fields and levels, (4) analyze the current allocation of resources to various types of activities, and (5) study historical changes in certain variables to determine the effects of policy changes.

Because of the flexibility of the MSUSIM2 system, there is a wide variety of types of data which may be supplied to the system, only a portion of which are actually required for any one problem. The user, with the help of this manual, should determine what computational commands will be

required for his problem, then supply only the data required for those calculations. For example, if the user wishes to project enrollment for some years into the future but does not wish to use financial aid as a control variable, he need not supply the STUDENT ASSISTANTSHIP or SCHOLARSHIP ATTRACTION or RETENTION tables but should include all student transitions in the STUDENT TRANSITION TABLE. If the user instead is predicting faculty demand five years hence and has already developed a projected enrollment, he need only input that enrollment (HERE IS ENROLLMENT), whatever faculty effort tables he wishes to consider, the DEMAND FOR CREDIT HOURS and RESEARCH GRANTS tables, and compute the required faculty. He may then perform whatever manipulations he desires on the effort parameters to obtain an upper and lower limit for faculty, for example. If faculty salaries are to be considered, then the FACULTY SALARY SCALE must be supplied; and any other costs to be used must also be input. In general, however, only that data to be used need be supplied. If the user wishes to project enrollment or costs for one year under several sets of conditions, he will find the BACK YEAR command useful.

Of course, in many instances the user will already have developed a file of data in a previous use of the MSUSIM2 system. In this case, he does not have to ESTABLISH BACKGROUND and input all of his data but can instead INITIALIZE FROM DATA FILE, which inputs data previously stored on magnetic tape for use by the system. The user may then change any parameters he wishes before beginning his computations.

All of the commands are described in detail in this manual, and their relationships to one another should be clear.

2. Establishment and Initialization of Parameters

ESTABLISH BACKGROUND

This command causes several things to happen. First, all of the system parameters are set to zero. Next, the numbers of fields, levels, and ranks are read, in that order, from the card following the ESTABLISH command. These numbers must be two digits each and must be in the first 6 card columns. For example, the two-card sequence

```
ESTABLISH BACKGROUND
080502
```

would set up the system for 8 fields, 5 levels, and 2 ranks, which is the maximum size allowed.

The system then generates labels for output. These labels are "FIELD 1", "FIELD 2", "LEVEL 1", "RANK 1", etc. The user may later supply his own labels by use of the DESCRIPTION command (see below).

After an ESTABLISH command, the user must specify data before any computations can be done. This may be done with the HERE IS or READ IN commands (see below).

INITIALIZE FROM DATA FILE

A way to introduce a background and data into the system is with the INITIALIZE command. This command must be followed by a file-number-card (see Data File Manipulation, Chapter 5). INITIALIZE causes the data files specified on the file-number-card to be brought into the system. Note that INITIALIZE assumes that all parameters for the system have been included in the file. Any parameters which were not put into the file will be zero after the INITIALIZE. Any data which were in the system before the INITIALIZE will no longer be present. The file number specified for an INITIALIZE must be between 1 and 99.

3. Parameters and Manipulation Commands

In order to describe the parameters used by MSUSIM2, it is helpful to establish the following conventions.

The number of fields under consideration will be written as NF. The number of levels (of students and classes) will be written as NL. The number of faculty ranks will be written as NR. The number of field-level combinations will be denoted NFL, and the number of field-rank combinations, NFR. Thus, since MSUSIM2 allows a maximum of 8 fields, 5 levels, and 2 ranks, the maximum values of NFL and NFR are 40 and 16, respectively (NFL always equals NF times NL; NFR is NF times NR). When data is maintained for each field and level, or each field and rank, it is convenient to regard field 1, level 1 as field-level 1; field 1, level 2 as field-level 2; field 1, level 3 as field-level 3, etc. Thus, if NF were 4, NL were 3, and NR were 2, the field-levels and field-ranks would be numbered as follows:

<u>field</u>	<u>level</u>	<u>field-level</u>	<u>field</u>	<u>rank</u>	<u>field-rank</u>
1	1	1	1	1	1
1	2	2	1	2	2
1	3	3	2	1	3
2	1	4	2	2	4
2	2	5	3	1	5
2	3	6	3	2	6
3	1	7	4	1	7
.	.	.	4	2	8
.	.	.			
.	.	.			
4	3	12			

Data for each parameter is stored in ascending order of field, level, rank, field-level, or field-rank, depending, of course, on the nature of the parameter involved. Each parameter is described in detail below, making

use of the conventions already established.

There are several commands which allow the user to reference a single parameter within the system. Each of these commands is followed (on the same card) by a parameter name which specifies the particular parameter which is to be manipulated.

SHOW ME

This command causes the system to print the data which is indicated by the parameter name. If the parameter is a table, it will be printed one row at a time. SHOW ME prints up to 8 numbers per line. If the number of elements in a row (i. e. , the number of columns) is less than or equal to 8, each row will be printed on a single line. For example, a table with 5 columns and 6 rows will produce 6 lines of output, each line having 5 numbers. EXCEPTION: If a table has only 1 column, the numbers will be printed 8 to a line for as many lines as are needed. For example, a table with 1 column and 12 rows would print 2 lines. Line 1 would contain the first 8 elements of the table (the first 8 rows), and line 2 would contain the remaining 4. If the number of columns is greater than 8, 8 numbers are printed per line for as many lines as are as needed to print a row. Each row begins printing on a new line. If, for example, a table has 2 rows and 13 columns, 4 lines will be printed. Line 1 will contain the first 8 elements of row 1, line 2 the last 5 elements from row 1, line 3 the first 8 elements of row 2, and line 4 the last 5 elements of row 2. Of course, if the parameter to be printed is not a table, only one number is printed.

READ IN

This command causes the system to input data for the parameter

specified by the parameter name. The numbers will be read row-wise, beginning with the card immediately following the READ IN. Numbers are to be punched 8 to a card, each number within a ten column field. Thus the first number goes in card columns 1-10, the second in columns 11-20, etc. EXCEPTION: the READ IN YEAR command must have the year punched cols. 1-4. Each number punched must include a decimal point except for READ IN YEAR which may not have a decimal point (see the example below). Note that there is no correspondence between the number of elements in a row and the number of elements punched on a single card. There must be 8 numbers on each card except the last, which needs to have only enough numbers to fill out the table. If, for example, a table has 3 rows and 7 columns, a READ IN command would require 3 data cards. The first two cards would contain 8 numbers, and the third card only 5 numbers. The first row will be filled with the first 7 numbers from card 1, the second row with the last number from card 1 and the first six from card 2, and the third row with the last 2 numbers from card 2 and the first 5 numbers from card 3. The last 30 columns of card 3 would be ignored. Note that READ IN attempts to fill the entire table from data cards following the command. If there are not enough cards to fill the table, an error will occur.

Of course, if the parameter to be read is not a table, only one number is needed, punched in columns 1-10.

HERE IS

This command causes the system to do two things. First, data is read into the parameter (specified by the parameter name) in the same

manner as the READ IN. Secondly, the system prints the data in the same manner as the SHOW ME command. Thus the following two command sequences are equivalent:

HERE IS RESEARCH GRANTS

1.0 2.5 0.54

or

READ IN RESEARCH GRANTS

1.0 2.5 0.54

SHOW ME RESEARCH GRANTS

INFLATE

The INFLATE command is actually a group of commands which allow the user to increase or decrease all or part of any parameter by a proportion specified by the user. For example, if it is desired to give all faculty a raise of 10%, the command would be

INFLATE FACULTY SALARY SCALE
ALL
.10

The INFLATE command is actually composed of three separate cards: The first contains the word INFLATE followed by the name of the parameter to be increased or decreased, specified exactly as it is in a HERE IS, READ IN, or SHOW ME command. The second card specifies what part of the parameter is to be changed; the possible sub-commands which may be used are

ALL
ROWS
COLS
ONLY ROW n
ONLY COL n
ELEMENT m n

If ALL is used, the third card must contain the factor to be used in changing the parameter, punched in the first ten columns of the card.

If the parameter is a table, each entry in the table will be increased by the proportion specified. A negative value, of course, will cause a decrease.

Example:

```
INFLATE FACULTY SALARY SCALE
ALL
.10
```

will give all faculty a 10% raise

```
INFLATE STUDENT TRANSITION TABLE
ALL
-.20
```

will cause each entry in the transition
table to be lowered by 20%.

If ROWS is used as the sub-command, the third card must contain one entry for each row in the table (parameter) to be inflated. For example, if the student transition table is to be inflated, and if there are 3 fields and 2 levels, then the student transition table has 6 rows and 6 columns, and the third card must have 6 entries, each in 10 columns of the card. An illustration is:

```
INFLATE STUDENT TRANSITION TABLE
ROWS
.10      .08      .06      .08      .10      .09
  {       {       {       {       {       {
10 col's 10 col's 10 col's 10 col's 10 col's 10 col's
```

This command would inflate all entries in the first row by 10%, in the second row by 8%, in the third by 6%, etc. Any fields left blank are treated as 0 by the system (i. e. , the corresponding row is unchanged).

If COLS is used as the sub-command, the third card is prepared

as for ROWS, but the command inflates the first column by the first value, the second column by the second value, etc.

If ONLY ROW nn is used, the third card must contain only one entry, in the first 10 columns, and n must be a two-digit number. The user must be certain that the row number specified is not greater than the number of rows in the table he is altering.

Example:

```
INFLATE STUDENT TRANSITION TABLE
ONLY ROW 03
. 15
```

This command inflates row 3 of the table
by 15%.

If ONLY COL nn is used, the third card is prepared as in ONLY ROW nn. Column n is altered, instead of row n.

Example:

```
INFLATE STUDENT TRANSITION TABLE
ONLY COL 02
-. 10
```

This command reduces column 2 by 10%.

If ELEMENT mm nn is used, the third card contains one entry in the first 10 columns. Both m and n must be 2-digit numbers, specifying the row and column, respectively, of the entry to be inflated.

Example:

```
INFLATE DEMAND FOR CREDIT HOURS
ELEMENT 02 03
. 12
```

This command inflates the entry in row
2, column 3 of the DEMAND FOR CREDIT
HOURS table by 12%.

ENROLLMENT

For the purposes of MSUSIM2, enrollment means the number of students in each field-level under consideration in a given year. The enrollment is stored as a table with one column, and with one row for each field-level. Thus, for example, if $NF = 4$, $NL = 3$, then the input cards

HERE IS ENROLLMENT

250.	230.	55.	600.	350.	125.	170.	150.
60.	150.	88.	35.				

would indicate to MSUSIM2 that the enrollment to be considered is 250 field-level 1 students, 230 field-level 2 students, etc., finally up to 35 field-level 12 students. After this command is executed, the fourth row of the enrollment table will contain the number 600, for example.

The enrollment table always contains the last enrollment input or computed by a COMPUTE ENROLLMENT command. (Of course, INFLATE ENROLLMENT also alters the enrollment table.)

NUMBER OF TOTAL NEW STUDENTS

The number of total new students is the number of students entering the university in the year under consideration who were not in the university the previous year. Both students attracted by financial aid and those who enter independent of aid are included. No division into fields and levels is done at this stage; the proportion of the total new students who enter each field-level is stored as the PERCENT BREAK-DOWN OF TOTAL NEW STUDENTS table, described next. NUMBER OF TOTAL NEW STUDENTS is used only by the COMPUTE ENROLLMENT

FROM TOTAL NEW STUDENTS command; if this command is not used, NUMBER OF TOTAL NEW STUDENTS need not be supplied.

PERCENT BREAKDOWN OF TOTAL NEW STUDENTS

This table is a single column which contains one row (a single entry) for each field-level category. The entry in row J is just the proportion of total new students (for the year under consideration) who enter field-level J. Thus, for example, if 10 percent of all new students enter field-level 3, then .10 should be the third entry of the table. This parameter is necessary only when the COMPUTE ENROLLMENT FROM TOTAL NEW STUDENTS command is to be used.

NUMBER OF NEW STUDENTS AID INDEPENDENT

The number of new students, aid-independent, is the number of students entering the university in the year under consideration who were not in the university the previous year but who would have entered the university even if financial aid were not offered them. This number includes students who receive aid but would attend even if they did not have aid together with all students who do not receive aid. This parameter is used, in conjunction with the PERCENT BREAKDOWN OF NEW STUDENTS AID INDEPENDENT, whenever the COMPUTE ENROLLMENT FROM NEW STUDENTS AID INDEPENDENT command is executed.

STUDENT TRANSITION TABLE

This table describes the movement of students already within the university among the various field-levels from one year to the next, independent of financial aid. The table has NFL rows and NFL columns, i. e., a row and column for each field-level. The information recorded

in the entry of the i^{th} row and j^{th} column is the proportion of students in field-level j in year $t-1$ who are in field-level i in year t . For example, if the entry in row 4 column 3 is .50, this indicates that 50% of the students who were in field-level 3 in year $t-1$ are in field-level 4 in year t and would be in field-level 4 whether they were offered financial aid or not. (Note - if the user wishes to ignore the effects of financial aid on enrollment, he may include all transitions, whether induced by financial aid or not, in the transition table. He must then make certain that the scholarship and assistantship attraction and retention tables described below are all 0.) The STUDENT TRANSITION TABLE is used when either COMPUTE ENROLLMENT FROM NEW STUDENTS AID INDEPENDENT or COMPUTE ENROLLMENT FROM TOTAL NEW STUDENTS is executed. Of course, when the user is projecting a future enrollment, the transition table is only an estimate of the transitions to be expected, and the user may wish to use the transition table for the most recent year, an average over several previous years, or some other estimate of the transitions to be expected.

STUDENT ASSISTANTSHIP ATTRACTION TABLE

This table specifies the effect of financial aid in the form of teaching and research assistantships in causing students to enter or remain at the university in a given field-level. There are NFL rows in this table (and only one column). The i^{th} row in the table is the number of students who will be in field-level i in year t who would not be in the university if an assistantship were not offered in field-level i , per assistantship to be offered for year t in field-level i . (Clearly, the attraction of students outside field-level i by an assistantship in field-level i is assumed to be small and is therefore ignored.) For example, if each assistantship in

field-level 3 attracted .7 students, then the third row should contain .7. Of course, assistantships are normally offered only in graduate levels, so all undergraduate field-levels will usually be 0.

STUDENT SCHOLARSHIP ATTRACTION TABLE

This table is identical to the STUDENT ASSISTANTSHIP ATTRACTION TABLE, except that it deals with students attracted by scholarships, fellowships, and traineeships, rather than by assistantships. (As undergraduates receive scholarships, the undergraduate levels will not in general be 0, as they were in the assistantship table.) There remains for the user the problem of deciding how many scholarships are "available" in each field-level, since some do not require that the recipient be a student in a particular field-level--it may be that the user wishes to recognize only those scholarships which specify a field or field-level of recipient, or the user may instead "assign" scholarships to field-levels in proportion to their enrollments. Any such scheme is acceptable so long as it is applied consistently within any single set of data, i. e., for those parameters specifying numbers "independent of financial aid," only those types of aid considered in the STUDENT SCHOLARSHIP ATTRACTION TABLE and the STUDENT ASSISTANTSHIP ATTRACTION TABLE should be considered as financial aid.

STUDENT ASSISTANTSHIP RETENTION TABLE

This table describes the effect of assistantships in causing students to remain in the university. It is a square table, with NFL rows and NFL columns. The entry in row i , column j is the number of students in field-level i in year $t-1$ who are induced not to depart from

the university by an assistantship offered for year t in field-level j . For example, if each assistantship offered in field-level 5 for year t causes .8 students from field-level 4 in year $t-1$ not to depart from the university, then the entry in row 4, column 5 should be .8. (It is to be expected that many seniors and graduate students will be induced not to leave by assistantships and that rows corresponding to other levels (and columns corresponding to all undergraduate levels) will be 0 or nearly 0.)

STUDENT SCHOLARSHIP RETENTION TABLE

This table is identical to the STUDENT ASSISTANTSHIP RETENTION TABLE except that it deals with students induced not to depart by scholarships rather than by assistantships.

DEMAND FOR TEACHING ASSISTANTS

This table contains information about the number of graduate teaching assistants required for each student credit hour taught. The table has NFL rows and NFL columns. Each row represents a field-level of graduate assistants, i. e., the level of student and field of the assistantship; since undergraduates are not teaching assistants, rows corresponding to undergraduate levels will be 0. Each column represents a field-level of student credit hours. Thus the entry in row i , column j is the number of teaching assistants of field-level i required to teach one student credit hour of a class in field-level j . For example, if row 5 column 2 contains .006 and if field-level 5 represents graduate students in field 1, this indicates that .006 graduate teaching assistants in field 1 are required for each student credit hour taken at level 2 in field 1.

It may be convenient to measure graduate assistantships in

units of half-time equivalents rather than in head count; this may be done, but it must be done consistently in the STUDENT ASSISTANTSHIP ATTRACTION and RETENTION tables also. (If this table is not supplied, teaching assistants cannot be computed, and the effect of teaching assistantships in attracting and retaining students cannot be computed.)

DEMAND FOR RESEARCH ASSISTANTS

This table contains information about the number of research assistants required per \$1000 of research grants in a given field. The table has NFL rows and NF columns. The entry in row i , column j is the number of research assistants of field-level i required per \$1000 of research grants in field j . As in the case with teaching assistants, the user may wish to define a full-time or half-time research assistant to use instead of a head count.

RESEARCH GRANTS

This table contains the amount of research grants held in each field. There are NF rows, only one column. The entry in row i is the number of thousands of dollars of research grants in field i for the year under consideration. For example, if field 3 has \$72,500 in grants for the year under consideration, the third entry in the table should be 72.5. (The user may choose to consider research funds from various sources, of course, so long as he is consistent in using funds considered in determining the EFFORT FOR RESEARCH and the DEMAND FOR RESEARCH ASSISTANTS tables.)

STUDENT GRADUATION PERCENT TABLE

This table contains the proportion of students of each field and level who graduate during the year under consideration. The table has NFL rows and a single column. Row i contains the proportion of field-level i students who graduate in a given year. Of course, only those rows corresponding to senior and graduate levels will contain non-zero entries.

DEMAND FOR CREDIT HOURS

This table contains the credit-hour requirements of all students. The table has NFL rows and NFL columns; the entry in row i , column j is the number of student credit hours of courses at field-level i that are required per student at field-level j . Thus, if row 3, column 2 contains 11.6, it indicates that each student at level 2 required 11.6 student credits at field-level 3 (i.e., if field-level 2 is sophomore-level mathematics and field-level 3 is junior-level mathematics, the 11.6 represents 11.6 credits of junior-level math courses taken by the average sophomore-level mathematics major). While the user might ordinarily wish to count credits demanded over a period of an academic year, he may instead use credits for an "average quarter"; all that is required is that the same scheme be used consistently, for example, in determining the effort for undergraduate and graduate instruction tables.

NUMBER OF SCHOLARSHIPS

This table specifies for each field-level the number of scholarships, fellowships and traineeships to be offered for students entering or remaining in that field-level. Thus the table has NFR rows and a single column. The units of scholarships must be chosen by the user,

of course; he may wish to define a standard scholarship or some such quantity in terms of which to express scholarships of different values. He should, of course, use the same units in calculating the STUDENT SCHOLARSHIP ATTRACTION TABLE and the STUDENT SCHOLARSHIP RETENTION TABLE.

The following twelve tables represent the various activities faculty may devote time to. The amount of time devoted to the first six of these activities is assumed to be a direct function of some other variable. The entries in these six tables, therefore, have the units "FTEs per some quantity." The last six of these tables do not depend on any clear cut demand. The entries in these tables, therefore, have the units "fraction of FTEs."

These tables are all required by the commands: COMPUTE FACULTY; COMPUTE FACULTY COSTS; and COMPUTE TOTAL COSTS.

EFFORT FOR UNDERGRADUATE INSTRUCTION

This table gives the amount of effort per credit spent by faculty of each field and rank teaching undergraduate courses of each field and level. The number of FTEs spent by the faculty of a given field and rank teaching undergraduate courses of a given field and level is divided by the total number of undergraduate credits taken in the given field and level from the faculty of the given field and rank.

This table has NFR rows and NFL columns. The entry in row i column j is the number of FTEs per student credit spent by the faculty of field-rank i teaching undergraduate courses for students in field-level j . For example, if the faculty of field-rank 3 spend 0.35 FTEs teaching undergraduate courses of field-level 8 and if these courses

represented 100 student credits, then $0.0035 \left(\frac{.35}{100} \right)$ would be entered in row 3, column 8 of the table.

EFFORT FOR GRADUATE INSTRUCTION

This table is equivalent to the EFFORT FOR UNDERGRADUATE INSTRUCTION table except that it gives the number of FTEs spent by the faculty of each field and rank teaching graduate courses in each field and level.

This table has NFR rows and NFL columns. As an example of an entry, suppose that the faculty of field-rank 5 spent 0.25 FTEs teaching graduate courses in field-level 15 and suppose that these courses totaled 50 student credits, then $0.005 \left(\frac{0.25}{50} \right)$ would be entered in row 5, column 15 of the table.

EFFORT FOR UNDERGRADUATE ADVISING

This table gives the effort per student spent by faculty of each field and rank performing undergraduate advising for students of each field and level. The number of FTEs spent by faculty of a given field and rank performing undergraduate advising for students of a given field and level is divided by the number of students in that field and level.

This table has NFR rows and NFL columns. The entry in row i , column j is the number of FTEs per student spent by faculty of field-rank i performing undergraduate advising for students of field-level j . For example, if faculty of field-rank 3 spend 0.1 FTEs advising students of field-level 20 and if there are 100 students in field-level 20, then $0.001 \left(\frac{0.1}{100} \right)$ would be entered in row 3, column 20 of the table.

EFFORT FOR GRADUATE ADVISING

This table is equivalent to the EFFORT FOR UNDERGRADUATE ADVISING table except that it gives the effort per student spent by faculty of each field and rank performing graduate advising for students of each field and level.

This table has NFR rows and NFL columns. As an example of an entry, suppose faculty of field-rank 2 spent 0.05 FTEs performing graduate advising for students of field-level 5 and that there are twenty-five students in field-level 5, then $0.002 \left(\frac{0.05}{25} \right)$ would be entered in row 2, column 5 of the table.

EFFORT FOR THESIS SUPERVISION

This table is equivalent to the EFFORT FOR UNDERGRADUATE ADVISING table except that it gives the effort per student spent by faculty of each field and rank performing thesis supervision for students of each field and level.

This table has NFR rows and NFL columns. As an example of an entry, suppose that faculty of field-rank 10 spent 0.04 FTEs performing thesis supervision for students in field-level 7 and that there are twenty students in field-level 7, then $0.002 \left(\frac{0.04}{20} \right)$ would be entered in row 10, column 7 of the table. Since undergraduates do not in general write theses, the columns corresponding to undergraduate levels will normally be 0.

EFFORT FOR RESEARCH

This table contains the effort spent by faculty of each field-rank doing research, per \$1000 of research grants in each field. The number of FTEs spent by faculty of a given field and rank performing research in

in a given field is divided by the total number of \$1000 of outside research grants received for research in that field.

This table has NFR rows and NF columns. The entry in row i , column j is the number of FTEs per \$1000 outside research grants held by faculty of field-rank i doing research in field j . For example, if faculty of field-rank 9 spent 4 FTEs performing research in field 5 and field 5 has received a total of \$200,000 in outside research grants, then 0.02 ($4/200$) would be entered in row 9 column 5 of the table.

In general, of course, most faculty research effort in a given field will be provided by faculty of the same field, so many entries will be zero.

Each of the following six tables relates faculty effort for some activity to the sum of all faculty effort for the six activities above. That is, for example, a typical entry in the EFFORT FOR SEMINARS AND MEETINGS table is the ratio of the effort a faculty member of a given field and rank spends on seminars and meetings to what he spends on teaching, advising, and research taken together (i.e., on the activities described by EFFORT FOR UNDERGRADUATE and GRADUATE INSTRUCTION, FOR UNDERGRADUATE and GRADUATE ADVISING, FOR THESIS SUPERVISION, and FOR RESEARCH--see above).

EFFORT FOR COMMITTEE WORK

This table has NFR rows, each a single entry. The entry in row j is the ratio of the average effort a faculty member in field-rank j spends on committee work to the effort he spends on teaching, advising, and research (as discussed above).

EFFORT FOR UNDERGRADUATE COURSE DEVELOPMENT

This table has NFR rows, each containing a single entry. The entry in row j is the ratio of the average effort a faculty member in field-rank j spends on undergraduate course development to the effort he spends on teaching, advising, and research (as discussed above).

EFFORT FOR GRADUATE COURSE DEVELOPMENT

This table is identical to the **EFFORT FOR UNDERGRADUATE COURSE DEVELOPMENT** table, except that the effort under consideration is that for graduate course development.

EFFORT FOR PUBLIC SERVICE

This table is identical to the **EFFORT FOR UNDERGRADUATE COURSE DEVELOPMENT** table, except that the effort under consideration is that for public service.

EFFORT FOR SEMINARS AND MEETINGS

This table is identical to the **EFFORT FOR UNDERGRADUATE COURSE DEVELOPMENT** table, except that the effort for seminars and meetings (excluding that effort attributable to one of the other activities such as research, etc.) is to be considered instead of the effort for undergraduate course development.

EFFORT FOR ADMINISTRATION

This table is identical to the **EFFORT FOR UNDERGRADUATE COURSE DEVELOPMENT** table, except that the effort to be considered is that spent on administration (excluding that effort attributable to one of the other activities, such as research, etc.).

The following twelve tables are very similar. A detailed description will be given of the first and the minor differences will be pointed out for those remaining.

FRACTION COST OF SECRETARIES FOR UNDERGRADS

This is a table with NF rows and one column. It contains information on what proportion of the total costs of secretaries for each field is devoted to work directly related to undergraduates. For example, if the secretaries in field 3 devoted 20% of their time to undergraduate related work, the third element of the table should contain a .20. This and the other tables like it are used only by a COMPUTE TOTAL COSTS command and need not be supplied if the user is not interested in the overhead or total costs.

FRACTION COST OF SECRETARIES FOR GRADS

This table is exactly like the above except that it provides information on proportions of time devoted to work directly related to graduate students.

FRACTION COST OF SECRETARIES FOR THESIS AND RESEARCH

This table is exactly the same as the first except that it supplies information on proportions of work related to thesis and research.

FRACTION COST OF EQUIPMENT FOR UNDERGRADS

This table differs from the first in that it contains the proportions of the total costs of equipment of each field that is related to undergraduates.

FRACTION COST OF EQUIPMENT FOR GRADS

This table is the same as the above except that it applies to

equipment costs related to the graduate program.

FRACTION COST OF EQUIPMENT FOR THESIS AND RESEARCH

This table is the same as the above except that it refers to equipment costs related to thesis and research.

FRACTION COST OF SUPPLIES AND SERVICES FOR UNDERGRADS

This table is the same as the first except that it applies to cost of supplies and services related to undergraduate studies.

FRACTION COST OF SUPPLIES AND SERVICES FOR GRADS

This table is the same as the above except that it applies to graduate studies.

FRACTION COST OF SUPPLIES AND SERVICES FOR THESIS AND RESEARCH

This table is the same as the above except that it applies to thesis and research.

FRACTION COST OF LABOR FOR UNDERGRADS

This table is the same as the first except that it contains the proportions of costs of labor related to undergraduate studies in each field. Labor includes all types of labor except that of secretaries and graduate assistants.

FRACTION COST OF LABOR FOR GRADS

This table is the same as the above except that it applies to graduate studies.

FRACTION COST OF LABOR FOR THESIS AND RESEARCH

This table is the same as the above except that it applies to thesis and research.

The costs not accounted for by the preceding 12 tables will be treated as cost of other activities by the program. For example, if the secretaries in field 2 devote 20% of their time to undergraduate related work, 20% of their time to graduate related work, and 30% of their time to thesis and research related work, the program will assume that 30% of their time is devoted to other activities.

FACULTY SALARY SCALE

This table contains salary information for each field and rank of faculty. There are NFR rows each of which contains a single entry. The entry in row j is the average salary of a faculty member of field-rank j. This table is used when the COMPUTE FACULTY COSTS or COMPUTE TOTAL COSTS commands are executed.

ASSISTANTSHIP SALARY SCALE

This table contains salary information for graduate assistants. The table has NF rows and one column. The entry in row j is the average salary of a graduate assistant in field j. (As should be clear, no differentiation is made as to the level of the graduate assistant -- an overall average figure is used.)

4. Computational and Display Commands

COMPUTE ENROLLMENT FROM NEW STUDENTS AID INDEPENDENT

This command causes a projection from year $t-1$ to year t of the number of students in each field and level. The program calculates the number of students attracted by financial aid, using a preliminary estimate of the number of teaching assistants required for the next year, together with the number of scholarships offered and the number of research assistants required. It adds these students to the students entering independent of aid to obtain the total number of new students entering the university in year t , then calculates the number of students expected to carry over, finally obtaining the estimate of the enrollment for year t . Also calculated are the number of students expected to leave the university during or after year $t-1$, the number expected to graduate in year $t-1$, and the projection of student credit hours in each field and level which will be required for year t . The year is finally advanced by 1, and what was formerly regarded as year t will be regarded as year $t-1$ when enrollment is projected again. It is the projection of enrollment which causes this advance of the year under consideration, as the variable assumed best to describe the "state" of the university is the enrollment in each field and level, and when it is projected ahead a year, the university is essentially "in" that new year. All calculations performed by this command may be printed by using the DISPLAY ENROLLMENT command.

COMPUTE ENROLLMENT FROM TOTAL NEW STUDENTS

This command causes a projection from year $t-1$ to year t of the number of students in each field and level and advances the year by 1.

The program calculates the expected enrollment, calculates how many of the new students were attracted by aid, then subtracts to determine how many students entered independent of financial aid. Also calculated are the number of students expected to leave the university during or after year $t-1$ and the number expected to graduate in year $t-1$. The results of all of these calculations may be printed by the DISPLAY ENROLLMENT command.

COMPUTE FACULTY

This command causes calculation of the number of full-time equivalent faculty and half-time graduate assistants which will be required to meet the demands placed upon the university by the student sector and by external demands, such as research grants, during the year under consideration (year t). It utilizes the student enrollment most recently computed or input, together with the demand for credit hours, the amount of research grants, and the faculty effort parameters, to calculate the total number of full-time equivalent faculty of each field and each rank which are required to satisfy the demands. Also calculated are the numbers of graduate assistants required for teaching and research in each field, assuming that each assistant is appointed half-time. The results of these calculations may be printed via the DISPLAY FACULTY command.

COMPUTE FACULTY COSTS

This command causes computation of the direct costs for faculty of each field and rank for the undergraduate program, for the graduate program, for thesis direction and research work, and for other activities. Included as "other activities" are administration, public service,

seminars and meetings, and committee work. This command also causes the calculations of the COMPUTE FACULTY command to be done, so COMPUTE FACULTY need not be used first; instead the command sequence should be COMPUTE FACULTY COSTS, DISPLAY FACULTY, and DISPLAY FACULTY COSTS. Graduate assistants are not included in the costs calculated by this command. In addition to the data required to COMPUTE FACULTY, this command requires the faculty salary scale.

COMPUTE TOTAL COSTS

This command causes computation of overhead costs by field including secretarial, supplies and services, equipment, and labor costs. Each of these costs is distributed among the undergraduate, graduate, and thesis and research programs of each field according to "fraction costs" data, with the proportion of costs not attributable to those programs assigned as "cost of other activities." Costs of graduate research assistants and of graduate teaching assistants are computed. Total costs by field (including faculty, overhead, and graduate assistants) are computed for the undergraduate program, the graduate program, the thesis and research program, and other activities, and the sum of the four is computed (total costs). In addition to the fraction cost data, this command utilizes the assistantship salary scale and the secretarial, labor, equipment, and supplies and services costs. The calculations performed include those of the COMPUTE FACULTY COSTS and COMPUTE FACULTY commands, so if total costs are to be calculated, neither of the former commands need be used -- instead the command sequence might be COMPUTE TOTAL COSTS, DISPLAY FACULTY, DISPLAY FACULTY COSTS, and DISPLAY TOTAL COSTS (however, it

is not necessary to display either faculty or faculty costs unless desired).

DISPLAY ENROLLMENT

This command prints the information computed by the commands COMPUTE ENROLLMENT FROM TOTAL NEW STUDENTS or COMPUTE ENROLLMENT FROM NEW STUDENTS AID INDEPENDENT.

DISPLAY FACULTY

This command prints the information computed by the COMPUTE FACULTY command. It may also be used after the commands COMPUTE FACULTY COSTS or COMPUTE TOTAL COSTS have been executed.

DISPLAY FACULTY COSTS

This command prints the information computed by the COMPUTE FACULTY COSTS command. It may also be used after COMPUTE TOTAL COSTS has been executed.

DISPLAY TOTAL COSTS

This command prints the information computed by the COMPUTE TOTAL COSTS command.

BACK YEAR

This command causes the year to be decremented by one and the enrollment to be replaced by the preceding year's enrollment. The purpose of this instruction is to allow the user to project the enrollment under varying conditions. BACK YEAR should not follow a READ IN YEAR, HERE IS YEAR, INITIALIZE, HERE IS ENROLLMENT, INFLATE ENROLLMENT, READ IN ENROLLMENT, or BACK YEAR without first using a COMPUTE ENROLLMENT or an error flag will be given. It is the user's

responsibility to restore any changes he has made to variables other than the enrollment. BACK YEAR simply replaces the projected enrollment with the enrollment of the year prior to the projection and decrements of the year. No other changes are made by BACK YEAR.

5. Data File Manipulation

Data for MSUSIM2 may be stored on magnetic tape as permanent or semi-permanent files. (See B for details on how to set up the tape configuration for your computer system.) MSUSIM2 allows up to 99 files on any one reel of tape. Each file can contain up to one complete set of parameters for the system. For example, a data file could contain: data for the various departments in a college in a given year; data for several of the colleges in a university in a given year; a projection ahead to a given year; or possibly data from a past year for analysis purposes.

There are three basic commands for manipulating data files. The card following each of these command cards must be a file-number-card. This card must have a 2-digit file number in columns one and two. This file number tells the system which file is to be manipulated.

AUGMENT DATA FILE

The AUGMENT command causes a new file to be put on the tape. The data which goes onto the tape contains all of the parameters which the system has at the time when the command is given. (This data could have been introduced to the system by an INITIALIZE, or by an ESTABLISH followed by a set of HERE IS or READ IN commands.) After the AUGMENT has been done, the parameters remain intact within the system (i. e. , no data are destroyed).

The file number specified for the AUGMENT must be between 0 and 99. If the file number is zero, the system assigns the first available number to the file. In this way the user may AUGMENT the tape without knowing what files are already on it. Note, however, that to reference this file, the user must check his program printout to find its assigned

number. Thus, it would be impossible to reference that file again in the same run.

If the specified file number is between 1 and 99, the file is assigned the specified number unless a file with that number already exists. In this case the system assigns the next available number to the file, and a message is printed giving the number which was actually assigned. An example is:

AUGMENT DATA FILE

02

THE AUGMENT YOU HAVE REQUESTED CANNOT BE MADE. FILE 2 ALREADY EXISTS. FOR THIS RUN ONLY, REFERENCES TO FILE 2 WILL BE INTERPRETED AS REFERENCES TO FILE 4. IN FUTURE RUNS, HOWEVER, YOU MUST CORRECTLY REFERENCE THE DATA SET AS FILE 4.

In this case the user wanted to add a file 2 to the tape, but since there already was a file number 2 on the tape, the system assigned the file to number 4. Then, for the rest of the run, the system remembers that what the user calls file 2 is actually file 4. For example, the command

UPDATE DATA FILE

02

will cause file 4 to be updated as described below.

This relationship between file numbers is called "equivalence"; in this example file 2 is "equivalent" to file 4. The user may have up to five equivalenced files at any one time. Recall that at the end of a run all equivalences are lost.

Following the file-number-card for the AUGMENT command, there must be five cards. The information on these cards will be included with the file information on the tape. These cards may contain a name or description for the file, or they may be blank, but all five cards must be there.

UPDATE DATA FILE

This command causes the data of an already-existing file to be replaced by the data which is currently in the system. The file to be UPDATED is indicated on a file-number-card as described above. The file number must be between 1 and 99. Note that an UPDATE is a total replacement; none of the old data is saved. If the user wishes to change only a small part of a file, one possible command sequence is:

```
INITIALIZE FROM DATA FILE
17
HERE IS
.
.
.
READ IN
.
.
.
INFLATE
.
.
.
UPDATE DATA FILE
17
```

This command sequence causes the following things to happen:

- (1) The data from file 17 is brought into the system.
- (2) The data is altered within the system using any legal user commands (the examples shown are HERE IS, READ IN, and INFLATE).
- (3) The altered data from the system replaces the old data in file 17.

DELETE FROM DATA TAPE

This command causes a file to drop from the tape. All of the data from the file is lost. The file to be DELETED is specified on a file-number-card, and must be between 1 and 99.

There are also three auxiliary commands for manipulating the data tape as a whole. File-number-cards are not allowed after these

commands.

LIST DATA TAPE

This command causes the system to print a complete listing of the files currently on the tape. For each file the system prints the file number, the data when the file was augmented or updated the last time, and the five-card description of the file.

Q25QCOPY

This command causes the system to write a complete copy of the current data tape. This copy can be used as a safety backup, or the two tapes can be used interchangeably.

Q25QINIT

This is a special command, and should be used very carefully. When a fresh tape is to be used for a data tape, Q25QINIT causes the system to write certain essential information on the tape. Q25QINIT must be used before the first AUGMENT command is done on the tape, or an unpredictable error will occur. WARNING: If the command Q25QINIT is given when a tape already has data files on it, all of the files will be destroyed and this data lost!!

6. Miscellaneous Commands

NO LIST

This command prevents all commands following it from being listed in the program output. The main purpose of this command is to allow the user to have program output without commands interspaced in it once he has established a working set of commands. However, a HERE IS or SHOW ME command will cause the referenced variable to be printed. It is the user's responsibility to provide labels for variables referred to by a HERE IS or SHOW ME command while in NO LIST mode. The simultaneous use of DEBUG and NO LIST is not recommended.

HEADING ...

This command allows the user to write headings for anything that is printed in the program output. The heading can be punched in any of the columns after column eight of the HEADING card. If more than one card is required, the word HEADING should appear on each card starting in the first column. The heading will appear in the output with the word HEADING when in LIST mode and without the word HEADING when in NO LIST mode.

DESCRIPTION ...

This command allows the user to provide labels for the fields of study, levels of students, and ranks of faculty. The user should specify which description he is providing by completing the DESCRIPTION card with either OF FIELDS, OF LEVELS, or OF RANKS. On the next card after the DESCRIPTION card the user should punch the labels he wishes to provide, starting in column one of the card. Each label should be

exactly eight characters long. If the label is less than eight characters, the user should leave blanks to fill the remaining spaces. In no case should the label be more than eight characters.

Examples

DESCRIPTION OF FIELDS
CEM^ ^ ^ ^ ^ HPR^ ^ ^ ^ ^ SOC SCI^

DESCRIPTION OF LEVELS
FROSH^ ^ ^ SOPH^ ^ ^ ^ JUNIOR^ ^ SENIOR^ ^

DESCRIPTION OF RANKS
HIGH RANK LOW RANK^

DEBUG

This command prevents the execution of all commands following it that involve computation, display, or tape handling. The purpose of this command is to run a set of instructions and discover any errors that it may contain without the expense of meaningless computation. INITIALIZE, ESTABLISH BACKGROUND, HERE IS, READ IN, and SHOW ME are the only instructions executed while in DEBUG mode. Since the AUGMENT DATA FILE command is not executed in DEBUG mode, care should be taken not to initialize with a file created by an AUGMENT in DEBUG mode because the file will not exist. Care should also be taken to be sure that the data input with a HERE IS or READ IN command, following an ESTABLISH BACKGROUND, is compatible with the number of fields, levels and ranks given, or the program may be terminated.

LIST COMMANDS

This command causes all commands to be listed again after listing has been prevented by a NO LIST command. LIST COMMANDS need

only be used after a NO LIST, but redundant use of it will be treated as a "do nothing" command.

COMMENT

This command allows the user to insert comments throughout a set of commands. The comment can be punched in any of the columns after column eight of the COMMENT card. If a comment requires more than one card, the word COMMENT should appear in the first seven columns of each card. The word COMMENT is printed with the comment in LIST mode and neither the word COMMENT nor the comment is printed in NO LIST mode.

RECOVER

Whenever MSUSIM2 is operating in DEBUG mode, RECOVER is a do-nothing command. Otherwise, when an error occurs, the system prints an error message and scans through the remaining commands (without executing them) until it reads a RECOVER command. RECOVER indicates to the system that it is safe to continue executing even though an error has previously occurred. The RECOVER command should be used sparingly to avoid wasteful computation and possible loss of data. For example, consider the following command sequence:

```

.
.
.
.
INITIALIZE FROM DATA FILE
17
RECOVER
INFLATE STUDENT TRANSITION TABLE
ALL
.05
COMPUTE ENROLLMENT FROM TOTAL NEW STUDENTS

```

```
RECOVER
UPDATE DATA FILE
17
DISPLAY ENROLLMENT
.
.
.
.
```

The mis-spelled INITIALIZE will not be recognized, causing an error. The data from file 17 will not be read in, and the system will begin to scan. A RECOVER command is found almost immediately, and the system continues execution with the INFLATE command. Note, however, that the INITIALIZE was not executed, so that the data within the system is whatever was left over from preceding commands. Thus, when the UPDATE is performed, the data in file 17 will be lost. Always remember: use RECOVER commands sparingly!! (As a rule of thumb, RECOVER should be used only when the commands which follow the RECOVER card should be properly executed even before any of the commands prior to the RECOVER card had been executed.)

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