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Title: SOME ANALYTICAL TECHNIQUES FOR IMPROVING RESOURCE ALLOCATION IN A UNIVERSITY SYSTEM

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Some of the problems concerning the present educational programs which confront the institutions of higher education are reviewed. Resources allocation is at the root of the issue.

Budgeting orientations are presented with special emphasis on Planning Programming Budgeting Systems. PPBS is still in its developmental stage in the field of education, primarily due to the difficulty of measuring educational outputs.

Siegel's method and the improved Churchman-Ackoff procedure are introduced for measuring the relative significance of educational outputs, and for comparing the desirability of alternative programs which are to achieve the organization's objectives.

Cause and effect analysis and input-output analysis procedures are discussed. Linear programming, methods from welfare economics and capital budgeting techniques are presented as potential optimization tools for a university. The following conclusions were made.

1. For more effective analysis and subsequently better decisions in regard to resource allocation, more comprehensive and more relevant data is needed.

2. A management information system may be designed and implemented to meet this need.

3. With the development of new measurement methods and further application of the currently available ones, the output of a university will be more satisfactorily measured. This prepares the way for introducing many analysis and optimization techniques which are widely used in other areas, to the field of education.

4. In applying the Planning Programming Budgeting concepts a long span of time into the future should be considered for more meaningful planning and budgeting.

5. A management information system may be designed to fulfill the information requirements of a Planning Programming Budgeting System.

Some Analytical Techniques for Improving Resource Allocation in a University System

by

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Without the aid and reassurance of my wife, Marie, this task would have not been accomplished. Her interest in discussing the ideas in this thesis and making available her study of the effects of the family background variables on college graduation are very much appreciated.

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CHAPTER I

INTRODUCTION

Purpose of the Study

Some of the contributing factors to ineffective university resource allocation are investigated. The study will also propose techniques and concepts which are expected to help administrators in the institutions of higher education make decisions with more awareness of the cost implications and benefits of the proposed programs. These programs are designed and selected for achieving the institutional goals with defined priorities. The investigation will also provide means of studying some of the educational system's needs and requirements in the future and thus aid in the review and updating of previously chosen objectives. In summary, the purpose of the thesis is threefold, (1) to study and develop procedures for quantifying and evaluating a university's goals, (2) to present ways of relating the university resources (inputs) to the defined objectives, and (3) to propose models for predicting the future requirements of a university.

Statement of the Problem

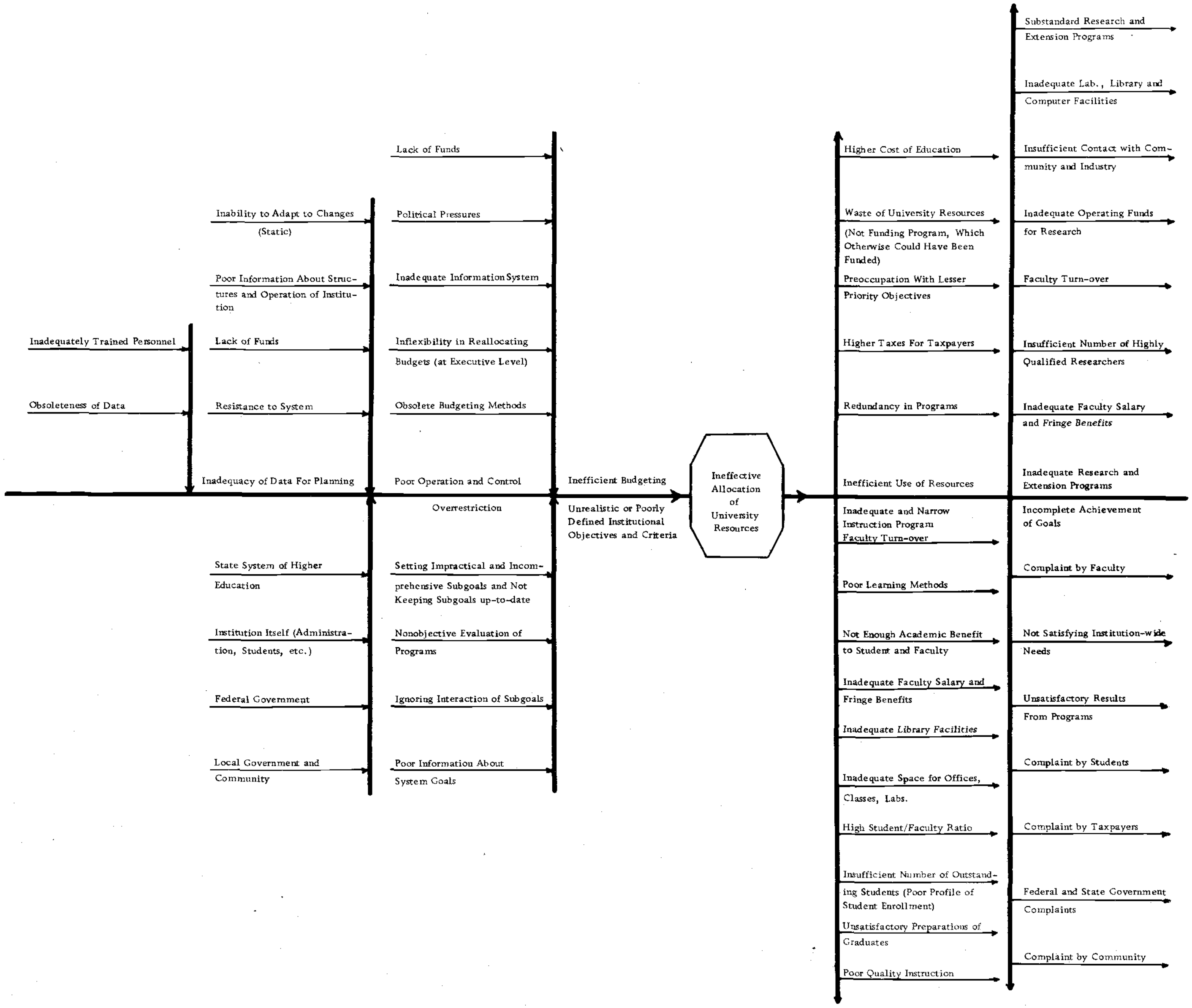
Resource allocation is one of the most significant problems facing today's universities. Some of the contributing factors to ineffective resource allocation include inadequate information systems, obsolete budgeting methods, and poorly defined institutional objectives and criteria.

The cause and effect analysis method was applied and a cause and effect diagram was constructed (Figure 1) to summarize some of the major factors which contribute to ineffective allocation of university resources, and their consequences (Inoue and Riggs, 1970). Resource allocation seems to influence many of the important problems facing today's universities.

Five major causes which underlie the ineffective allocation of the University resources are (1) Inadequate data for institutional planning, (2) Poor operation and control, (3) Over-restriction, (4) Inefficient budgeting, and (5) Unrealistic or poorly defined university objectives and criteria. The institutions of higher education are often criticized for the ineffective allocation of their resources and inefficient use of their assets. The seriousness of the problem has been expressed by President Nixon in these words, "We have neglected to plan how we will deal with school finance. We have great instability and uncertainty in the financial structure of education" (The Associated Press, March 4, 1970). Of course, there are other causes within and without the system which contribute to the problem. But the forementioned five causes are those which more directly relate to the fields of Industrial Engineering, Economics and Business Administration.

Figure 1. A cause and effect diagram[a] for the problem of ineffective allocation of university resources.

[a]This cause and effect diagram was constructed on the basis of the cause and effect analysis procedure (Inoue and Riggs, 1970). In its development and completion the following individuals were consulted: 1) Mr. Tony Birch, Budgeting Officer and Chairman of University Management Data Systems Committee, 2) Dr. Emery Castle, Head of Department of Agricultural Economics and member of the President's Committee on University Goals, 3) Dr. Morris LeMay, Associate Dean of Students and member of University Management Data Systems Committee, and 4) Dr. James Riggs, Head of Department of Industrial Engineering (all from Oregon State University).


Inadequately Trained Personnel
Obsoleteness of Data
Inadequacy of Data For Planning
Inability to Adapt to Changes (Static)
Poor Information About Structures and Operation of Institution
Lack of Funds
Resistance to System
State System of Higher Education
Institution Itself (Administration, Students, etc.)
Federal Government
Local Government and Community
Lack of Funds
Political Pressures
Inadequate Information System
Inflexibility in Reallocating Budgets (at Executive Level)
Obsolete Budgeting Methods
Poor Operation and Control
Overrestriction
Setting Impractical and Incomprehensive Subgoals and Not Keeping Subgoals up-to-date
Nonobjective Evaluation of Programs
Ignoring Interaction of Subgoals
Poor Information About System Goals
Inefficient Budgeting
Unrealistic or Poorly Defined Institutional Objectives and Criteria
Ineffective Allocation of University Resources
Higher Cost of Education
Waste of University Resources (Not Funding Program, Which Otherwise Could Have Been Funded)
Preoccupation With Lesser Priority Objectives
Higher Taxes For Taxpayers
Redundancy in Programs
Inefficient Use of Resources
Inadequate and Narrow Instruction Program
Faculty Turn-over
Poor Learning Methods
Not Enough Academic Benefit to Student and Faculty
Inadequate Faculty Salary and Fringe Benefits
Inadequate Library Facilities
Inadequate Space for Offices, Classes, Labs.
High Student/Faculty Ratio
Insufficient Number of Outstanding Students (Poor Profile of Student Enrollment)
Unsatisfactory Preparations of Graduates
Poor Quality Instruction
Substandard Research and Extension Programs
Inadequate Lab., Library and Computer Facilities
Insufficient Contact with Community and Industry
Inadequate Operating Funds for Research
Faculty Turn-over
Insufficient Number of Highly Qualified Researchers
Inadequate Faculty Salary and Fringe Benefits
Inadequate Research and Extension Programs
Incomplete Achievement of Goals
Complaint by Faculty
Not Satisfying Institution-wide Needs
Unsatisfactory Results From Programs
Complaint by Students
Complaint by Taxpayers
Federal and State Government Complaints
Complaint by Community

These and other causes lead to less effective use of university assets. The gravity of the problem is confirmed by its effects or symptoms which are discussed in the next section of this chapter.

Background

Demands for more and better educational services in the last two decades have placed increasing burdens on universities and other institutions of higher education. Instruction and research, the two basic services of the university, have lagged behind the critical demand factor of increased population. A larger proportion of high school students are entering college. There are estimates and projections that student enrollments doubled between 1960 and 1970 and (the 1960 figure) will triple by 1985 (United States Bureau of the Census, 1966). Social and technical changes have also inflated the enrollment in higher education.

The rate of increase in university resources has not kept pace with the increase in demand. The cost of higher education has risen much faster than academic revenue. Because of this, numbers of prestigious institutions have sizeable annual operating deficits. An example is Yale's educational costs which are rising at a rate of about 8.5 percent annually (in comparison to the income rise of about 7 percent).

The enrollment in private institutions of higher learning, which number two thirds of the nation's 2,200 colleges and universities, has slipped from 50 percent in 1950 to about 34 percent of the total enrollment in 1968 (Hartley, 1968). The growing challenge to state institutions may only be met with more funds from the state and federal governments, expanded endowment funds and other resources. This must be done in order to keep pace with the expanding staff salaries, expensive research, and costly library and computer facilities.

Increased enrollment in the universities in the past two decades, on the one hand, and the lack of funds to keep up with the demand, on the other hand, have confronted many universities with numerous complicated problems. This and the lack of achievement of university goals have raised many relevant questions. "Who is to be educated?"; "What is the Education to be?", and "At what cost?"

Student rebellions, sit-ins, campus disturbances, faculty turnover, higher costs for education, and increased taxes are some of the symptoms of the need for a more clear definition of university functions and goals, and a more effective management of the university system and its resources.

The Current Budgeting and Planning Practices in the Institutions of Higher Learning

> Higher education in the United States is in the midst of a managerial revolution. A tremendous population growth in an era of accelerated social and technological change has created unprecedented demands upon the services of

> colleges and universities in the areas of both instruction and research. These demands have created unusual pressures upon the limited resources, both human and financial, available to the institutions of higher learning (Swanson, Arden and Still, 1966, p. 3).

Efforts have been made in the direction of fund-raising and more efficient use of the available resources. Yale University set the largest fund-raising goal ever for a university at 388 million dollars for the period of 1968-1977 (Hartley, 1968). A symposium on operations analysis of education in 1968 revealed that many institutions of higher learning including California, Toronto and Michigan State universities were making efforts to devise conceptual management techniques.

Current budgetary practices in higher education are concerned with budgets designed for short periods, usually one year.

Koenig, McIntyre and Scheuerman describe the state of planning and budgeting in public higher education institutions in California in 1967 in these words:

> With the exception of the five years capital outlay programs, educational planning and budgeting have run along separate tracks. The annual budget cycle, rather than long-range educational plans, has dictated the pace and limited the vision of the budget plans. All financial decisions are wedged within the repetitive one-year span of the cycle. Budgeting has been oriented to the management of ongoing activities and the control of spending, leaving strategic planning unattended. On the other hand, long-range planning activities, such as the academic planning . . . often excludes multi-year cost implications (Koenig, McIntyre and Scheuerman, 1967, p. 3).

Long-range planning is necessary for making rational decisions regarding investments in personnel, building, and equipment, and educational programs. However, it is neglected in many colleges and universities throughout the nation. At the present time, university budgets reflect one, two, or sometimes even ten years of previous operation, "but very seldom project for more than one or two years" (Williams, 1966, p. 2). Improper planning and overoccupation with past data do not take into account such basic and urgent questions as:

> Why does this college or university exist and for what purposes was it established?
> Were those purposes meaningful?
> To what extent have these purposes been achieved?
> Where does the college or university currently stand with reference to its long-range objectives and purposes?
> To what extent does this college or university contain the necessary flexibility to meet uncertain future requirements? (Williams, 1966, p. 34).

In the planning stage, many other questions should also be answered:

1. What should be the profile of the students enrolled in the present and future. What should be done about the recruitment of talent?

2. What benefits should a student expect to receive from a degree program? What degrees should be granted? A study concerning doctoral training revealed that 69 percent of the graduate faculty and 76 percent of recent doctoral recipients felt that more interdepartmental and similar programs should be developed in order to broaden doctoral study. In another survey, of those who had worked

for two years after completion of their graduate work, long enough to have compared their training against their job experience, 51 percent were very satisfied with their training while 39 percent were fairly satisfied, seven percent just satisfied and the rest were dissatisfied (Berelson, 1960).

3. For how long should the student be educated? In how many years should he receive a degree? Rosenhaupt's study (in Carmichael, 1961) revealed that the average time spent at Columbia University in pursuit of the Ph. D., after admission to graduate school in the following subjects was:

English	10.1 years	Physics	7.0 years
French	9.7 years	History	9.5 years
German	12.5 years	Psychology	5.5 years
Mathematics	7.4 years	Sociology	10.1 years
Chemistry	5.3 years		

(Carmichael, 1961, p. 31)

4. Where should the student be educated? In what institution, school and department?

5. How should the student be educated? Are the present teaching and learning methods satisfactory?

According to Carmichael:

> One of the most difficult adjustments required of university education has been that of fitting the scientific approach to learning into the framework of the historical and traditional modes of thinking and instructional policies inherited from the Middle Ages (Carmichael, 1961, p. 63).

The interaction among the above five factors should be investigated. For instance, "How does the number of required years of education influence the number of applicants?" A nationwide study by the Office of Education's (1965) Center for Statistics revealed that of those who pursue graduate work, only about one-half went immediately from their undergraduate schools into a graduate program, and about one-fifth waited five or six years before entering a graduate school. This might be of concern in the face of pressing needs at the national and state levels for "highly trained manpower and the competition between government, industry, and institutions of higher education for the output of the graduate schools" (Office of Education, 1965, p. 111).

The purpose of each undergraduate and graduate program should be studied. Some believe that the dual purpose of Ph.D. programs--preparation for teaching in the colleges and universities and research work in university, industrial or independent laboratories--has not, as yet, been fully recognized in most universities (Carmichael, 1961, p. 47).

Participatory planning is needed in order to enable teachers and others to take part in the development of policies which concern them. Presently, the educational programs are usually planned by the head of a department, without the participation of all the personnel involved in the program. During the program review and approval, anyone in the chain of command may change the budget without full evaluation of existing and proposed programs. In many instances there is only a vague correlation between an approved budget and the stated objectives of the institution.

There should be an analysis of the "whole system" in order to efficiently use the budget for performing the functions determined by the university objectives.

> In this respect, and in the absence of long-range projections, participatory planning, cost analysis and program analysis, the current budgetary practices are limited as a tool for fact findings, planning, reporting to the decision makers of the institution (Hartley, 1968, p. 215).

In addition, the present budget as an instrument of fiscal control is only input-oriented, while there is much need for an output-oriented financial planning technique.

In the face of increasing demand for the university services and the university's very limited resources, inadequate techniques of allocating scarce resources among competing programs (demands) result in incomplete achievement of the organizational goals. The loss from this misallocation should be measured not only in terms of dollars wasted, but more so in terms of the foregone benefits from the objectives not achieved and the programs not funded.

CHAPTER II

HISTORY AND CONCEPTS OF THE BUDGETING PROCESS

Budgeting has always implied a process of relating expenditures to the accomplishment of objectives. But not until recently was this relationship made explicit.

> Very rarely are planning, management, and control given equal attention in the operation of budget systems. As a practical matter, planning, management and control have tended to be competing processes in budgeting with no neat division of functions among the various participants (Lyden and Miller, 1967, p. 28).

Stages of Budgetary Reform

With these functions in mind, the budget reform may be better studied. Every reform has altered the planning-management-control balance. On this basis, three successive stages of budget reform are identified. First the 1920-1935 period which emphasized the development of an adequate system of central expenditure control. The second stage came into being during the New Deal and culminated in the development of performance budgeting which was more oriented toward the management function. The third stage emerged fully with the institutionalization of planning-programming-budgeting (PPB) which attempts "to link planning and budgeting as well as welfare economics, but its recent development is a product of modern informational and decisional technologies. . ." (Lyden and Miller, 1967, p. 30).

The first wave of reform was based on line itemization of sometimes detailed tabulations of items necessary to operate an administrative unit. Expenditures were commonly classified by class of work, organizational unit, character of expense and method of financing. Functional classification was only sometimes used. The budget, as an instrument of planning, was to include the details of the work plans and specifications of work costs. However, there were some advocates of functional accounting during the 1920's and 1930's.

The expansion of industry, business and government in the New Deal years, the implications of Keynesian economics, as well as other factors changed the orientation to coordination of activities under management. "Accompanying the growing management use of budget process for the appraisal and improvement of administrative performance, and the scientific management movement with its historical linkage to public administration, were far more relevant applications of managerial cost accounting to the governmental operations" (Lyden and Miller, 1967, p. 37). Later, Schick took another aspect of the movement. "Performance budgeting is management-oriented; its principal thrust is to help administrators to assess the work-efficiency of operating units by (1) casting budget categories in functional terms, and (2) providing work-cost measurements to facilitate the efficient performance of prescribed activities (1966, p. 250).

Three major factors have influenced the gradual change from a management to a planning orientation:

> (1) Economic analysis--macro and micro--has had an increasing part in the shaping of fiscal and budgeting policy. (2) The development of new informational and decisional technologies has enlarged the applicability of objective analysis to policy making. And, (3) There has been a gradual convergence of planning and budgeting processes (Schick, 1966, p. 253).

Table 1 exhibits some major differences in budget orientations (Lyden and Miller, 1967, p. 50). In the planning orientation, the emphasis is on defining system's goals in terms of budgeting objectives. The informal and decisional flow is downward. For example, policy instructions are issued prior to the preparation of budget estimates at lower levels. Management responsibility is mainly supervisory. Comprehensiveness of data is also stressed.

Table 1. Some Basic Differences Between Budget Orientations

Characteristic	Control	Management	Planning
Personnel Skill	Accounting	Administration	Economics
Information Focus	Objects	Activities	Purposes
Key Budget Stage (central)	Execution	Preparation	Pre-preparation
Breadth of Measurement	Discrete	Discrete/ activities	Comprehensive
Role of Budget Agency	Fiduciary	Efficiency	Policy
Decisional-Flow	Upward-aggregative	Upward-aggregative	Downward-disaggregative
Type of Choice	Incremental	Incremental	Teletic
Control Responsibility	Central	Operating	Operating
Management Responsibility	Dispersed	Central	Supervisory
Planning Responsibility	Dispersed	Dispersed	Central
Budget-Appropriations Classifications	Same	Same	Different
Appropriations-Organizational Link	Direct	Direct	Crosswalk

Several years lapsed between the peak of performance budgeting in the early 1950's and formation of program budgeting concepts. The first substantial interest in program budgeting emerged in the mid-1950's when several economists, including Smithies, Novick, and McKean, recommended reforming the federal budget system. Smithies also formulated some budget rules, (1) budget proposals should be considered on the basis of objectives which are to be furthered by them, and (2) generally final expenditure decisions should be made only after all claims on the budget are submitted (Lyden and Miller, 1967).

Table 2 summarizes the stages of budgetary reform in the federal government with the administrative concepts and budget formats used by local schools (Hartley, 1968, p. 49). Both planning and systems analysis stages focus on the program objectives, long-range planning and objective criteria for evaluating competing programs. Planning-programming-budgeting is more inclined towards planning than the two previous budgeting reforms. It attempts to improve policy-making by supplying data on the costs and benefits of alternative means of achieving organizational objectives and output measurements to expedite the effective attainment of the stated objectives.

> In order to enable budget-makers to evaluate the costs and benefits of alternative expenditure options, program budgeting focuses on expenditure aggregates; the details come

Table 2. Comparison of the Stages of Budgetary Reform in the Federal Government of the United States with the Dominant Administrative Doctrines and Budget Formats Used by Local School Districts

FEDERAL GOVERNMENT BUDGET REFORM			LOCAL SCHOOL ADMINISTRATION-BUDGET REFORM			
Major Orientation	Approximate Period	Budgetary Intent	Dominant Doctrine of Administration	Approximate Period	Budget Format	Budgetary Intent
			1. Teaching teachers	1870-1885	Underdeveloped	N/A
1. Control	1920-1935	Central control of spending; Prevent administrative abuses	2. Applied Philosophy	1886-1905	Nonstandardized	N/A
			3. Business Management	1906-1935	Object-of-expense	Fiscal accountability; Focus upon things purchased
2. Management	1936-1965	Assess work efficiency; Emphasize performance measurement	4. Technical Expertise	1936-1950	Function-object	Apply industrial management concepts to school finance; provide broad functional categories; unit cost analyses
			5. Administrative Science	1951-1967	Function-object	Apply industrial management concepts to school finance; provide broad functional categories; unit cost analyses
3. Planning	1966	Use budget for policy formulation; Teletic, Extend time horizon; Emphasize programmatic outcomes	6. Systems Analysis	1968	Program	Focus upon instructional programs and objectives; long-range emphasis; specify assumptions; explicit evaluative criteria

> into play only as they contribute to an analysis of the total (the system) or of marginal trade-offs among competing proposals. Thus, in this macroanalytic approach, the accent is on comprehensiveness and on grouping data into categories that allow comparisons among alternative expenditure mixes (Lyden and Miller, 1967, p. 38).

A Brief History of PPBS in the United States

There are two roots of the Planning, Programming, Budgeting Systems (PPBS) in the United States. The first was in the Federal Government where program budgeting was initiated as part of the war-time control system in 1942 (Novick, 1968, p. 8). The second, larger and older, is in industry. It dates back to 1924. According to Novick written documents indicate that the "program budget" was first introduced in General Motors (U. S. Congress, 1967, p. 28).

The Production Requirements Plan of the Federal Government was developed shortly after the Pearl Harbor incident. This was in order to deal with priority and allocation problems. In early 1942, the War Production Board became concerned about the total military and civilian requirements. From 1943 through 1945, the Controlled Materials Plan which may be called the First Federal program budget, made a successful attempt to control the system of production and distribution of its output in the United States. Novick states the following major characteristics which classified Controlled Materials Plan as a program budget:

I. Major goals were identified.
II. Each major goal was identified in program objectives
III. Program objectives were further defined in program elements
IV. Programs crossed service lines so as to identify land, sea, and air forces as well as essential non-military contributions to identical objectives
V. There was an extended time horizon
VI. Alternatives were examined and systematic analysis was made of both supply and requirements (U. S. Congress. Selected Comment, 1967, p. 30).

In 1949 RAND Corporation completed a study on "weapons systems analysis." RAND also published a proposal on the first application of the program budget to the Air Force in 1953. It further suggested extending of the program budget to all military systems.

Finally, in 1961 the initial attempt to adapt PPBS was made in the Department of Defense (Hirsch, 1965). The implementers of this system have made strong claims. Hitch, then the director of the system, summarized his views in these words:

> . . . we have provided for the Secretary of Defense and his principal military and civilian advisors a system which brings together at one place and at one time all of the relevant information that they need to make sound decisions on the forward program and to control the execution of that program. And we have provided the necessary flexibility in the form of a program change control system. The plan . . . extends more than one year into the future; budgets are in balance with programs, programs with force requirements, force requirements with military missions, and military missions with national security objectives.
>
> With this management tool at his command, the Secretary of Defense is now in a position to carry out the responsibilities assigned to him . . . namely to exercise 'direction, authority, and control over the Department of Defense'--and without another major organization of defense establishment (U. S. Congress. Initial Memorandum, 1967, p. 3).

In August, 1965, President Johnson stated that following the success of PPBS in the Department of Defense, he was recommending PPB to be applied to all the executive offices and agencies of the United States Government (Novick, 1968, p. 7).

PPB Concepts and Characteristics

Planning-Programming-Budgeting is one more step to make the budgetary process a more versatile and helpful instrument for the administrator.

While the traditional budget is formulated in terms of expenditures or "inputs," PPBS attempts to link the resources an agency uses to its mission or "outputs." Probing several years into the future PPBS makes an effort to improve the decision-maker's appraisal by investigating the effect of a budget cut or increase on the organizational objectives. Table 3 compares program budgeting with fiduciary budgeting in a university (Williams, 1966).

Key elements of the PPBS approach are program budgeting and systems analysis. "Program budgeting and systems analysis have provided the vehicle by which program planning and budgeting have been joined on one track" (Koenig, McIntyre and Scheuerman, 1967, p. 5). Rath (1968) takes a broader view. "The program budget is only one element of a planning-programming-budgeting system. PPBS embraces five other concepts: systems analysis, multiyear plan, objective-based programs, cost inclusiveness, and administrative commitment" (Rath, 1968, p. 53).

Table 3. The Focus of Program and Fiduciary Budgets

Program Budgeting	Fiduciary Budgeting
Alternative ways to achieve university goals and objectives. Major programs in teaching and research. Resource requirements explicitly related to each program and subprogram. "True" costs of major programs and program elements. Marginal and opportunity costs. Long time periods. Level of activities "produced."	Sources of funds. Constraints on receipt and expenditure of funds. Aggregates of expenditures on Administration Teaching and Research Maintenance Student Services. Legal and administrative accounting for funds. Average cost ratios. Short time periods. Purely fiscal matters.

Systems analysis is intended to present decision-makers with a systematic and comprehensive comparison of the costs and benefits of alternative approaches to a policy goal. It takes advantage of techniques of operations research and cost-effectiveness studies with an emphasis on quantitative analysis. Systems analysis, in this sense, is designed "to maximize or at least increase the value of the objectives achieved by an organization, minus the value of the resources it uses" (Hitch, 1967, p. 37).

Systems analysis serves on the tactical level, presenting decision-makers with a systematic and comprehensive comparison of the costs and benefits of alternative approaches to a goal. It applies the techniques of operations research and cost-effectiveness studies for quantitative analysis. Systems analysis is applied to program budgeting in order to provide it with a general conceptual basis. On the other hand, "program budgeting is the detailed expression of the methodology of systems analysis. The programs of a school cannot be adequately designed and supported without an understanding of the total system that they support" (Hartley, 1968, p. 69). Traditional budgets were preoccupied with the allocation of resources with little regard to the efficiency in attaining the system's objectives. But the emergence of systems analysis and its success in other areas of decision-making made a great impact on the budgeting process. Hitch (1967) states that systems analysis was introduced in the Defense Department with the PPB concept to provide a criterion "for making the hard choices to achieve some rationality and optimality in planning" (p. 38).

Though program budgeting is considered another element within PPBS, the term is also used more broadly to mean the whole planning, programming, budgeting system. Program budgeting produces a program which is (1) organized by programs rather than by the traditional budget objects of expenditure, and (2) extended into the future to give more realistic information about the full resource requirements and financial implications of the scheduled outputs (Hitch, 1967). According to Koenig, McIntyre and Scheuerman (1967):

> Program budgeting and systems analysis commences with the basic assumption that limited resources constrain institutions in satisfying competing demands. The development of a program structure and program statements serves to clarify the nature and extent of the competing demands. The problem of allocating the scarce resources effectively is then met by analytical studies. These so-called cost benefit studies compare the relative costs and effectiveness to an institution's mission (1) of alternative allocations of resources among competing demands and (2) of alternative levels and uses of resources within a program (p. 6).

Planning is the process of deciding on the general objectives, policies and restrictions of the organization. It explores alternative and existing resource limitations which pertain to each alternative or set of alternatives. The planning function may be analyzed by the distance of time into the future to which it corresponds. Long-range planning is usually concerned with new developments with long lead times. This lead time is ten years at the Defense Department while it is about 35 years at the University of California (Hitch, 1967, p. 38). Another critical classification is that of substantive versus fiscal planning. The former is the planning of intermediate and ultimate objectives, while the latter is the planning of future budgets and specifying the way the funds should be spent.

Williams (1966) defines the programming in a university setting as the process by which it can specify more immediate shorter range goals for each of its operating units, these goals reflecting rather directly the results of planning. Programming may be generally defined as the evaluation of the different programs with their unique combination of the available resources which would attain the goals of the institution. It is concerned with the gains and costs of the various objectives. Figure 2 shows the length of time that planning, programming, and budgeting probe into the future (Williams, 1966, p. 33). Programming relates the planned goals to specified alternative programs. In the programming phase, inputs are associated with outputs by lines of action that contain immediate, intermediate and long-run objectives. Existing objectives are reviewed in relation to alternative means and thus revision of procedures are encouraged when needed. Programming is also the specification and assignment of the resources (manpower, materials and facilities) needed to support the programs.

Budgeting is the allocation of resources to the programs in order to accomplish the institutional objectives for which the programs are selected. Budgeting in PPBS, in lieu of expressing budget dollars by an object-of-expenditure classification, shows the dollars in relation to outputs, or programs. A program budget, according to Williams (1966) is "a policy and planning document rather than an accounting document. Its goals are to define program elements at as high a level of aggregation as possible while remaining consistent with a desireable level of homogeneity" (p. 44).

Output orientation is an essential characteristic of PPBS. Each

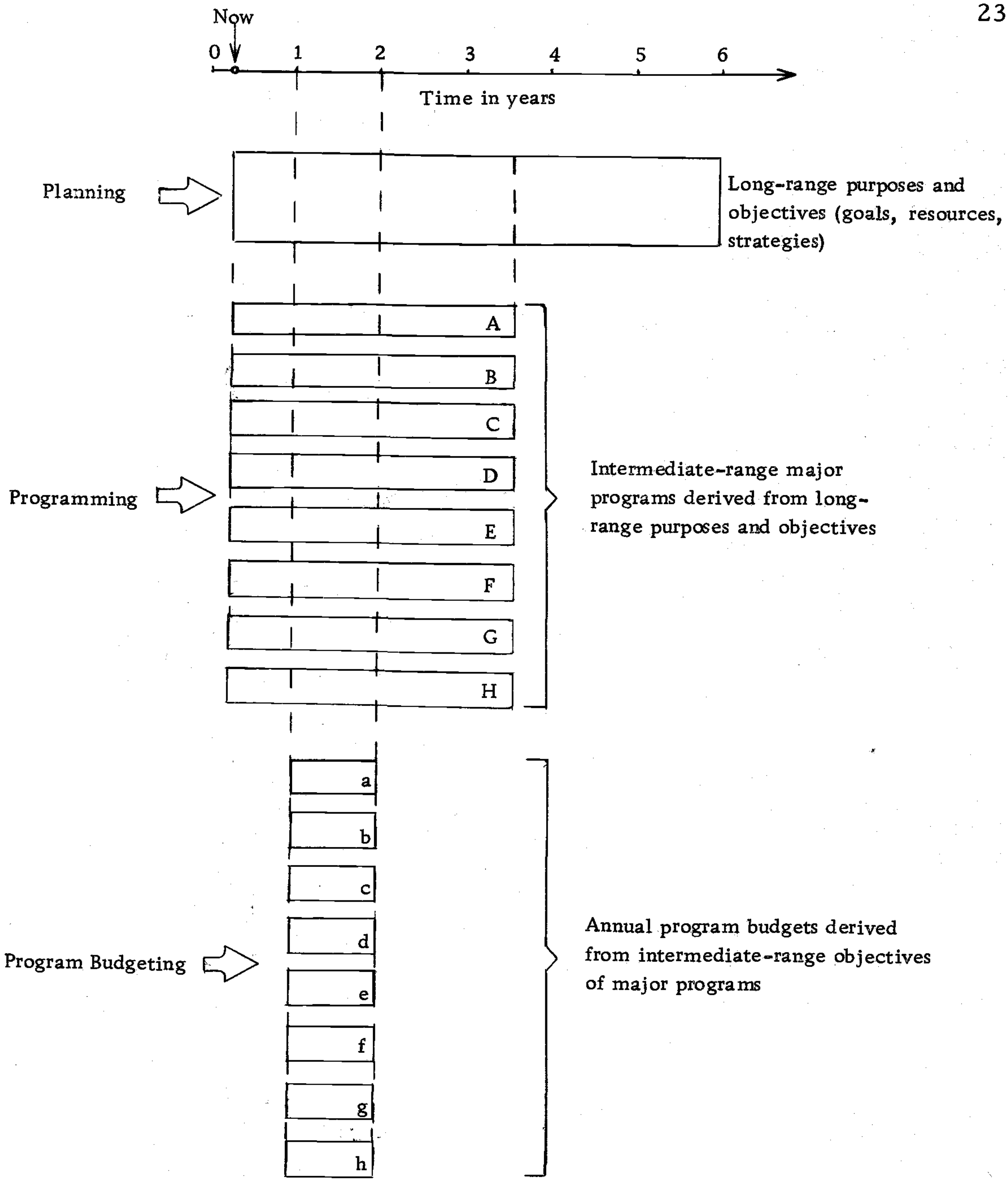


Figure 2. The derivation of program budgets.

subsystem of a PPBS is responsible for compiling several lists of output categories which cover its entire work. Hartley (1968) enumerates 29 other characteristics and advantages of PPBS of which the following are the most important:

1. Strategic Planning-The planning orientation ensures that the budget is to be viewed as the financial expression of a well-defined program structure. It may also serve as an estimate of the requirements for a proposed plan of action.

2. Input-Output Coordination-[The program budget] provides meaningful information on the relation of inputs to outputs or programs of the organization. This represents a rational means-ends calculus which accommodates changes in interests and the priority of objectives.

3. Explicit Objectives-In order to avoid ambiguity of purpose, the objectives for the total system and for each program are specified in operational terms.

4. Long-Range Fiscal Planning-The annual budget is integrated with multiyear projections on a continuing basis.

5. Systems Sciences-Systems analysis procedures are used extensively. Contributions from general system theory, cybernetics, operations research, administrative theory, management sciences, and other systems sciences can be incorporated into the PPBS process in order to make it more responsible to complex human needs.

6. Quantitative Analysis-In order to analyze comparative benefits, quantitative measures are applied if they are available. These include such techniques as: input-output analysis, benefit-cost analysis, cost-effectiveness evaluation, operations analysis, management information system, linear programming, simulation, queuing, gaming, and others. Qualitative measures are also included, and they should play a major role in educational planning.

7. Expenditures by Program Category-Conventional line-item objects are classified according to the end-product, program, or service they support. Thus, all expenditures are classified by program category.

8. Optimal Resource Allocation-[The program budget] is intended to allocate scarce resources in the most efficient manner possible. Solutions to specific subproblems result in suboptimizations. In some cases, however, factors other than optimization may influence decisions.

9. Economic Rationality-[The program budget] is essentially an economic concept designed to serve in the political arena. It represents an encroachment of economics upon politics, and is an embodiment of classical political economy.

10. Models-The construction of management information systems and behavioral-theoretical models is encouraged in order to process data, examine the system's operations, and to specify alternative options. If a computer is used, a model of the organization can be constructed for purposes of simulation and improved program design.

11. Network Diagrams-Complex development projects are created and budgeted for by programming of systematic task-sequence network diagrams. The costing of such packages may be done by PERT/Cost procedures, for example.

12. Decision Centers-Within some organizations using PPBS, decision centers and cost centers are developed so that administrators can have at their fingertips historical and projected information from all phases of activity. These are retrievable from a computer data bank. Simulators of the budget can be developed (p. 90-94).

It should be also emphasized that the program budget incorporates the best features of the executive budget, line-item and object budgets as well as performance budgeting formats. The program budget may thus preserve the past budgeting procedures on both an input and output basis.

The program budget is a proven success in the sense that it has worked with reasonable achievement in agencies at federal, state and local governments, and industry. It seems promising for educational planning.

However, PPBS, like other budgeting systems, has its limitations. Mitchell (1970) summarizes some of the shortcomings, the most significant being:

1. Increased costs - PPBS is designed to increase effectiveness and not to reduce costs. "Not only are there some new costs in management and accounting but, more importantly, many hours of valuable professional time are consumed in making it work" (Gibbs, 1970, p. 55).

2. Goals become distorted - More emphasis may be placed on attaining more measurable goals and thus other objectives be neglected.

3. Measurement difficulties - Matching program objectives against performance is more complicated than some analysts may expect.

4. Overemphasis of efficiency - Sometimes misunderstanding could lead to placing higher priority on "saving" at the expense of "accomplishing."

5. The centralization syndrome - Systems analysis and

electronic data processing are inclined to centralize planning.

6. Organizational strains - After school's objectives are defined analytically, there may be more political resentments and conflict of the old interests. There will be resistance by some teachers to analysis as an intrusion into their professional activities.

7. Transfer problems - The systems models and procedures, developed in other areas, are not applicable to education in their current form.

A systems analyst may, therefore, consider PPBS only as a set of sharp tools which provides the decision-maker with a more rational basis for choosing among alternative policies on the basis of comparing their costs and gains. One must remember that the PPBS concept provides a framework for better management of the available resources, but it will not solve the important problem of raising more funds. In summary, PPBS attempts to enable the decision-maker to:

1. Identify agency goals explicitly and on a time continuum.
2. Select the goals with higher priority.
3. Investigate alternative means of reaching the selected goals (using effectiveness and cost as his criteria).
4. Aquaint himself with the costs of organizational programs in the future years.
5. Measure the performance of organizational programs. In order to do this, he compares the worth of the output

(goods and services) with the dollar value of its input(s) (U. S. Congress, Initial Memorandum, 1967).

CHAPTER III

MEASUREMENT OF EDUCATIONAL OUTPUT

Introduction

Better decision making is probably the most important single factor which could contribute to increasing the effectiveness of university resource allocation. However, to improve the efficient use of the limited resources, human and nonhuman, a system should first lay the foundation for a long-range financial plan. This is based on the institutional goals and objectives, which are to be achieved. A clear set of objectives should be defined and then listed in the order of their priority. This is a prerequisite to Hartley's recommendation. "It is imperative that . . . educational institutions employ all available tools to allocate scarce resources efficiently for those present and future programs demanded by their rapidly growing and changing clientele" (Hartley, 1968, p. 212).

In order to decide on the institutional goals, the system output(s) should first be defined. After the output is determined and measured, one or several objective functions may be formulated and the system's inputs (resources) could be allocated in such a way as to optimize the system's objectives. Anshen (1965) interprets decision making while having the educational system and its peculiarities in mind:

> It is the essence of decision making . . . to choose among alternative ends and to ration scarce means to their accomplishment. At this level of description, no significant distinction exists between profit and nonprofit organizations, or between private and public organizations. All require the ordering of goals, the analysis of their relative contributions to the great aims of the total undertaking, the development of plans, the measurement of alternative resource inputs and their relation to progress toward objectives, rational choice of feasible ends, allocation of means, monitoring of progress and appraisal of results (1965,. p. 1)

The importance of a well-defined set of goals for better analysis of alternatives cannot be overemphasized:

> The highest goal of PPBS is to help decision makers make better decisions--those based on both a clear understanding of organizational objectives and an awareness of the resources available to meet these objectives. These decisions generally follow consideration of programs that can meet new objectives or more effectively deal with existing objectives (Gibbs, 1968, p. 52).

However, one must take notice that not all tasks of PPBS are currently feasible in an educational setting, since PPBS is concerned with:

1. Defining organizational objectives
2. Developing programs to achieve these objectives
3. Measuring benefits and costs of each alternative in attaining each goal
4. Constructing long-range plans, and
5. Investigating, systematically, the most effective alternatives (programs) for reaching defined objectives.

Gibbs, immediately acknowledges the above fact:

> The development of the instruments of evaluation is presently the most difficult portion of PPBS to implement. It requires that objectives be stated in such a manner that measurement is possible; and this supposes that instruments for measurement have been developed. Thus, the means of evaluation cannot be separated from the work of stating objectives, to a viable objective. We will need to develop many more measuring instruments than are presently available . . . (Gibbs, 1968, p. 52).

Judy also brings up the same point. "If goals and objective functions are extraordinarily difficult to specify, outputs inevitably must be difficult to identify and measure" (Judy, 1967, p. 42).

This problem still confronts systems analysts in the institutions of higher education since it is difficult to define an end product or output for a university. Conceptions of the product of the university system are numerous and different. This and the difficulty of applying quantitative measures to them has defied efforts to design a truly satisfactory measure of university output.

> Because we cannot measure directly the true output of universities--incremental knowledge--we use such substitute measures of university output as student credit-hours, student clock-hours, student enrollment, or students graduated. These measures may be satisfactory for some purposes (Firmin et al., 1967, p. 21).

Koenig, McIntyre and Scheuerman explain the situation in these words:

> It is assumed in applying systems analysis to most organizations that the end product goals can be quantified. In higher

> education, the principal end products are educational students, additions to the fund of knowledge and other institutional services used by the public. It appears impossible at present to measure these outputs in any meaningful fashion. For example, the numbers of degrees awarded can be measured, but the changes in qualities of students caused by the educational environment are not readily measurable. Similarly, the economic pay off of newly discovered knowledge is difficult to identify and measure without a lapse of many years (Koenig, McIntyre and Scheuerman, 1967, p. 11).

Swanson, Arden and Still in Financial Analysis of Current Operations of Colleges and Universities point out:

> The measurement of [the] products [of institutions of higher learning] involves a qualitative judgement on the value or success of the services performed. Unfortunately, in the field of higher education, the development of measures of such success has not proceeded to point even approaching the possibility of universal or widespread agreement. It, therefore, would be extremely difficult and even dangerous to try to relate a financial analysis to the 'products' of an institution of higher learning when these products cannot be clearly defined, let alone given any sort of qualitative measure (Swanson, Arden and Still, 1966, p. 27).

Swanson, Arden and Still (1966) further state that "a measurement of quality in higher education at the present time is a highly subjective matter." This fact limits the application of PPBS to higher education at its present stage of development, in the sense that "the potential payout for PPBS is management decisions which help the system accomplish its objectives in the most effective manner" (Gibbs, 1968, p. 55). PPBS in the field of education is still in its developmental stage. In fact, "the planning techniques of varying levels of sophistication that have been employed in noneducational settings may suggest some useful carryover for education" (Hartley, 1968, p. 18). Other tools and models developed in noneducational contexts may also be valuable in the development of programming and budgeting stages of an educational PPBS. "Maximization methods such as linear programming, simulation, game theory, and other techniques . . . have been developed to help assess the efficiency of alternative input combinations for achieving output goals" (Hartley, 1968, p. 30). But these models are still not suitable for the educational institutions due to measurement problems which are associated with nonprofit organizations.

Attempts have been made in the past to measure and evaluate instruction. Alkin, (1967) used the systems approach to investigate the problem of evaluating instruction and to specify the basic components of the educational output.

Measurement Concepts and Techniques For an Educational System

Measurement of utility is known to date back to Jeremy Bentham (1789), but it was not until 1943 that Von Neumann and Morgenstern (1953) developed a more widely accepted procedure.

Von Neumann and Morgenstern (1953), in their calculation of utility made the following assumptions about the subject's behavior:

1. Transitivity - If the subject prefers A to B and B to C,

then he prefers A to C. This argument may also be made for the subject's indifference to the alternatives where indifference-curves are constructed on this basis.

2. Continuity of Preference - If S prefers A to (N)(M) when $N = X_1$, and prefers (N)(M) to A when $N = X_2$, then at some point between the values X_1 and X_2 he is indifferent between (N)(M) and A. In other words if $X_1 M \geq A$ and $A \geq X_2 M$, there exists a probability, Pa, such that A and $\{Pa:X_1 M, (1-Pa):X_2 M\}$ are indifferent.

3. Independence - If S is indifferent between A and B, and between C and D, then he must be indifferent between the choices [P:A, (1-P):C] and [P:B, (1-P):D]. In other words, if A = B and C = B, then [P:A, (1-P):C] = [P:B, (1-P):D] for any probability P.

4. Desire for high probability of success - This is in order to eliminate the subjects who sometimes prefer danger and adverse odds. Thus, if S prefers E to D, then for any two probabilities P_1 and P_2, $[P_1:E, (1-P_1):D] > [P_2:E, (1-P_2):D]$, if and only if $P_1 > P_2$.

5. Compound Probabilities - When compound probabilities are involved, the S's attitude should be "the same as though he had gone through all the probability calculations to find out . . . ultimate odds of winning and losing" (Baumol, 1965, p. 522). Consequently, for

any alternatives E and D and any probabilities P, Pa, and Pb, $\{P:[Pa:E, (1-Pa):D], (1-P):[Pb:E, (1-Pb):D]\} = [r:E, (1-r):D]$ where r is a probability equal to $PPa + (1-P)Pb$.

The above five assumptions made by Von Neumann and Morgenstern are considered attractive by many, but they have been challenged. Though there is not an intention of judging these assumptions here, but assumptions three and five have been rather controversial in the past.

Another basic assumption of the utility measurement is that if the utility of A is U_a and the probability of attaining A is p, then the utility of the outcome is pU_a.

In order to estimate the utility of outcomes to the decision maker, one may determine $A > B$ type of preference relationships, and then find the probability p such that $pA = B$. That is the utility of A with a probability of p is equal to the utility of B with certainty. Also in a more general case involving n outcomes, the decision maker ranks the outcomes in the order of his preference and then considers pairs of outcomes.

Churchman and Ackoff (1954) developed an alternative procedure which does not involve probabilities but is suitable only for go-no-go outcomes which have independent utilities. Siegel (1964) also developed a method for obtaining an ordered metric scale which is based on a person's utility of two entities or two groups of entities, each of the two outcomes having a probability of $\frac{1}{2}$.

There are two sides to every theory of measurement--the logical side and the operational side. The first corresponds to a set of axioms specifying operations and relationships. The second corresponds to "A set of operations on objects themselves by means of which they can be observed, in respect to some attribute, to satisfy certain axioms" (Coombs, 1952, p. 3). Scales, developed on the basis of measurement correspond in principle to a set of axioms.

Figure 3 shows a lattice of scales. The connecting lines between two scales show that the axioms of the lower scale are included in the postulates of the higher scale. The higher the scale the less is its generality, i.e., fewer object systems can satisfy it (Coombs, 1952).

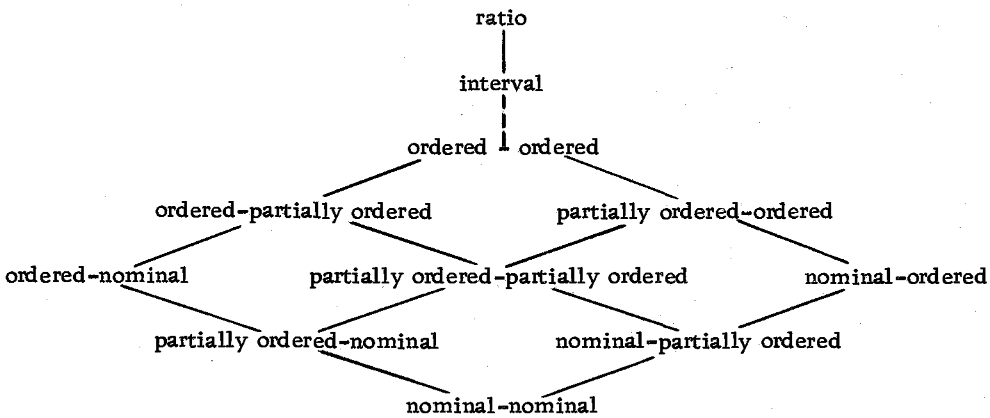


Figure 3. A lattice of scales.

There are basically four scales of measurement, the ratio scale, the interval scale, the ordinal scale, and the nominal scale. Von Neumann and Morgenstern's measurement (1953) of utility gives the information for the selection of an origin and a unit of measurement which are required for an interval scale.

Siegel's Method for Obtaining an Ordered Metric Scale

An ordered metric scale gives the order of objects (or goals) on a continuum and also the distances between the objects which are at least partially ordered. Therefore this type of scale is weaker than an interval scale, but more powerful than an ordinal scale.

For the construction of this scale, Siegel (1964) points out that the subject must be both consistent and transitive in his preferences with respect to a group of objects or entities.[1] The method is based on paired comparisons. "This method is particularly suitable for the measurement of utility, which is a central concept in decision theory" (Siegel, 1964, p. 62). The derived metric scale provides the following information:

1. The order of the entities, i.e., A>B>C>D ....
2. The order of distances between the entities, e.g., $\overline{AB}>\overline{CD}>\overline{BC}$ ... where the distances designated by the letters

---

[1] Siegel defines the utility of an entity as, roughly, the subjective value of that entity.

imply the difference between the utilities of the corresponding entities.

3. The order of all possible combinations of adjoining distances between the entities, i. e., say $\overline{AB}+\overline{BC}+\overline{CD}>\overline{EF}+\overline{FG}$.

The scale may be called higher-ordered metric because the information in part (3) is additional to that required for a partial ordering of distances between the objects.

The method is versatile and practical in the sense a subject can rather easily: (1) decide whether he prefers one entity to another, (2) completely order probability combinations of entities. This is particularly more convenient when the choice is of the form, say, $(A, E; \frac{1}{2})$ or $(B, D; \frac{1}{2})$. The subject can attain a clear understanding that he must choose between A or E with a 50-50 chance, and B or D with an equal certainty of occurrence. This information gives the differences between the entities on a utility scale (Figure 4).

Lattice theory offers a heuristic device for signifying the minimum information required for constructing a higher-ordering of probability combinations of entities. It also demonstrates which probability combinations are nonorderable (the lattice points not connected, e.g., $(A, C; \frac{1}{2})$ and $(B, B; \frac{1}{2})$. If $A>B>C>D>E$, any two probability combinations connected by lines which are consistently going up can be ordered, with the higher-probability combination being preferable to the lower. For example,

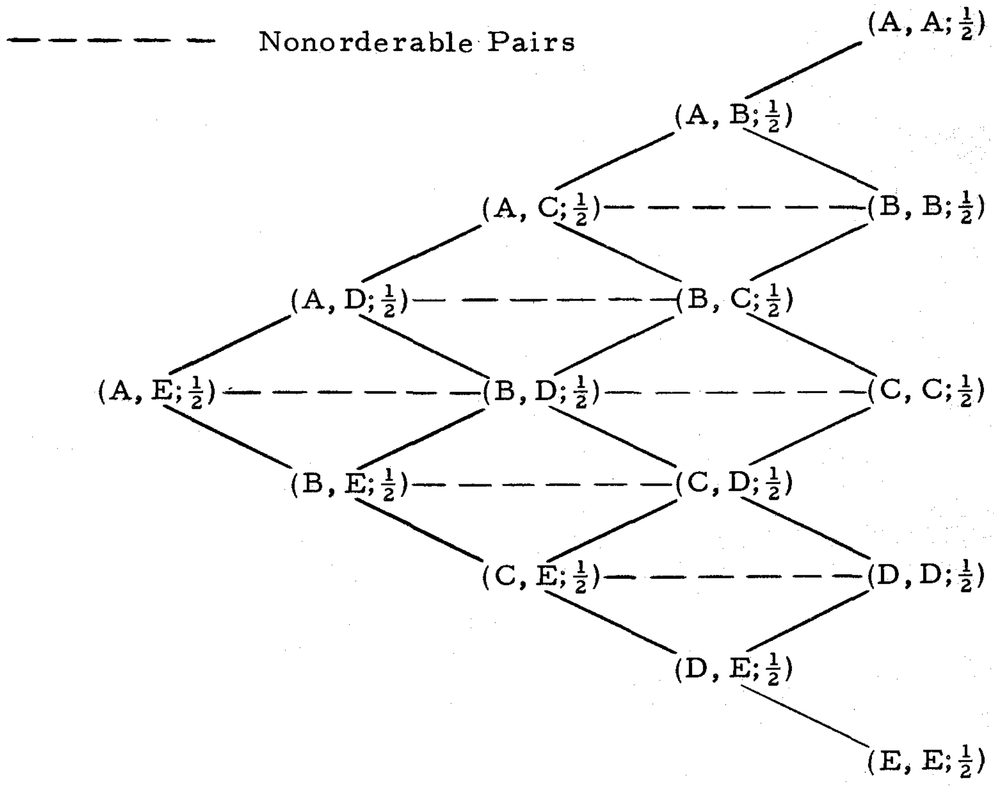


Figure 4. Lattice for ordering entities.

$$(A, D; \tfrac{1}{2}) > (B, D; \tfrac{1}{2})$$

$$(A, B; \tfrac{1}{2}) > (B, B; \tfrac{1}{2})$$

$$(B, C; \tfrac{1}{2}) > (B, D; \tfrac{1}{2})$$

But the information about the preference between some of the nonorderable probability combinations is necessary for a higher-ordered metric measurement. The information about the remaining nonorderable pairs can be predicted from the constructed scale and may be used as a check. The expression $\binom{N+1}{4}$ gives the number of nonorderable pairs, where N is the number of entities to be scaled.

The Algorithm. Siegel (1964) developed the following algorithm for constructing a higher-ordered metric scale:

1. Consider p in the probability combination (X, Y;p) to be subjective, or represent the degree of belief.
2. Let the subject find an entity with a subjective probability of one-half. This is to be determined experimentally.
3. Confront the subject with entities which he will rank by the method of paired comparisons.
4. Require the person to rank the nonorderable pair of probability combinations (those which cannot be ordered from the lattice).
5. Select those choices which can be used to determine an ordered metric scale.
6. Group the choices which will aid the determination of

higher-ordered metric scale. And finally,

7. Check the remaining choices for consistency with the scale constructed from step (6). This is done by comparing the choices stated against those predicted from the scale.

Step (3) is equivalent to a one-person game where the person is to choose between two alternatives, each with two outcomes:

	(P)	(1-P)
Alternative 1	A	B
Alternative 2	C	D

If the subject chooses Alternative 1 his utility is equal to $(U_a)(p) + (U_b)(1-p)$, where $p = \frac{1}{2}$.

In an experiment which involved five objects, Siegel (1964) required the subject to state his preference. The subject made the following choices:

A > B	B > D
A > D	B > E
A > C	C > D
A > E	C > E
B > C	D > E

which give the ranking A > B > C > D > E.

Then the subject was introduced to the one-person game. He made these choices:

a. $(A, C; \frac{1}{2}) > (B, B; \frac{1}{2})$

b. $(B, D; \frac{1}{2}) > (C, C; \frac{1}{2})$

c. $(D, D; \frac{1}{2}) > (C, E; \frac{1}{2})$

d. $(C, D; \frac{1}{2}) > (B, E; \frac{1}{2})$

e. $(B, D; \frac{1}{2}) > (A, E; \frac{1}{2})$

f. $(D, D; \frac{1}{2}) > (A, E; \frac{1}{2})$

g. $(A, D; \frac{1}{2}) > (B, B; \frac{1}{2})$

h. $(A, D; \frac{1}{2}) > (B, C; \frac{1}{2})$

i. $(B, B; \frac{1}{2}) > (A, E; \frac{1}{2})$

j. $(C, C; \frac{1}{2}) > (B, E; \frac{1}{2})$

k. $(B, C; \frac{1}{2}) > (A, E; \frac{1}{2})$

l. $(A, D; \frac{1}{2}) > (C, C; \frac{1}{2})$

m. $(D, D; \frac{1}{2}) > (B, E; \frac{1}{2})$

n. $(C, D; \frac{1}{2}) > (A, E; \frac{1}{2})$

o. $(C, C; \frac{1}{2}) > (A, E; \frac{1}{2})$

From an expression such as $(U_a)(p) + (U_b)(1-p) > (U_c)(p) + (U_d)(1-p)$ where $p = \frac{1}{2}$, one can write $U_a + U_b > U_c + U_d$ or $U_a - U_c > U_d - U_b$ which on the scale is equivalent to $\overline{AC} > \overline{DB}$, i.e., the difference between the utility of A and C is greater than that of D and B. Thus, from the choices made in a through o, we can correspondingly write:

a'. $\overline{AB} > \overline{BC}$

b'. $\overline{BC} > \overline{CD}$

c'. $\overline{DE} > \overline{CD}$

d'. $\overline{DE} > \overline{BC}$

e'. $\overline{DE} > \overline{AB}$

f'. $\overline{DE} > \overline{AD}$

g'. $\overline{AB} > \overline{BD}$

h'. $\overline{AB} > \overline{CD}$

i'. $\overline{BE} > \overline{AB}$

j'. $\overline{CE} > \overline{BC}$

k'. $\overline{CE} > \overline{AB}$

l'. $\overline{AC} > \overline{CD}$

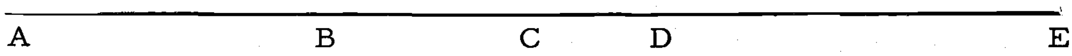
m'. $\overline{DE} > \overline{BD}$

n'. $\overline{DE} > \overline{AC}$

o'. $\overline{CE} > \overline{AC}$

From the first five relations we may construct an ordered metric scale, $\overline{DE} > \overline{AB} > \overline{BC} > \overline{CD}$. Statements f' and g' add the further information needed for a higher-ordered metric scale. The remaining relations provide checks on the uniqueness and validity of the derived higher-ordered metric scale.

The information $A > B > C > D > E$ is required for an ordinal scale, while $\overline{DE} > \overline{AB} > \overline{BC} > \overline{CD}$ is needed for an ordered metric scale. We also know that $\overline{AE} > \overline{BE} > \overline{CE} > \overline{DE} > \overline{AD} > \overline{AC} > \overline{AB} > \overline{BD} > \overline{BC} > \overline{CD}$ which measures a higher-ordered metric scale.



The experiment with 10 subjects showed that 9 were consistent in their ranking.(Siegel, 1964).

Siegel's method seems applicable to an educational setting where the university official may go through the algorithm in order to construct his higher-order metric scales for university goals and objectives and to define institutional priorities.

Churchman-Ackoff Evaluation of Outcomes

This measurement procedure is based on the following assumptions (Ackoff and Sasieni, 1968)

1. A real nonnegative number, U_j, corresponds to every outcome (alternative or goal), A_j. U_j may be interpreted as

a measure of relative importance of A_j or its utility.

2. $U_j > U_k$ means that A_j is more important than A_k and $U_j = U_k$ denotes that A_j and A_k are of equal importance.

3. The utilities of A_j and A_k are additive, i.e., the importance of A_j and A_k combined is $U_j + U_k$. If A_j and A_k are mutually exclusive or dependent outcomes, this assumption is not valid.

The Algorithm. In order to generate utilities, based on the above assumptions, the following procedure should be followed:

Step 1. Require the decision maker to rank all the outcomes, n, in the order of his preference. Label the outcomes A_1 through An, A_1 being the most preferred and An the least favored.

Step 2. Let U_n, the utility of A_n, equal to "1" and ask the decision maker to assign numbers, according to his preference, to the remaining outcomes.

Step 3. Have him study the program of choices presented in Table 4 Require him to state his preference starting from upper-left hand corner of the table. As soon as the left-hand side of a choice is stated to be equal to or more important than the right-hand side advance to the top of the next column to the right.

Table 4. John Plummer's Augmented Program of Churchman-Ackoff Utility Choices.

Start A_1 or $A_2 + A_3 + \ldots + A_n$	A_2 or $A_3 + A_4 + \ldots + A_n$		A_{n-2} or $A_{n-1} + A_n$
A_1 or $A_2 + A_3 + \ldots + A_{n-1}$	A_2 or $A_3 + A_4 + \ldots + A_{n-1}$		Stop
A_1 or $A_2 + A_3 + \ldots + A_{n-2} + A_n$	A_2 or $A_3 + A_4 + \ldots + A_{n-2} + A_n$		
A_1 or $A_2 + A_3 + \ldots + A_{n-2}$	.		
A_1 or $A_2 + A_3 + \ldots + A_{n-3} + A_{n-1} + A_n$	.		
A_1 or $A_2 + A_3 + \ldots + A_{n-3} + A_{n-1}$	.		
.		. . .	
.			
.			
A_1 or $A_2 + A_3$	A_2 or $A_3 + A_4$		
Next column	Next column		

Step 4. Check the numbers obtained in step (2), which have been concealed from the subject against the choices made in step (3). If the results from steps (2) and (3) are not consistent make the minimum adjustment in the numbers to make them agree with the inequalities.

Step (4) may be done by the application of a linear programming model which will give almost identical answers to the trial and error method (Inoue and Ghaffari, 1970). Gross inconsistencies in steps (2) and (3) will result in unbounded or infeasible answers in the LP model.

Example. Ackoff and Sasieni (1968) give, as an example, the following weights to five alternatives (steps 1 and 2):

(a) A_1:7

(b) A_2:4

(c) A_3:2

(d) A_4:1.5

(e) A_5:1 ,

where A_1 may be an instruction program, A_2 a research program, A_3 a public information service program, A_4 a student activity program, and A_5 a construction project.

From the choices in Table 4 , they state the following preferences:

(1) $A_1 < A_2 + A_3 + A_4 + A_5$

(2) $A_1 < A_2 + A_3 + A_4$

(3) $A_1 < A_2 + A_3 + A_5$

(4) $A_1 > A_2 + A_3$

(5) $A_2 < A_3 + A_4 + A_5$

(6) $A_2 > A_3 + A_4$

(7) $A_3 > A_4 + A_5$

Finally, they make the necessary trial and error adjustments, to make the assigned numbers consistent with the stated inequalities. The resulting relative utilities are:

the instruction program,	A_1:8.5
the research program,	A_2:5
the public information service program,	A_3:3
the student activity program,	A_4:1.5
the construction project,	A_5:1

The linear programming model is based on the rankings of step (2) and the inequalities in step (3). The model maximizes the weighted sum of the alternatives:

Maximize $Z = 7A_1 + 4A_2 + 2A_3 + 1.5A_4 + A_5$

Subject to: $A_j \geq o$, for $j = 1, \ldots, 5$

(1') $A_1 - A_2 - A_3 - A_4 - A_5 \leq o$

(2') $A_1 - A_2 - A_3 - A_4 \leq o$

(3') $A_1 - A_2 - A_3 - A_5 \leq o$

$$(4') \quad -A_1 + A_2 + A_3 \leq 0$$

$$(5') \quad A_2 - A_3 - A_4 - A_5 \leq 0$$

$$(6') \quad -A_2 + A_3 + A_4 \leq 0$$

$$(7') \quad -A_3 + A_4 + A_5 \leq 0$$

$$(a') \quad -A_1 + A_2 \leq 0$$

$$(b') \quad -A_2 + A_3 \leq 0$$

$$(c') \quad -A_3 + A_4 \leq 0$$

$$(d') \quad -A_4 + A_5 \leq 0$$

$$(e') \quad A_5 = 1$$

$$A_1 + A_2 + A_3 + A_4 + A_5 = 19$$

The equation $A_5 = 1$ is specified in order to avoid the assignment of a null utility. Another set of restrictions of the type $A_i \geq A_{i+1} + C$ could be added to assure a minimum distinguishable difference between each pair of alternatives. The last statement is made in order to set an upper limit for the utility values so the solution will be bounded. In this case it is set equal to 19 so that the answers could be compared with the previously obtained values:

Alternatives	Original estimates	Ackoff and Sasieni Trial and Error	LP
A_1	7	8.5	9.0
A_2	4	5	5.0
A_3	2	3	3.0
A_4	1.5	1.5	1.0
A_5	1.0	1.0	1.0
		19.0	19.0

The linear programming answers compare favorably with the result of the trial and error procedure of step (4). The initial and final tableaux of the model are presented in the Appendix.

The trial and error method of step (4) gives non-unique answers and could become time consuming. The linear programming procedure is more structured and alleviates these difficulties. When the set of data, provided by the decision makers is inadequate or conflicting it will result in an unbounded or non-existent solution.

On the basis of this algorithm a scale may be constructed for a large number of alternatives. This is done by the described routine which may be applied to groups of as many as eight entities at a time (Ackoff and Sasieni, 1968). This and the assumption of independence of the value of alternatives will erase Fishburn's (1964) objections to astronomical number of outcomes (when there are even 10 variables which could take on 10 values there may be up to 10^{10} outcomes), and the subject's inability to clearly state his preference in situations where outcomes are composed of a large number of variables.

The above procedures may be further supplemented with an <u>exponential comparison model</u>. The objectives of a university may be ranked from several aspects such as economic, academic, and political. According to each criterion, one scale may be constructed for the alternatives or competing objectives. Then, each scale is assigned a weight. Finally the alternatives may be compared two at a time. This process may also be followed for decisions at the programming level of PPBS where a program must be selected. An example may help to explain the model.

The following three scales are constructed and then assigned the importance weights of 4, 3, and 5 (Figure 5). On the basis of the scale weights one of the three programs 1, 2, and 3 must be chosen.

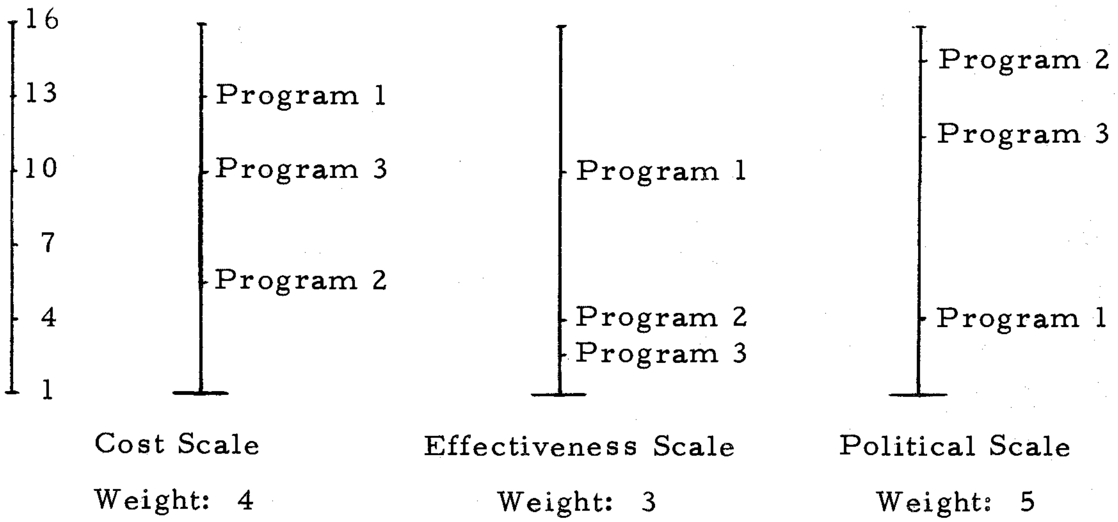


Figure 5. Scales for exponential comparison.

The exponential model makes the following evaluations:

$$\frac{\text{Program 1}}{\text{Program 2}} = \left(\frac{13}{5.5}\right)^4 \left(\frac{10}{4}\right)^3 \left(\frac{4}{14.5}\right)^5$$

$$= (2.36)^4 (2.5)^3 (0.276)^5$$

$$= 0.83 < 1$$

Since preference is indicated by larger numbers, the larger denominator indicates that Program 2 is favored over Program 1. In the same manner Program 3 may be compared with Program 2:

$$\frac{\text{Program 3}}{\text{Program 2}} = \left(\frac{10}{5.5}\right)^4 \quad \left(\frac{2.5}{4}\right)^3 \quad \left(\frac{11.5}{14.5}\right)^5$$

$$= (1.82)^4 \quad (0.625)^3 \quad (0.793)^5$$

$$= 0.85 < 1$$

Consequently, Program 2 is to be chosen. The strength of the exponential model is in its incorporation of objective as well as subjective measures (Riggs, 1970). So the comparison may include such dimensions as dollars, academic benefit to the students and public relations.

Development of a Single Scale Representing Group Preference

Objective measures of an institution's utility or priority of each of its many objectives is essential for a more clear definition of relationships between the inputs and outputs of the organization.

However, there are many decision makers in a university system. For such situations there are basically two kinds of procedures (Ackoff and Sasieni, 1968):

1. Open decisions. An open vote can be taken on each choice offered to the decision makers, and some criterion as 'majority rules' can be applied to the outcome. The criterion selected should be the same one used in their normal decision-making procedure.
2. Closed decisions. Each decision maker goes through the evaluation procedure privately. Then the utility assigned to each outcome is some function of the utilities of the individuals; for example, the average. In some cases the individual decision makers may themselves be weighed

> by a superior who desires to have the value that he places on their judgements reflected in the ultimate utilities. The superior can be put through the Churchman-Ackoff procedure to obtain weights on each manager, W_k. Then we obtain each manager's (k) utility of the jth outcome, U_{jk}. The final utility of an outcome can then be $\sum_k W_k U_{jk}$ (p. 55).

Elsner, in his discussion of scale synthesis, proposes a similar procedure ". . . once these competence percentage evaluations are made, they can be incorporated into the scale synthesis procedure by multiplying them by the respective scale position values" (Elsner, 1970, p. 63). These procedures could be applied to construct a single scale for a panel of decision makers who determine the priorities of the university objectives. There are alternative ways of constructing a single scale representing the preference of a panel of decision-makers. One is the traditional and simple round-table discussion among the panel members which requires them to arrive at an agreed-upon group scale for the alternatives. Helmer (1967) raises the objection that:

> The outcome is apt to be a compromise between divergent views, arrived at all too often under the undue influence of certain psychological factors, such as specious persuasion by the member with the greatest supposed authority or even merely the loudest voice, and the bandwagon effect of majority opinion (p. 7).

He proposes The Delphi Method of obtaining a consensus opinion. In this technique, the decision-makers are given an instruction sheet and the list of alternatives and are asked to rank them. Then, a questionnaire is given to the participants with a summary of the distribution of the initial responses by indicating the median and the interquartile range. The respondents are then asked to reconsider their previous rankings and revise them if they desire. The decision-makers who assign values outside the interquartile range in this round are asked to state their reasons for the high or low values. This action has the effect of bringing those without strong convictions to adjust their rankings closer to the median, while those with good arguments tend to stay close to their original numbers.

In the next round, the responses (which now hopefully have a smaller spread) are again outlined, and the reasons for supporting extreme positions are summarized. After exposure to this material, the members are once again asked to revise their answers. Those still remaining outside the interquartile range are required to state their reasons for not agreeing with the majority.

In the final round these arguments are resubmitted and the decision-makers are given a last chance to revise their ratings. The median of these responses for each alternative may be considered representative of the group consensus.

According to Helmer "convergence of opinions has been observed in the majority of cases where the Delphi approach has been used" (Helmer, 1967, p. 9). In a few cases the opinions tended to polarize. This could have been because of different interpretation of the same information or due to different sets of data.

The number of rounds in the Delphi method may be increased when more convergence of opinions is desirable. The technique could be coupled with the concept of assigning weights to opinions. In that case, only the persons with higher competence (based on self-appraisal or appraisal by other members) in a particular field may be considered in the calculation of the median for the group.

Helmer points out that a typical application of the technique is in budgetary decisions based on cost-benefit estimates; "in practice, benefits resulting from the choice of given policy alternatives are almost never capable of unambiguous measurement. In such cases, a consensus of judgements made by experts may be helpful in obtaining an appraisal" (Helmer, 1967, p. 10).

Two other points also merit attention, (1) selection of experts or panel of decision-makers and (2) conditions under which they perform. The qualification of experts (decision-makers), and the decision environment are at least as important as the procedure by which a valid measurement scale is to be developed.

From a psychological and sociological point of view, an individual's decisions are generally influenced by the preference of colleagues and superiors. Ideally, a person's decision would be a free decision if "he could have made a different one if nothing . . . had been different from what it was" (Ofstad, 1961, p. 19). In a group decision-making situation, a decision maker is influenced by others in the group because dissent may result in some type of punishment. In other words, persons who command reward and punishment stimuli may be able to influence the decision of other group members. It is proposed that "high power persons are resistent to specific influence by others and less constrained by group norms. Low power persons are generally deferential, although they may be less constrained when supported by their peers" (Collins and Guetzkow, 1964, p. 164).

Conclusions

Better decision making requires better analysis which is based on quantitative and exact measures as well as qualitative investigation. But quantitative approaches in the realm of operations research are only an aid to judgement. In fact, even when the quantitative data and model are available, the decision maker still influences the selected alternative because he implicitly assigns a different weight of "being successful" to each one. As it was stated before "Judgement is supreme." In using quantitative analysis, the analyst should not substitute it for judgement but should use it to accomodate the decision-maker's subjective opinion. Statistical methods and mathematical formulations should be employed as a tool "to increase the effectiveness of managerial decisions as an objective supplement to the subjective feeling of the decision maker" (di Roccaferrera, 1967, p. 17).

One may consider the principal objective of a qualitative or quantitative model to be its use as a factual tool for analysis by providing "the necessary useful elements for understanding, measuring, or evaluating a real problem" (di Roccaferrera, 1967, p. 21).

In defining an objective function for a university, or developing measurement scales for evaluating competing programs, the psychological, sociological and political factors may carry more weight than some are willing to accept.

The conclusions of this chapter concur with the statement made by Bartram et al. (1968), "identifying and measuring the quality [and quantity] of educational outputs is difficult. Agreement on indicators, terms, measures and measuring techniques can only be achieved slowly. But significant efforts have been made and will continue to be made" (p. 23-24).

CHAPTER IV

SOME ANALYSIS AND OPTIMIZATION TOOLS FOR A UNIVERSITY SYSTEM

Introduction

An objective function is defined by the methods described in Chapter III for a hypothetical university. Experiments may now be designed to evaluate the effects of the system's inputs on the outputs expressed in the objective function. These experiments measure and compare the consequences of some input variations or their combinations on an output. Input-output relationships must be defined and analyzed. With this information and the knowledge of the objective function, several optimization techniques may be applied, at different system levels, to a university. While linear programming has potential use at the level of the "whole university system," the methods of welfare economics are applicable at the school and departmental levels, as well. Capital budgeting methods are most promising for selection from among a group of competing research projects.

Analysis of Variable Causes and Effects

One way of investigating the factors and their effects is by constructing a cause and effect diagram. With this diagram, all or most of the pertinent factors may be included and their relationships demonstrated. Some factors may initially appear to be trivial, but their interaction with other factors may prove to have significant effects.

There are many ways of classifying the causes. One is grouping them under the categories "what," "when," "where," "who," "how," "whom," and "why" (Inoue and Riggs, 1970). Another classification is by the sequence of the processes, such as receiving, processing and shipping. A further way of assorting is by the subsystems of the system, for instance, the raw material, semi-finished material, and finished product departments. In the cause and effect diagram in Figure 1 in Chapter I, the factors were identified according to an optimization model, where an objective function and a set of constraints are given.

Next, the subfactors are identified to supplement the fish-bone form cause and effect diagram constructed in the previous step.

After the comprehensiveness and validity of the constructed diagram are established, the effect of the factors and their interactions may be studied with the aid of a factorial experiment design. Finally, the significant effects of the factors may be identified from the standard analysis of variance procedure.

Analysis of University Input Variables

In a university system, the analysis of factors or inputs should be made in order to investigate their effects on the system's outputs, and thus upon the institutional objectives.

Many of the factors (causes) itemized in the cause and effect diagram (Figure 1), and their effects, either have not been measured in the past or are not recorded in a form suitable for a valid study. However, a study has been conducted which demonstrates the applicability of factor analysis in identifying relevant variables in a university (R. M. Ghaffari, 1970). The study attempts to find the effect of family background variables on the graduation rate of the Fall 1963 matriculating female students at Oregon State University. It should be pointed out that graduation rate is an indicator of the true output of the university which may be considered in terms of, according to Firmin et al. (1967), "incremental knowledge."

The cause and effect diagram in Figure 6 portrays the family background factors of parents' education, family size, birth order, and their interactions which are unknown at this stage. Two levels are identified for each factor. The four variables have four main effects, a, b, c, d, and 11 interactions, ab, ac, ad, bc, bd, cd, abc, acd, abd, bcd, and abcd.

The tabulation of data (Table 5) follows the orthogonal arrays

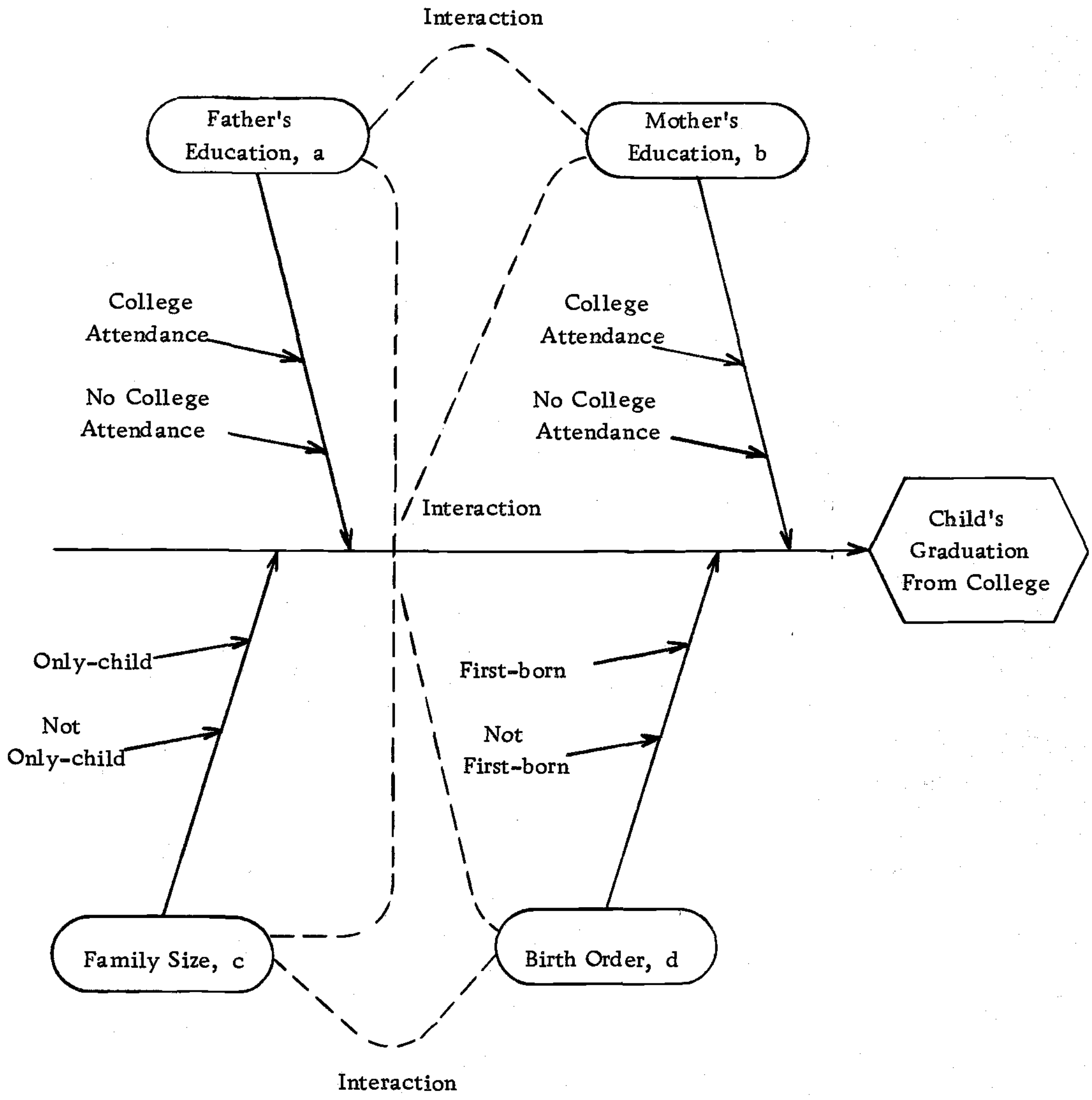


Figure 6. Cause and effect diagram for the study of effect of family background variables on college graduation.

Table 5. Model for investigating the effect of family background variables on college graduation.

Row \ Column	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Data in percent
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	62
2	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	0
3	1	1	1	2	2	2	2	1	1	1	1	2	2	2	2	58
4	1	1	1	2	2	2	2	2	2	2	2	1	1	1	1	45
5	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2	44
6	1	2	2	1	1	2	2	2	2	1	1	2	2	1	1	0
7	1	2	2	2	2	1	1	1	1	2	2	2	2	1	1	45
8	1	2	2	2	2	1	1	2	2	1	1	1	1	2	2	44
9	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2	42
10	2	1	2	1	2	1	2	2	1	2	1	2	1	2	1	0
11	2	1	2	2	1	2	1	1	2	1	2	2	1	2	1	42
12	2	1	2	2	1	2	1	2	1	2	1	1	2	1	2	49
13	2	2	1	1	2	2	1	1	2	2	1	1	2	2	1	33
14	2	2	1	1	2	2	1	2	1	1	2	2	1	1	2	0
15	2	2	1	2	1	1	2	1	2	2	1	2	1	1	2	32
16	2	2	1	2	1	1	2	2	1	1	2	1	2	2	1	32
Factors and Interactions	a	b	a b	c	a c	b c	a b c	d	a d	b d	a b d	c d	a c d	b c d	a b c d	

Table 6. Initial calculations for investigating the effect of family background variables on college graduation.

Column / Row	a	b	a b	c	a c	b c	a b c	d	a d	b d	a b d	c d	a c d	b c d	a b c d	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1.. SS = Sum Sqaures $= S^2/16$	289	289	1	1722	2	12	30	2209	169	64	49	1892	6	30	15	
2. MSS = SS/d. f.	289	289		1722			30	2209	169	64	49	1892		30		
3. MSS errors			1		2	12							6		6	$\frac{27}{5}$ = 5. 4 degrees of freedom
4. F = MSS/MSS errors	53. 5	53. 5		318. 9			5. 6	409. 1	31. 3	11. 9	9. 1	350. 4		5. 6		$n_1 = 1$, $n_2 = 5$ F* = 6. 61 F** = 16. 26
5. * (95% significant) ** (99% significant)	*	*		**				**				**				MSS* = 35. 7 MSS** = 88. 0

Table 7. Revised calculations for investigating the effect of family background variables on college graduation.

	a	b	a b	c	a c	b c	a b c	d	a d	b d	a b d	c d	a c d	b c d	a b c d	
Column / Row	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1. SS = Sum Squares = $S^2/16$	289	289	1	1722	2	12	30	2209	169	64	49	1892	6	30	6	
2. MSS = SS/d. f.	289	289		1722				2209	169	64		1892				
3. MSS errors			1		2	12	30				49		6	30	6	$\frac{136}{8}$ = 17.0 degrees of freedom
4. F = MSS/MSS errors	17.0	17.0		101.3				130.0	9.9	3.8		111.3				$n_1 = 1$, $n_2 = 8$ F* = 5.32 F** = 11.26
5. * (95% significant) ** (99% significant)				*				*				*				MSS* = 90.5 MSS** = 191.5

developed and presently extensively used in Japan (Inoue and Riggs, 1970). Calculations are presented in Table 6 and Table 7.

The analysis of variance for a two-way classification with a single case in each class (Duncan, 1965) was used to calculate the F values which are compared with critical F values at the 0.01 and 0.05 significance levels. It should be kept in mind that the analysis assumes balanced data, but the data used was unbalanced. However, the analysis still demonstrates its potential. The variables family size, birth order, and their interaction (c, d, and c-d, respectively) were found to be significant at the 0.01 level, while the main factors a and b (parents' college education) were significant only at the 0.05 level. Treating all the remaining effects which were not significant at the 0.05 alpha level, except for a-d and b-d which have rather large values, as error and combining them with the noise, the analysis was repeated (Inoue and Riggs, 1970). The main factors c, d and their interaction, c-d, were found significant at the 0.05 level, while the remaining factors and interactions were insignificant at both 0.01 and 0.05 levels. The last set of results indicate that at the 0.05 significance level, (1) a first-born child has a better chance of graduating from college, (2) an only-child has a higher probability of finishing college, (3) parents' college education does not affect a child's chance of college graduation, and (4) the interaction between family size and birth order factors has a significant influence on the probability of a child's graduation from college. A section of the computer program output is included in the Appendix.[2]

The analysis of variance has meaningful utility and applicability in investigating the effects of a set of factors on an output variable. The availability of relevant data will make it possible to determine the effect of any number of input factors on the variables in the right hand side of the cause and effect diagram presented in Chapter I. The conclusions drawn from this type of analysis will be useful in increasing the effectiveness of resource allocation in a university system.

Definition of Input-Output Relationships

"We do not know, for example how many units of professional knowledge must be introduced into the system to produce a specific increment in student knowledge" (Firmin _et al._, 1967, p. 17).

A useful tool for investigating the relationship between the inputs and outputs of a system is input-output analysis. An input-output table shows

> how the output of each industry [or, say, school] is distributed among other industries [schools] and sectors of the economy [other structural components of the university]. At the same time it shows the _inputs_ [resources] to each

---

[2]The program NANOVA for k-Factor Analysis of Variance was used here. The program was written by Mr. Lynn Scheurman, Oregon State University Computer Center.

> industry [school] from other industries [schools] and sectors [other university components such as the library and the computer center] (Miernyk, 1965, p. 8).

Input-output analysis attempts to determine what can be produced in a system, and the quantity of each intermediate product which is used in the production of the final output, subject to the limited resources and the state of technology (method of transformation of input to output). Bartram et al., in their study of university inputs and outputs, concluded

> . . . the difference between IN(A)[input] and OUT (B) [output] may be interpreted as 'value added' or benefits either to the student, knowledge, or the public. Relating the amounts of resources used in a program (C) to the difference between IN and OUT, (B - A) yields a cost/benefit index [(B - A)/C] (Bartram et al., 1968, p. 21).

The input-output analysis qualifies for application to a university system for two reasons: 1) the components of a university such as the various schools and departments, the library, the computer center, etc., possess most of the characteristics common to industries in an economy, and 2) once the output of the university is defined its relationship to the university input (resources) may be established.

However, the basic assumptions of an input-output model must be studied first in order to realize its limitations:

(1) Each commodity (service) is supplied by a single production sector. In other words, each sector has only one primary

output and it is produced by the same method. For a university, the implications are such things as each department offers courses in a particular area and does not repeat courses offered in other departments, and the faculty-student ratio is fixed within a department.

(2) The inputs used by a sector are a function only of its level of output (Chenery and Clark, 1959). Therefore, a department in a university uses the services of other departments according to the number of its student-credit hours.

(3) The total product (services) of a sector is equal to the sum of its individual products (services). This assumption of additivity implies that, for example, the total services for departments A and B is equal to the sum of the services by department A and those by department B.

A small scale input-output table is presented here (Table 8). It includes six producers of input and four users of output.

From this model, the following equations are derived:

$$X_1 = Y_1 + a_1X_1 + a_2X_2 + a_3X_3$$

$$X_2 = Y_2 + b_1X_1 + b_2X_2 + b_3X_3$$

$$X_3 = Y_3 + c_1X_1 + c_2X_2 + c_3X_3$$

$$X_4 = d_1X_1 + d_2X_2 + d_3X_3$$

$$X_5 = e_1X_1 + e_2X_2 + e_3X_3$$

$$X_6 = f_1X_1 + f_2X_2 + f_3X_3$$

Table 8. An input-output model for the University.

Producers of Input: Engineering, Science, Humanities and S. S., Federal and State Funds, Student Fees, Endowments. Users of Output: Engineering I, Science II, Humanities and SS III.

School	Total Costs (Funds)	Fixed Costs	Allocation of Costs: Engineering I	Science II	Humanities and SS III
Engineering	X_1	Y_1	a_1X_1	a_2X_2	a_3X_3
Science	X_2	Y_2	b_1X_1	b_2X_2	b_3X_3
Humanities and S. S.	X_3	Y_3	c_1X_1	c_2X_2	c_3X_3
Federal and State Funds	X_4	-	d_1X_1	d_2X_2	d_3X_3
Student Fees	X_5	-	e_1X_1	e_2X_2	e_3X_3
Endowments	X_6	-	f_1X_1	f_2X_2	f_3X_3
Totals	X	-	X_1	X_2	X_3

The coefficients a_i, b_i, c_i, d_i, d_i, and f_i are determined by the planners and decision-makers on the basis of the university goals and objectives.

According to Baumol (1965), "basically the input-output analysis consists in nothing more complicated than the solution of a set of N simultaneous linear equations in N variables" (p. 481). Therefore, from the above equations, we may determine either the set of six unknowns, X_1, X_2, X_3, X_4, X_5, and X_6, or the alternate set of Y_1, Y_2, Y_3, X_4, X_5, and X_6, depending on the available information. For each dollar worth of service to become available, the inputs from several sectors must contribute to its production. For example, for one dollar worth of services X_1 (engineering education) the dollar contributions are a_1 from "engineering," b_1 from "science," c_1 from "humanities and social sciences," d_1 from "federal and state funds," e_1 from "student fees," and f_1 from "endowments." In other words, $a_1X_1 + b_1X_1 + c_1X_1 + d_1X_1 + e_1X_1 + f_1X_1 = X_1$. The entries in the table are interpreted in the following manner: X_1, X_2, and X_3 represent the total fund generated by the services of each school, and X_4, X_5, and X_6 are the total funds made available from sources outside "the school system." The sum of the last three items of funds must equal the fixed costs incurred by the schools for the services rendered to "the school system" and outside sources, i.e., $X_4 + X_5 + X_6 = Y_1 + Y_2 + Y_3$. In general, the rows in the table may be considered as inputs (expenditure) and the columns as outputs (income).

Another input-output table may be constructed which is similar to the model developed by Koenig (1969) who compiled the table coefficients from a faculty survey. While the inputs in Koenig's model are in terms of Full Time Equivalence (F. T. E.), the outputs are expressed in a variety of units such as numbers, student credit hours, and F. T. E. (See Appendix, p. 129-130). The input-output model in Table 9 on page 71 is more comprehensive since it includes, besides the human resources, the input of materials, supplies, building and equipment. On the output side, only the instructional services are expressed, but research, extension, and other services are actually implied. In other words, it is assumed that with each hour of instruction a certain amount of research, extension, and other services are produced in its support. Therefore, for example, by one term hour of upper division agriculture it is meant X_1 dollars of instruction, X_2 dollars of research, X_3 dollars of extension, and X_4 dollars of other basic services. The relative desirable amount (level) of these services for each school may be determined by the measurement techniques proposed in Chapter III.

The next step is compiling the input-output coefficients for this table. This can be done from a faculty survey (Koenig, 1969). In the initial attempt, the faculty may be asked to assign one of the values

Table 9. An input-output table for the University.

	1 LD Agric	2 UD Agric	3 GD Agric	4 LD PE	5 GD PE	6 LD Math	7 UD Math	8 GD Math	9 LD Phys Sci	10 UD Phys Sci	11 GD Phys Sci	12 LD Engin	13 UD Engin	14 GD Engin	15 LD Soc Sci & Hum	16 UD Soc Sci & Hum	17 GD Soc Sci & Hum	18 LD Ed	19 UD Ed	20 GD Ed	21 LD Forest	22 UD Forest	23 GD Forest	24 LD Bus & Tech	25 UD Bus & Tech	26 GD Bus & Tech	27 LD Bio Sci	28 UD Bio Sci	29 GD Bio Sci	30 LD Gen	31 UD Gen	32 GD Gen
1. (Cost of) Lectures and Seminars																																
2. (Cost of) Library Related services																																
3. Prof's, Assoc. Prof's and other teaching faculty (Salaries for Instruction)																																
4. (Cost of) Instructional Supplies																																
5. (Cost of) Laboratory Facilities																																
6. (Cost of) Computer Services																																
7. (Cost of) Building Use																																
8. Personnel (Salary and Wages)																																
9. (Salary of) Graduate Assistants																																
10. (Cost of) Research Facilities																																
11. (Cost of) Research Grants																																
12. Prof's, Assoc. Prof's, other research faculty (Salaries for research and extension)																																
13. Other (Costs)																																

(LD: Lower Division, UD: Upper Division, GD: Graduate Division)

0.00, 0.25, 0.50, 0.75, and 1.00 to each of the entries. The input-output relationships may be further refined from historical data as it becomes available from an input-output oriented information system. Thus, the actual coefficients may be compared to what they should be. Also, from this I/O table, the cost per student term hour for each field may be calculated and its sources of support could be determined. In University of California at Berkeley and University of California at Los Angeles efforts were made to obtain this type of information (Weathersby, 1967). Weathersby estimated the lower division teaching cost per student in these two universities to be essentially the same at about $385 per student per year. But a reliable I/O model will also provide other costs and for every school within the university. Therefore, when the demand for output (services) changes, it can be determined at what cost it can be satisfied and if enough resources are presently available for meeting the demand.

Optimization Techniques

Linear Programming

With the input-output data available a linear or non-linear programming model may be formulated for the university system or a part of the system. Weathersby (1967) proposed an LP model for minimizing the total cost of operating a university system. However, he pointed out two operational difficulties with a university application of LP: (1) the objective function is difficult to define and thus cannot be assumed linear, and (2) the constraints are also hard to define and estimate. The size of a large university system also renders an LP model practically inconvenient. But he immediately proposed ways of improving the situation by the use and application of "the decomposition principle for convex programs, two complementary and general extensions to mathematical programming" (Weathersby, 1967, p. 102). The measurement techniques proposed in the previous chapter and the I/O model, as well as numerical techniques of Econometrics (Tintner, 1952) should also be useful and applicable to the problem in this area.

Methods from Welfare Economics

There are many parallels between the concerns of the welfare economist and the university decision-maker. Baumol defines the welfare economics domain as "policy issues which arise out of allocation of resources--with the distribution of inputs among the various commodities and the distribution of commodities among the various consumers" (Baumol, 1965, p. 355). In the case of a university, the consumers are the benefactors of its instruction, research and basic services.

Subject to limited resources, the university is faced with the problem of moving resources into one output service, school, or department, at the expense of taking it out of another. The decision should be made on the basis of defined priorities and the interrelationships of output sectors. A major objective of the university, maximizing its services, is subject to limited assets. In such a situation, the core of the problem is in deciding whether less of one service can be justified by more of another.

> A simple value judgement is to consider a reallocation to represent an improvement in welfare [total services rendered] if it makes at least one [demand group] better off without making anybody worse off. If it is not possible to reallocate resources without making at least one [group] worse off, the existing allocation is Pareto-optimal" (Henderson and Quandt, 1958, p. 222).

In order for the condition of Pareto optimality to exist, it is necessary that:

1. The corresponding rates of substitution of all demand sectors be equal, e.g., $\frac{MU_{x1}}{MU_{y1}} = \frac{MU_{x2}}{MU_{y2}} = \frac{MU_{x3}}{MU_{y3}} = \ldots = \frac{\lambda_b}{\lambda_c}$. In other words the ratio of the marginal utility of service x to sector 1 to the marginal utility of service y to sector 1 must be equal to the corresponding ratio for the other sectors.

2. The corresponding rates of transformation of all services be equal. For example, an optimal use of any two inputs i and j, in their transformation to services x and y, requires that $\frac{MS_{ix}}{MS_{jx}} = \frac{MS_{iy}}{MS_{jy}}$, where MS_{ix} is the marginal service of i in its transformation to service x.

3. The rates of substitution equal the corresponding rates of transformation. Therefore, for example, $\frac{MSU_x}{MSC_x} = \frac{MSU_y}{MSC_y}$, i.e., the ratio of the marginal social utility of x to the marginal social cost of x (the quantity of resources needed to produce an additional unit of x) must equal the corresponding ratio for commodity y.

The optimization procedures in welfare economics seem to have a cross-over potential to the educational systems, where the output is difficult to quantify, but utility assignments are feasible. Marginal rules for the university setting accomplish the same task that the linear programming and similar mathematical optimization techniques have accomplished for profit-making institutions.

The prerequisite for using welfare economics guidelines is the construction of utility curves for the demand groups. This means that for a given budget the utility should be defined for the system outputs. It is then useful to the analysts to look at an Edgeworth box for any two demand groups in order to determine the optimal distribution of services among the demand groups. (It may even be practical to construct a multi-dimensional Edgeworth box and consider several demand groups simultaneously.)

The Edgeworth box could be used to schematically represent the Pareto-optimal condition.[3] The indifference curves of groups A and B (each convex to its own origin) are shown inside the box, Figure 7 on page 77. Pareto-optimality is reached with moving away from the two origins (increasing A's and B's utilities). Axes x and y represent the "quantities" of services x and y, e.g., instruction and research, which are to be exchanged. Each convex indifference-curve of A is tangent at some point to some particular indifference-curve of B. The locus of all these points of tangency is called Edgeworth's Contract-curve. On this curve the ratios of the marginal utilities of x and y are equal for A and B. "The ratio of the marginal utilities of x and y to A and B respectively are simultaneously equal to the price at that point" (Dobb, 1969, p. 15). This may be expressed mathematically as

$$\frac{\partial U_A}{\partial x} \cdot \frac{\partial U_B}{\partial y} = \frac{\partial U_A}{\partial y} \cdot \frac{\partial U_B}{\partial x}$$

or

$$(\partial U_A/\partial x)/(\partial U_A/\partial y) = (\partial U_B/\partial x)/(\partial U_B/\partial y).$$

The straight line going through point T represents a price line. As the bargaining and exchange continues, a point T is reached on the contract curve where any further exchange (movements away from the point) would result in going to a lower indifference-curve at least for

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[3] Concepts of Welfare Economics may be somewhat unfamiliar to many Industrial Engineers.

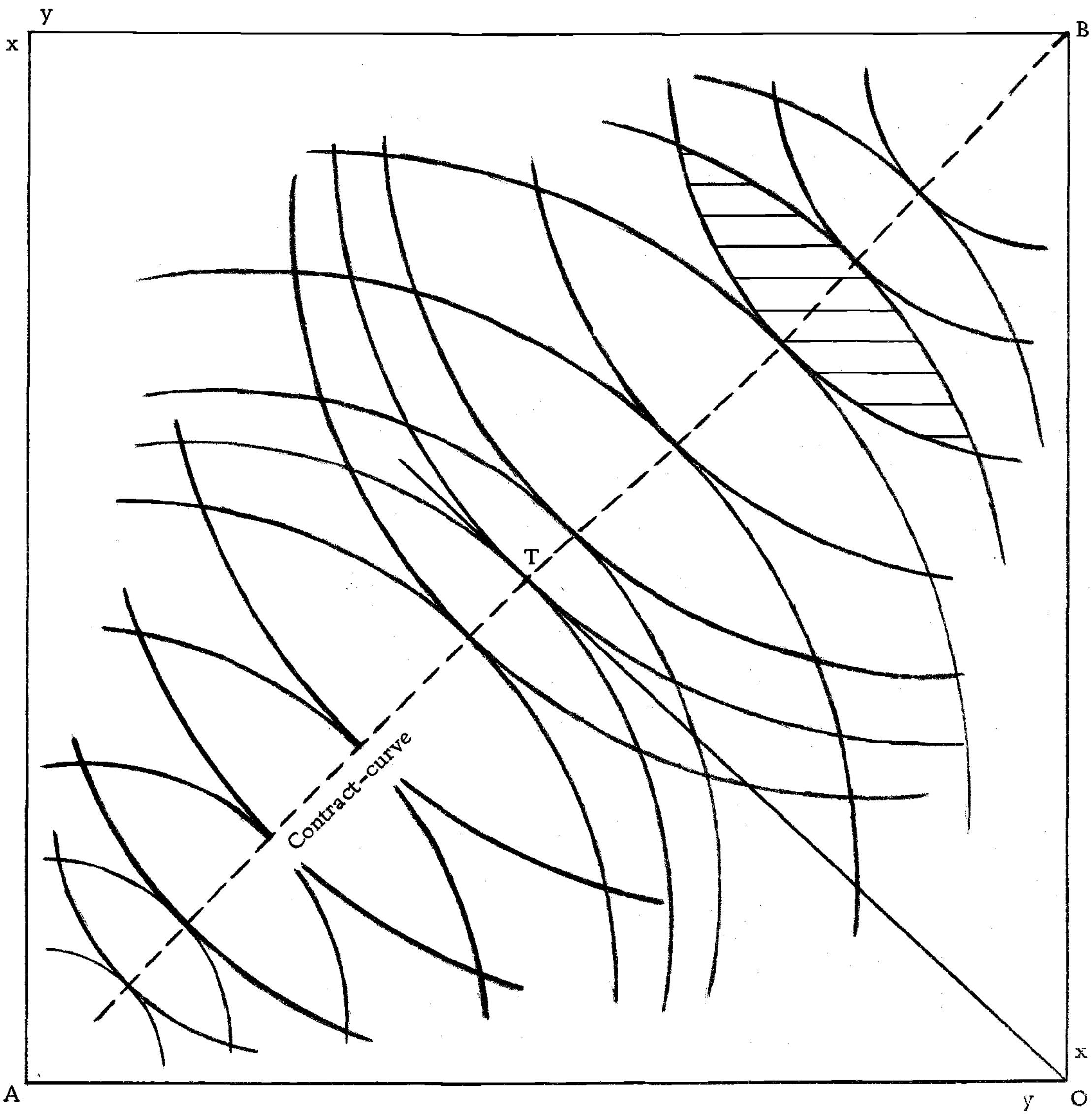

Figure 7. The Edgeworth Box.

one of the parties. Point T is Pareto-optimal relative to the starting point O.

This type of reasoning should at least aid the decision-makers in basing budget decisions more on the priority (utility) of individual segments within the university. The analysis should only be carried out with an awareness of the underlying assumptions and limitations of utility and perfect competition.

Capital Budgeting

Joel Dean (1951) pioneered the development of methods of capital rationing. His capital budgeting method proposes that the competing projects be ranked in decreasing rate of return and then selected from the top of the list. But this model is weakened by its assumption of certainty and its inability in handling non-independent projects. Lorie and Savage (1955) proposed the present value criterion for choosing the optimum projects subject to a budget constraint. They showed how Dean's rate of return criterion failed in some cases. It was not until almost a decade later that programming was first applied to capital budgeting problems by Weingartner (1963).

Capital budgeting methods are often applied for financial evaluation of investment in competing projects. A new investment must also pass "an intangible evaluation [which] investigates the worthiness of a project in terms of human values which are difficult to express quantitatively" (Riggs, 1970, p. 144). The university also faces a similar problem in its many investments. But of concern here is investment in research projects. The returns from many research projects are difficult to define and measure. But measurement techniques of Chapter III could be, once again, applied to measure and compare the benefits from these projects. Measurements become more difficult when the benefits are considered for projects which extend several years into the future. However, the concept of discounting may be applied to these benefit values since a benefit now is worth more than the same benefit, say, a few years from now.

The limitation of fixed budget is called capital rationing. The net present benefit value of the projects must be maximized subject to the constraint of restricted funds. We can formulate a programming model for independent projects as maximize $\sum_{j=1}^{n} b_j X_j$, subject to $\sum_{j=1}^{n} C_{tj} X_j \leq C_t$ and $0 \leq x_j \leq 1$.

In this formulation:

X_j represents the fraction of project j undertaken,

b_j is the net present benefit value of project j (the algebraic sum of its benefits and detriments discounted to the present),

C_{tj} is the present value of outlays for project j in period t discounted to the present,

C_t is the present value of the expenditure ceiling (the budget) in period t.

t represents the number of periods for which the projects are considered and n is the number of projects.

The objective function to be maximized is the total return (benefit) from investment j which is equal to the product of the net present benefit value of project j and X_j which is the fraction of project undertaken. The total of all the benefits from the selected projects represents the total yield of the research program adopted by the university.

One of the problems in the above formulation is the indivisibility of research projects. In other words, the accepted research projects must each be fully completed in t periods, if the evaluation is to be valid. The linear programming model usually gives fractional projects in the optimum solution. But it has been proven that the number of fractional projects is equal to or less than the number of periods under consideration. Usually the number of adopted fractional projects is less than the number of periods (Weingartner, 1963). The problem of fractional projects is solved by the integer programming approach which adds Gomory constraints in order to eliminate the fractional answers from the optimum solution. Thus, with the addition of the restriction $0 \leq X_j \leq 1$, the solution to X_j is either zero or one, i.e., the project is either totally rejected or entirely accepted.

Another problem is the handling of the projects which are mutually exclusive and those which are contingent upon others. For mutually exclusive projects, such as a and b, the restriction $0 \leq X_a + X_b \leq 1$ substitutes the previous constraint, $0 \leq X_j \leq 1$. This assures that if one of the projects is adopted, the other one is rejected. Of course, this constraint does not rule out the possibility of both projects being rejected. The same type of a constraint will work if only one of three or more projects must be undertaken. When project m is contingent upon project n, the difficulty is solved by adding the expression $X_m \leq X_n$ to the original set of constraints in the LP formulation. This constraint limits the possibilities to:

$X_n = 0$, thus $X_m = 0$, neither projects are accepted.

$X_n = 1$, but $X_m = 0$, project n is adopted and project m is rejected.

$X_n = 1$, and $X_m = 1$, both projects are accepted.

Weingartner's programming procedure alleviates the difficulties with interrelationships among the projects, the multi-period cases and the fractional projects. These points will be demonstrated in the following examples. (In these examples, the net present value of project benefits are expressed in utiles, but they may be stated in any similar qualitative measure.) According to Lyden and Miller (1967), "critical examination of alternatives typically involves numerous considerations, but the two main ones are assessment of the cost (in the sense of economic resource cost) and the utility (the benefits or gains) pertaining to each of the alternatives being compared to attain the stipulated objectives" (p. 185).

Example 1 In this example, Weingartner (1963) proves that the Lorie-Savage criterion for project selection is not always consistent. Lorie and Savage (1955) proposed that if the best use of money in one period does not exhaust the budget in the second period, then the optimum solution is the one that makes the best use of money in one of the two periods. But as it is clearly shown in the example of Table 10, p. 83 this criterion still leaves us in doubt as to which one of the two projects should be undertaken. The ratios in rows 4 and 5 favor project 2, while the ratio in row 6 favors project 1.

Example 2 Weingartner's linear programming formulation and solution procedure is computationally efficient, and it allows the present value of a project to be expressed in such nondollar units as utiles. Table 11 gives the relevant information for this problem. The objective function of the LP could be expressed as:

Maximize the total utility:

$$14X_1 + 17X_2 + 17X_3 + 15X_4 + 40X_5 + 12X_6 + 14X_7 + 10X_8 + 12X_9$$

subject to:

$$12X_1 + 54X_2 + 6X_3 + 6X_4 + 30X_5 + 6X_6 + 48X_7 + 36X_8 + 18X_9 + s_1 = 50$$

$$3X_1 + 7X_2 + 6X_3 + 2X_4 + 35X_5 + 6X_6 + 4X_7 + 3X_8 + 3X_9 + s_2 = 20$$

Table 10. Data for Example 1.

Row No.	Description	Project 1	Project 2
1	Net present value in utiles	30	28
2	Present value of outlay in year 1	$ 6.00	$18.00
3	Present value of outlay in year 2	$19.00	$ 3.00
4	Ratio of net present value of project to present value of outlay in second year	$\frac{30}{\$19} = 1.58 \frac{\text{utiles}}{\text{dollar}}$	$\frac{28}{\$3} = 9.33* \frac{\text{utiles}}{\text{dollar}}$
5	Ratio of present value to sum of flows in both years	$\frac{30}{(\$19 + \$6)} = 1.20 \frac{\text{utiles}}{\text{dollar}}$	$\frac{28}{(\$3 + \$18)} = 1.33* \frac{\text{utiles}}{\text{dollar}}$
6	Ratio of present value to present value of outlay in first year	$\frac{30}{\$6} = 5.00* \frac{\text{utiles}}{\text{dollar}}$	$\frac{28}{\$18} = 1.56 \frac{\text{utiles}}{\text{dollar}}$

Table 11. Data for Example 2

Projects	Present Value of Project (Y_j)	Present Value of Outlay in Period 1 (C_{1j})	Present Value of Outlay in Period 2 (C_{2j})
1	14	\$12	\$ 3
2	17	54	7
3	17	6	6
4	15	6	2
5	40	30	35
6	12	6	6
7	14	48	4
8	10	36	3
9	12	18	3

Present Value of Budgets: C_1 = \$50, C_2 = \$20

$X_1 + q_1 = 1$ $\qquad$ $X_4 + q_4 = 1$ $\qquad$ $X_7 + q_7 = 1$

$X_2 + q_2 = 1$ $\qquad$ $X_5 + q_5 = 1$ $\qquad$ $X_8 + q_8 = 1$

$X_3 + q_3 = 1$ $\qquad$ $X_6 + q_6 = 1$ $\qquad$ $X_9 + q_9 = 1$

Solution for the real variables is

$X_1 = 1.0$ $\qquad$ $X_4 = 1.0$ $\qquad$ $X_7 = 0.045$

$X_2 = 0$ $\qquad$ $X_5 = 0$ $\qquad$ $X_8 = 0$

$X_3 = 1.0$ $\qquad$ $X_6 = 0.970$ $\qquad$ $X_9 = 1.0$

The value of objective functions is 70.27 utiles.

The solution gives two fractional projects in the optimum solution, as it should be expected in a two period case. Baumol (1965) describes how integer values may be obtained for all the projects. First, the original problem is solved by the dual simplex method. Then, a Gomory constraint is added to the last tableau of the non-integer solution. Finally, the dual simplex computation is further carried out with the guarantee of integer answers.

Conclusions

Analysis and optimization tools presented in this chapter become applicable as more and better measurement techniques for quantifying educational outputs are developed. The models developed are based on many unrealistic assumptions, such as linearity or additivity of variables. However, these models are useful, at least, in obtaining a deeper insight into the input-output relationships and their effect on the achievement of institutional objectives.

In relating input data to output data, many questions that call for meaningful answers may be investigated. These include (Bartram *et al.*, 1968):

> The cost per student per year in particular fields of study
> The cost per degree in particular fields of study
> The cost of adding students to a particular field of study
> The cost of programs at particular levels of quality
> The cost of expanding existing programs/institutions
> The cost of establishing new programs/institutions
> Beneficial side effects on the institution itself
> Relationships between inputs and their associated costs and outputs and their associated benefits
> Relationships between costs and sources of funding
> Values added to the student, knowledge, and public service
> (p. 23-24).

CHAPTER V

A UNIVERSITY MANAGEMENT INFORMATION SYSTEM

Information for Institution-Wide Decisions

> Ultimately all policies are made . . . on the basis of judgements. There is no other way, and there never will be. The question is whether those judgements have to be made in the fog of inadequate and inaccurate data, unclear and undefined issues, and a welter of conflicting personal opinions, or whether they can be made on the basis of adequate, reliable information, relevant experience, and clearly drawn issues (Fisher, 1966, p. 4).

In seeking more effective allocation and better utilization of university resources, there will be more reliance on scrupulous and quantified techniques in the future. "Increasingly, decisions are based on systematically obtained data which are often subjected to quantitative analysis" (Systems for Measuring and Reporting, 1967, p. 235). Reliable information is needed regarding such items as institution's resources, current operations, and future programs.

At this time, there are a large number of universities, nationwide, that operate with inadequate information systems. The administrators of these universities still base their conclusions and decisions on rather nebulous data and vague information. Firmin et al. draw this conclusion from their interviews of university administrators at Tulane and a number of other universities:

> Most university administrators are not customarily provided with cost information of sufficient refinement to permit them

> to discharge efficiently their decision-making, planning, evaluation, and control functions; because university administrators generally have not been provided with adequate cost information, they do not fully understand or perceive the ways in which they could function more effectively if better cost information were made available to them (Firmin _et al._, 1967, p. 3).

An effective management information system aids in reversing the trend of unrealized opportunities for achieving additional objectives and/or incomplete achievement of selected objectives by providing more useful and comprehensive data.

The basic functions of a management information system (MIS) are collection, processing and distribution of data. Novick (1964) states two primary functions for an information system, in regard to supporting structural or format aspects of PPBS. They are "(1) progress reporting and control, and (2) providing data and information to serve as a basis for the analytical process--especially to facilitate the development of estimates of benefits and costs of alternative future courses of action" (p. 33). These estimates are a prerequisite to the construction of analysis and optimization models such as those offered in Chapter IV. Without reliable information, any conclusions drawn from these models will be inappropriate and of little value if any.

A management information system, in order to serve its functions effectively, should have the following characteristics (Bartram _et al._, 1968):

1. be structured in terms of output-oriented activities, such

as programs and sub-programs

2. systematize the programs and their elements and relate them to achievement of institutional objectives
3. integrate the academic, physical facility and fiscal planning
4. express capital and operating cost implications of each program and its elements
5. provide multi-year projections of outputs, costs and activity levels in programs
6. link outputs to programs and their activity levels
7. supply comparisons of predicted (or planned) costs and benefits with actual expenditures and performance
8. provide data for cost benefit analysis among competing programs

These characteristics are necessary for the integration of the activities of an MIS and the functions of a PPBS. The coordination of information system efforts with the information requirements of a planning programming budgeting system will minimize the collection, processing and storage of unnecessary data. A PPBS, being input-output oriented, demands information on the interrelationship of resources and services. Bartram _et al._ (1968) identifies two major information subsystems in a university:

Information subsystems related to _output_
Instructional Program
Research Program

External Service Program
Including Information on
Program objectives
Level of program activity
Program output

Information subsystems related to input
Student Records
Personnel Records (See Table 16, Appendix)
Faculty
Supporting staff
Facilities
Major supporting equipment
Finance (p. 24-25)

Five recommendations are made in Systems for Measuring and Reporting . . . (1967) for designing and developing a "total" information system:

1. Establish the long-range objectives and then work out a basic design for an information system that will enable the business [or university] to operate more effectively and at lower cost.
2. Analyze and define the information system currently in use.
3. Make short-range improvements in the existing system which are consistent with the long-range plan.
4. Establish a time schedule and assign responsibility for attaining the long-range objectives.
5. Accomplish the plan. (p. 245)

Firmin et al. (1967) recommended that the conventional fund oriented information systems be complemented by information systems which are operationally-oriented and management-oriented in order to meet the data needs of the planning and budgeting models.

The electronic computer, in a PPB-oriented information system, is not only useful for processing, storing data, but it could also be programmed for calling attention to the variances which require administrative attention (management by exception).

The cost of a university management information system is usually justified,

> not because it has reduced costs, but because it will aid in solving problems and making decisions; because it will provide a record of past and present performance, [and a projection of] performance, requirements, and needs into the future; and because it will do all these things with accuracy, on a timely and as-needed basis (Systems for Measuring and Reporting, 1967, p. 259-260).

Simulation: A Projection Technique

For an information system to be adequate it should not only supply information about the present state of the system it is serving, but also about its future requirements. There is a basic need for tools and techniques for projecting the system needs on the basis of presently available information. Nonetheless, the analyst must take precaution in drawing conclusions from these models because:

> Errors in judging the recent past have arisen from two sources: (1) insufficient [and invalid] data have been available to assess properly the year-by-year changes in the supply and demand for college faculty, and (2) models projecting future needs have commonly been constructed on assumptions that proved to be in error (Cartter, 1966, p. 1).

Projection models are still used in spite of their limitations.

They are better to have than not to have. An enrollment prediction model for Michigan State University was in error with the actual enrollment by as much as +24% and -27%, but it was considered to offer "a good hope of reasonably approximating the operation of the university" (Koenig, Keeney and Zemach, 1968, p. 139).

One problem with the validation of these type of models is the limitation of the available data.

A simulation model is a tool which may be used for making predictions about the future demands of a system. On the basis of the information regarding the system at the present time, the model simulates the system processes and produces an output. The output analysis indicates what could be expected from the system in the future.

Markov Chain Simulation

The Markov simulation model, to be presented here, is a model of the academic progression of Engineering students at Oregon State University. It is based on the Fall term enrollment and probation data for the academic years 1966 through 1970. This enrollment prediction model has some elements in common with that constructed by Firmin *et al.* (1967), but the latter model used an exponential smoothing procedure in order to assign greater weight to the more recent data.

The Theory. An operation, in a Markov process, is a repetitive activity performed to attain some desired result. This is to be done according to certain rules of operation called doctrine. The mathematical simulation of the operation is carried out "so that probable results of the application of different operating doctrines can be predicted and a choice can be made, ahead of time, of the particular doctrine which is most likely to achieve the desired end" (Morse, 1959, p. 84).

The Markov simulation model is probabilistic. In other words, the outcome of any single and specific operation cannot be predicted. But because the operations are repetitive, the average outcome of many operations can be anticipated. The model only gives expected values which are based on the average results of a large number of consecutive operations. Therefore, the results of a Markov simulation may be interpreted as the average outcome. Such a probabilistic model specifies the various distinguishable states and the probability of the system being found in each of the states at a given time after the beginning of the operation.

The Model. The data for the Markov simulation model is shown in Table 12.

Figure 8 shows the Markov chain process for the given data. The branches display the way the system may pass from one state to

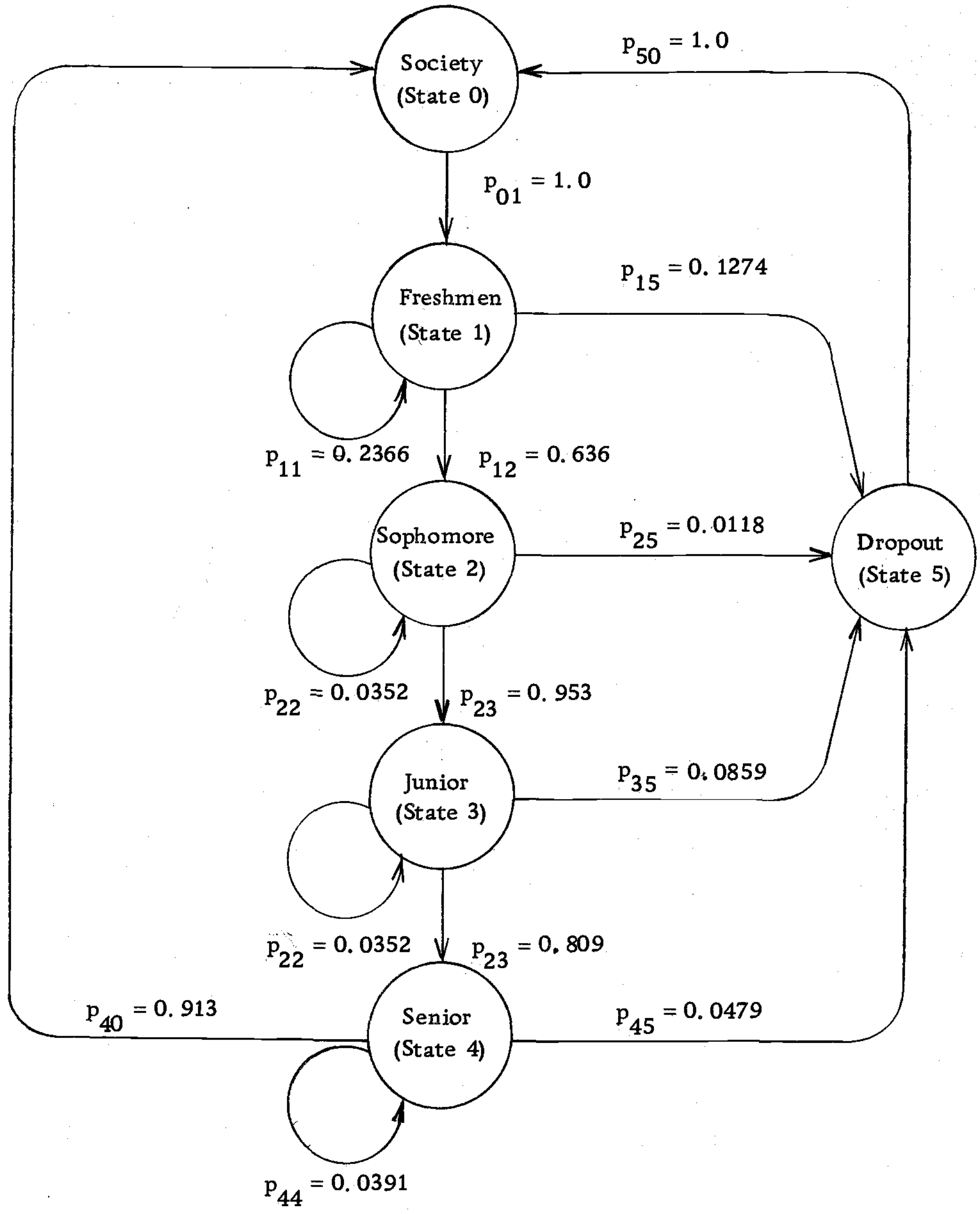

Figure 8. Markov chain process diagram for simulation of graduation of engineering students at OSU.

another. Each branch is identified by its beginning and end nodes. The probability associated with branch ij is the probability of transition from state i to state j. The transitional probabilities are constant (independent of time).

Table 12. Enrollment data for simulation of graduation of Engineering students at OSU.

Class	1966	1967	1968	1969	1970	Total
Freshman	578	611	555	699	673	3116
Sophomore	366	356	362	433	462	1979
Junior	290	349	379	447	421	1886
Senior	267	251	295	360	350	1523
Total	1501	1567	1591	1939	1906	8504
B.S. Graduate	238	251	262	325	315	1391

In the terminology of Markov chain theory, the conditional probability P_{ij} is called the probability of a transition from state i to state j. These probabilities were obtained from averaging the transition probabilities for the five years. Since the enrollment in these five years has generally increased, the probabilities shown below are more influenced by the more recent data.

$$
p = \begin{bmatrix}
p_{00}=0 & p_{01}=1.00 & p_{02}=0 & p_{03}=0 & p_{05}=0 & p_{05}=0 \\
p_{10}=0 & p_{11}=0.2366 & p_{12}=0.636 & p_{13}=0 & p_{14}=0 & p_{15}=0.1274 \\
p_{20}=0 & p_{21}=0 & p_{22}=0.0352 & p_{23}=0.953 & p_{24}=0 & p_{25}=0.0118 \\
p_{30}=0 & p_{31}=0 & p_{32}=0 & p_{33}=0.1051 & p_{34}=0.809 & p_{35}=0.0859 \\
p_{40}=0.913 & p_{41}=0 & p_{42}=0 & p_{43}=0 & p_{44}=0.0391 & p_{45}=0.0479 \\
p_{50}=1.00 & p_{51}=0 & p_{52}=0 & p_{53}=0 & p_{54}=0 & p_{55}=0
\end{bmatrix}
$$

The probabilities of the type $P_{i,i+1}$ were calculated from the original data. For example during the five years 1966-1970 a total of 3,116 freshmen and 1,979 sophomores registered for Fall term. Therefore, for freshman class, called "STATE 1," and sophomore class, "STATE 2," $p_{12} = \frac{1979}{3116} = 0.636$. The remaining 3116 - 1979 = 1137 freshmen repeated their freshman year, dropped out of school or transferred. The last two items were grouped and named DROP-OUT which is "STATE 5." The probabilities of transition to "STATE 5" were not available from the original data. An assumption had to be made for the proportion of students making the transition to "STATE 5." This transition was given a probability of 0.35 for the freshman, i.e., of all the freshmen who did not complete their class in one year 35 percent of them dropped out. Consequently $P_{15} = (0.35)(1-0.636) = 0.1274$ and $P_{11} = (1-0.35)(1-0.636) = 0.2366$. Similarly, the probability of dropping out for the sophomores was assumed to be 0.25. The probabilities for the juniors and seniors were set equal to 0.45 and 0.55, respectively. These probabilities were determined by trial and error. The chi-square test will show that they are acceptable estimates.

The Markov simulation was run for 250 time periods and the following distribution was found for the students in each of the states: number of freshmen = 70, number of sophomores = 42, number of juniors = 44, and number of seniors = 35. Sample runs were obtained from the computer program.[4] Several transitions are included in the Appendix. Also shown in the Appendix is the system at time 250.

In order to varify the assumptions made for some of the transition probabilities, a chi-square test is then conducted. In the simulation, at time = 250 there are a total of 191 students in states 1, 2, 3, and 4. On the basis of this total n, the theoretical frequencies are calculated in the following way:

$$f_1 = (\frac{3116}{8504})(191) = (0.366)(191) = 69.9$$

$$f_2 = (\frac{1979}{8504})(191) = (0.233)(191) = 44.5$$

$$f_3 = (\frac{1886}{8504})(191) = (0.222)(191) = 42.4$$

$$f_4 = (\frac{1523}{8504})(191) = (0.179)(191) = 34.2$$

Therefore,

$$\chi^2 = \frac{(70-69.9)^2}{69.9} + \frac{(42-44.5)^2}{44.5} + \frac{(44-42.4)^2}{42.4} + \frac{(35-34.2)^2}{34.2}$$

$$= 0.00014 + 0.1404 + 0.0603 + 0.00187$$

$$= 0.2027 < \chi^2_{0.025} = 0.2158 \text{ at 3 degrees of freedom.}$$

This means that the probability of occurrence, by chance, of a χ^2 larger than 0.2027 is less than 0.025.

---

[4] The program for Markov Simulation by Iterative Process was written by Dr. Michael S. Inoue and converted to OS-3 by Mr. Douglas Roberts of the Department of Industrial Engineering, Oregon State University.

Conclusions

An effective management information system could provide much of the information which is needed for making better decisions and taking timely action on many issues in a university.

The application of projection models such as simulations is a step in the direction of providing more information about the future outcomes. From a Markov chain model, it can be determined where the weakness of a particular instruction program lies and where the improvement efforts should be concentrated. This type of knowledge should be of particular interest to university administrators. Special programs may be developed for those students who need the extra academic help in order to persist on to graduation. This is noteworthy in the light of the need for highly educated personnel, and the investment which is made in the higher education of students who do not complete college. Taking action when the student is about to drop-out may be too late. This problem is akin to the quickening process in human engineering.

There are many other important matters which may be better handled if the university administrators had better and more comprehensive information. The development and use of an effective management information system (MIS) is an important measure in finding better and more timely solutions. The MIS concepts, more extensively applied in business and industry, have promising utility in the field of higher education.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

The primary purpose of this study was to investigate the utility of several analysis and optimization techniques in increasing the effectiveness of university resource allocation. These techniques have been applied in profit-oriented organizations for some time, but have not been used in universities on a wide scale. This has been mainly due to the university's particular output measurement problems. The university objectives have not been quantified, owing to this and the lack of a common conception of the university's end-product. When an end-product such as incremental knowledge was agreed upon, it could not be directly measured.

Chapter I overviewed the problems facing universities across the nation. A major issue is the insufficient funds for higher education at the time when demand for university graduates is still unfulfilled. The current budgeting and planning practices of the universities were also brought to attention. A number of relevant questions on the objectives and programs of a university were raised which have not, yet, been adequately answered.

Included in Chapter II, were a brief history of budgeting orientation and the related concepts, with special emphasis on Planning

Programming Budgeting (PPB). PPBS was found to be in its developmental stage in the field of education. It was concluded that PPB will be more effectively applied to university budgeting system when operations research and other mathematical models are modified to better suit the university purposes.

PPBS will provide the required flexible framework for relating resources to outputs and, thus, to objectives. Nonetheless, for a more effective university PPBS, the output must be quantified.

Two methods of measuring educational output were presented in Chapter III. First, Siegel's method for obtaining an ordered matric scale and then, the improved Churchman-Ackoff procedure for the evaluation of outcomes were discussed. The Delphi method was introduced for obtaining a consensus opinion among those deciding the relative importance of institutional goals.

Chapter IV discussed some of the analysis and optimization techniques which are suitable for an educational system. Cause and effect analysis was described as a tool for integrating a comprehensive list of relevant factors contributing to the problem at hand and its consequences. Input-output analysis was submitted as a way of investigating the input-output relationships in a university. Linear programming, methods from welfare economics and capital budgeting were suggested as applicable optimization techniques to a university system.

In Chapter V, the characteristics of an effective management information system were deliberated. Comprehensive and useful data about university input and output are required for making better resource allocation decisions. Information regarding state of the system in the future should be provided so that timely action can be taken in advance of occurrence of the coming events. Simulation models were proposed for projection purposes. A Markov chain simulation model for the graduation of Engineering students at OSU was given as an example.

Conclusions

There are many analysis and optimization techniques in the fields of Industrial Engineering, Business Administration and Economics which have not been applied to the university system. This is primarily due to its characteristic output measurement difficulties. However, measurement techniques are available in other spheres which can serve to alleviate the university's problem of quantification. The forementioned analysis and optimization procedures have been applied to profit making organizations with notable success. There are few real constraints to the usage of these methods in the institutions of higher education which are often confronted with effectiveness and efficiency problems. Appropriate application of these techniques, in a Planning Programming Budgeting structure, will increase the effectiveness of resource allocation so that the planned objectives may be achieved more fully. The competing programs, designed for the attainment of the university goals, may be evaluated and compared on the basis of more valid criteria and with a better knowledge of their cost-benefit implications. The more proficient use of the assets will make it possible to fund more programs.

Nevertheless, there is, in a university system, a basic barrier to utilizing and applying the widely adopted analysis and optimization methods. It is the new limitations these techniques may place on the academic freedom of the professors; especially in the light of the fact that the primary objective of a university is the pursuit of knowledge which can be better achieved in a less constrained environment.

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APPENDIX

GLOSSARY OF RELEVANT TERMS

Alternatives are options searched for meeting defined objectives. The alternatives are the means by which it is hoped to attain the objectives. They may be policies, strategies or specific actions. They need not be obvious substitutes for each other or perform the same specific functions (Quade, 1966).

Analysis is a process of systematically exploring and investigating full cost implications and benefits of program alternatives which are to meet the set objectives. Analysis requires the estimation of costs and gains in meeting those purposes by alternative programs. It calls for inquiring about the uncertainty of those estimates. It demands the validation and documentation of the information. This information are brought together to give greater accuracy to the benefits and costs of alternatives (George Washington University, 1968).

A Budget is "a financial expression of the purposes of an organization, and it consists of the stages of preparation, presentation, adoption, execution, and evaluation" (Hartley, 1968, p. 21).

Budgeting is the evaluation of costs, over a multi-year period, of attaining program objectives.

Cause and Effect Analysis attempts to identify the relationships between the inputs (causes) and selected outputs of the system. It also examines the effects of these causes upon the outputs.

Cost is "the monetary value of resources identified with a program" (Tenzer, Benton and Teng, 1969, p. 1). The choice of a particular alternative for accomplishing the objectives implies that certain specific resources can no longer be used for other purposes. These are the costs.

Cost Benefit Analysis is a set of analytic techniques which attempt to quantitatively compare the costs and gains of competing programs. It is aimed at maximizing "the present value of all benefits less that of all costs, subject to specified restraints" (Wildavsky, 1966, p. 10).

Cost-utility Analysis is

> the systematic examination and comparison of alternative causes of action which might be taken to achieve specified objectives for some future time period. Not only is it important to systematically examine all of the relevant alternatives that can be identified initially, but also to design additional ones if those examined are wanting. Finally, the analysis, particularly if thoroughly and imaginatively done, may at times result in modifications of the initially specified objectives (Fisher, 1964, p. 3).

A Criterion is a rule or standard according to which the alternatives are ranked in order of desirability. It supplies a means of weighing cost against effectiveness.

Management Control is the process by which managers assure that resources are obtained and used effectively and efficiently in the achievement of the organization's goals.

A Management Information System is "any formal system of procedures established to provide useful symbolic information in the planning and decision making process of management" (Hartley, 1968, p. 37-38)

A Model is

> a simplified, stylized representation of the real world that abstracts the cause-and-effect relationships essential to the question studied. The means of representation may range from a set of mathematical equations or a computer program to a purely verbal description of the situation, in which intuition alone is used to predict the consequences of various choices. In systems analysis (or any analysis of choice), the role of model (or models) is to estimate for each alternative the costs that would be incurred and the extent to which the objectives would be attained (Quade, 1966, p. 7)

Objectives are the organization's aims which, collectively, define the purpose of its existence.

Operational Control is aimed at assuring that specific activities are carried out effectively and efficiently.

Planning is the process of ascertaining what could be done over a multi-year period to achieve the objectives of a program. In other words, a set of decisions are prepared for action in the future. These decisions are directed at achieving goals by optimal means.

A Planning, Programming, Budgeting System (PPBS) is an integrated system designed to supply executive and legislative officials with better and more information for planning programs and for choosing among the optimal ways funds can be allocated to accomplish system objectives. It aids the decision-making process by helping find new ways, through analysis, and evaluation of programs (George Washington University, 1968).

A Program is a cluster of activities designed to achieve specific objectives over a multi-year period.

The Program Budget, as a component of the planning-programming-budgeting system (PPBS), supplies a framework for systematically relating the expenditure of funds to the accomplishment of planned objectives and programs.

Systems Analysis is undertaken primarily to help choose a course of action. The primary task of the analyst is to discover what the decision makers' objectives are (or should be) and, then, how to measure the extent to which these objectives are, in fact, achieved by various alternatives. Finally, strategies, policies, or possible actions can be examined, compared, and recommended on the basis of how well and how cheaply they can accomplish these objectives. In other words, Systems Analysis may be defined as "an approach to problems of decision-making which proceeds by ascertaining objectives, determining constraints, elaborating alternatives, and estimating the costs, benefits, and risks of feasible alternatives" (Judy, 1967).

Strategic Planning is the process of deciding on objectives of the organization and changes in these objectives. The resources, used to attain these objectives, and the policies which determine the acquisition, use, and disposition of these resources are also considered in this type of planning.

PROGRAM BUDGET STRUCTURES

Program budget structures resulting from revolutionary (distinguished by executive directives and imposition from top), and evolutionary (characterized by extensive inter-organizational communications and involvement) approaches (Tenzer, Benton and Teng, 1969, p. 13):

PROGRAM BUDGET I (Revolutionary)	PROGRAM BUDGET II (Evolutionary)
A. Organization is made to conform to the demands of systems analysis.	A'. Systems analysis is made to conform to the unique characteristics of the organization.
B. Top management and outside consultants develop the program-budget structure.	B'. The program-budget staff and the organizational subsystems collaborate in the development of the program-budget structure.
C. The organization's acceptance of the program budget is based on executive power.	C'. Organizational acceptance is based on compromise, iteration, feedback, and two-way communication.
D. Immediate redefinition or organizational objectives (based on the strategies of the "formal" organization) for different product designs, anticipated trends in the market, constituent demands of the future, current research, and outside sources of information.	D'. Gradual modification of organizational objectives in terms of currently perceived objectives with extensive participation of organizational subsystems in addition to external research and information. Development of new objectives occurs through two-way communication. Informal groups have some influence on goal definition.
E. Major programs ans subprograms in the program-budget format are linked to the newly defined objectives.	E'. Major programs and subprograms are linked to the organizational chart and the current operating procedures of the organization.
F. Process carried out essentially through executive directives.	F'. Process based on feedback between the program-budget staff and the organizational subsystems.
G. Program-budget is essentially a product of top management and is understood only by top management.	G'. Program budget is essentially a product of total interaction, and as many viewpoints as possible are represented.

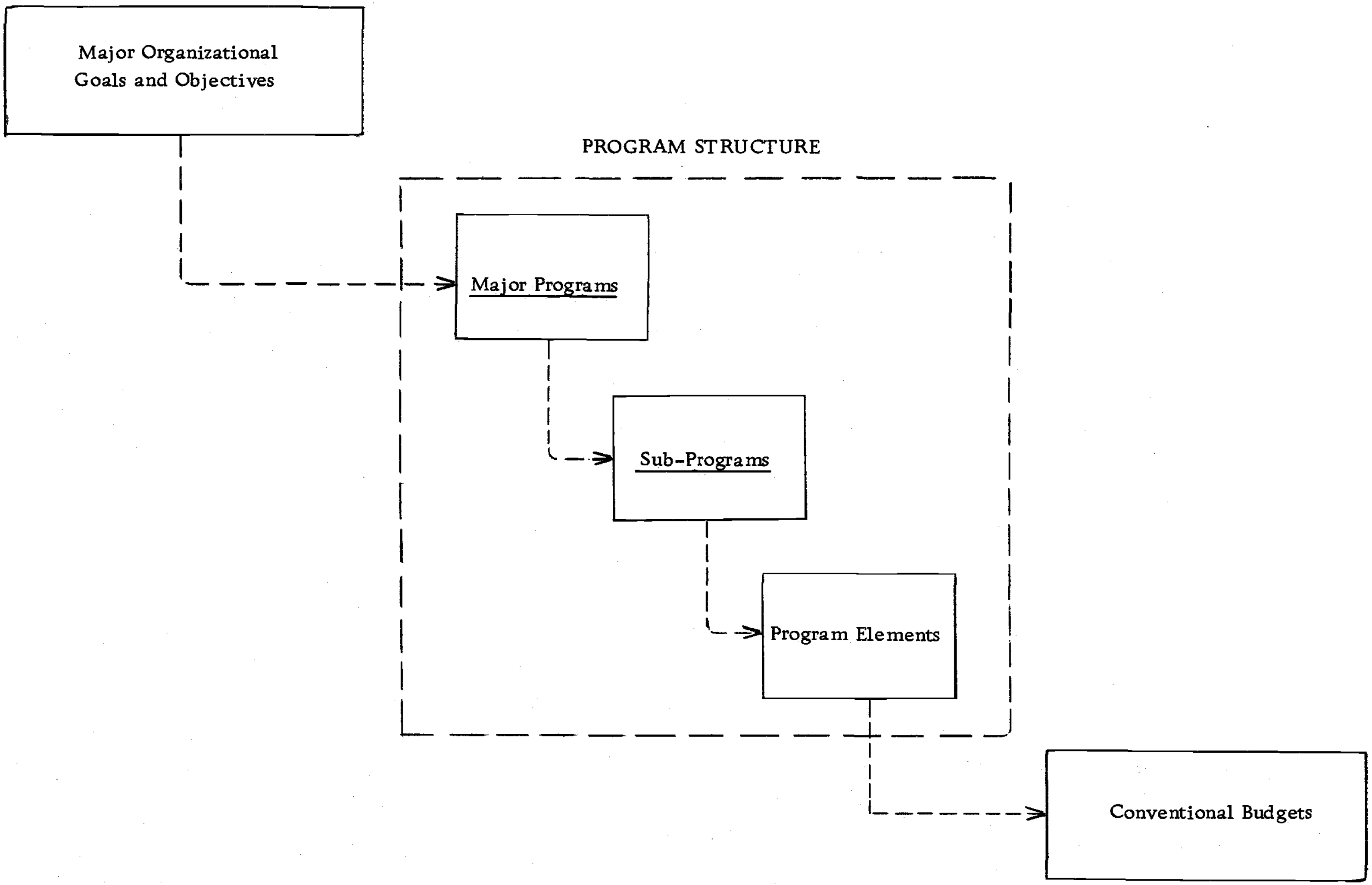


Figure 9. The relationship between organizational goals, the program structure, and the conventional budgets (Tenzer, Benton and Teng, 1969).

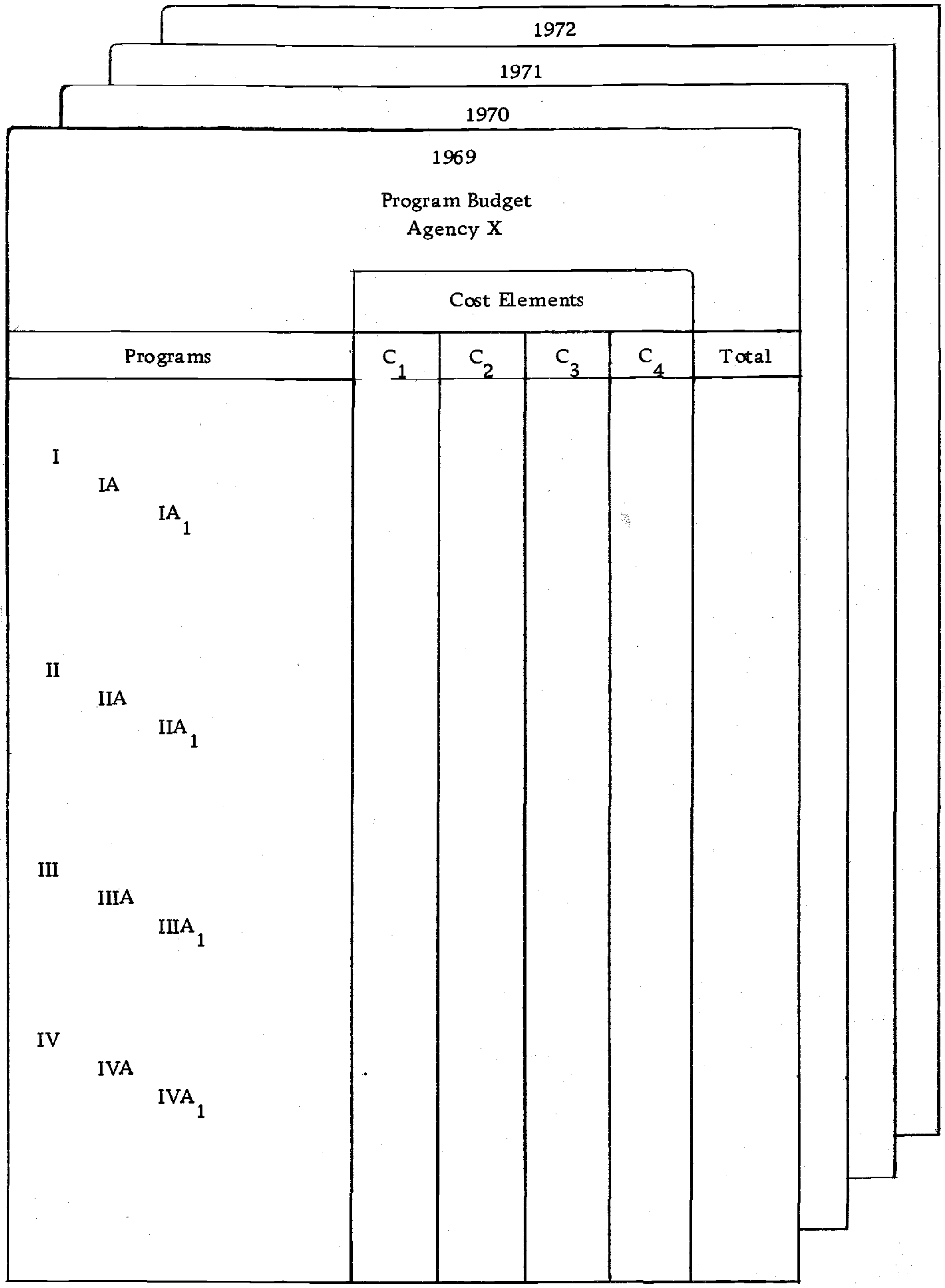


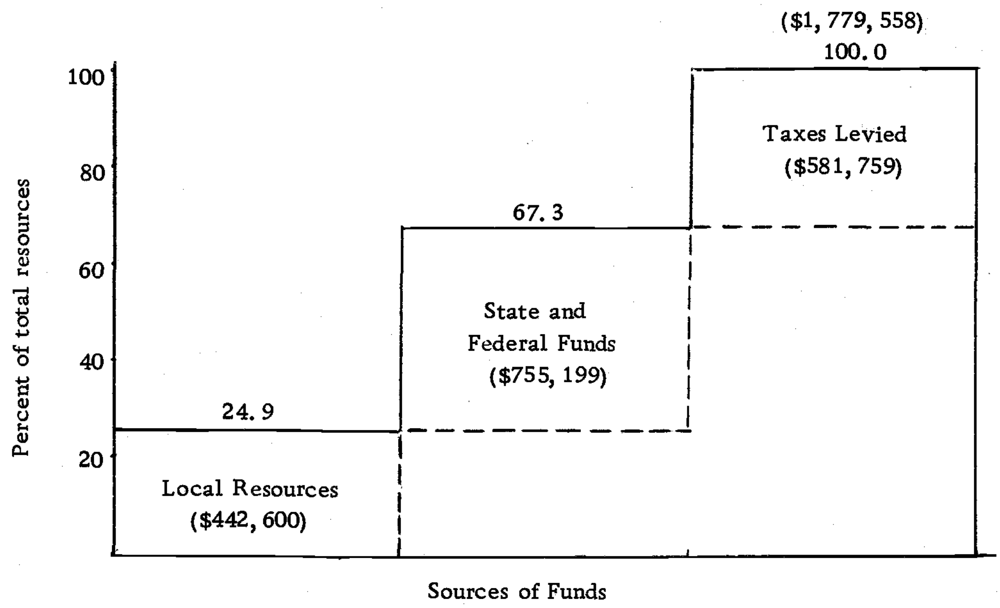
Figure 10. Program budget format (Tenzer, Benton and Teng, 1969).

Table 13. Comparative breakdown for an educational institution of budget expenditures by line-item functions and by programs (Hartley, 1968).

CONVENTIONAL BUDGET				PROGRAM BUDGET		
Functions	Appropriations	Relative Share		Programs	Appropriations	Relative Share
1. Administration	$ 301,379	8.6%	1.	Administration	$ 301,379	8.6%
2. Teaching	2,000,545	57.2	2.	Shared teacher services	235,488	6.7
3. Transportation	112,253	3.2	3.	Special education	1,651,486	47.7
4. Operation and Maintenance	585,391	16.8	4.	Psychiatric services	44,450	1.4
5. Undistributed	490,631	14.1	5.	Testing and counseling	119,515	3.5
6. Transfer to Other Funds	1,500	0.1	6.	Evening career counseling	5,130	0.2
			7.	College conference	6,501	0.2
			8.	Technical vocational education	574,195	15.9
			9.	Educational services and research	119,419	3.3
			10.	Data processing	258,688	7.4
			11.	Cerebral palsy, outside contract	55,000	1.6
			12.	Transportation	120,448	3.5
Total	$3,491,699	100.0%			$3,491,699	100.0%

Table 14. Breakdown for Linn-Benton Community College of budget expenditures by line-item functions (fiscal year 1969-1970).

CONVENTIONAL BUDGET			
Functions		Appropriations	Relative Share
1.	Administration	$ 111,354	6.26%
2.	Instruction	1,045,968	58.75
3.	Research	6,500	0.37
4.	Public Information Service	9,000	0.51
5.	Operation of Plant	41,600	2.33
6.	Maintenance of Plant	24,000	1.35
7.	Fixed Costs	215,824	12.12
8.	Auxiliary Activities and Services	129,005	7.25
9.	Capital Outlay	10,300	0.58
10.	Operating Contingency	116,000	6.51
11.	Federal Programs	70,007	3.97
	Total	$1,779,558	100.00%



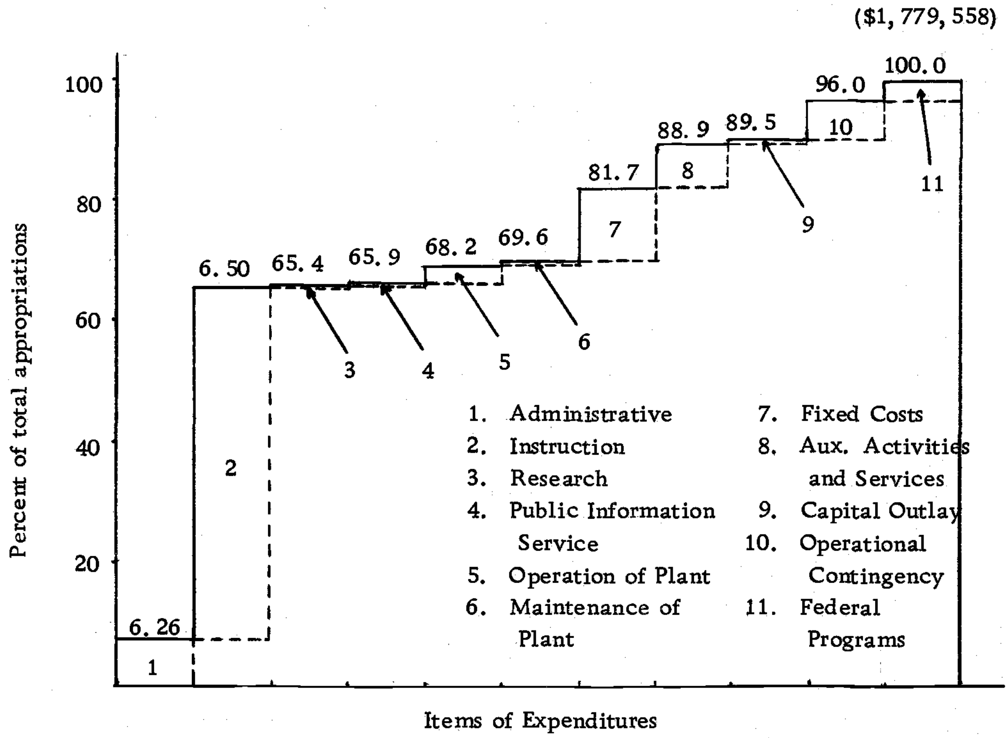


Figure 11. Cumulative diagrams of breakdown of resources and expenditures for Linn-Benton Community College adopted for fiscal year 1969-1970.

Table 15. Breakdown of full time equivalence (FTE) of all staff by type of funding at Oregon State University for fiscal year 1968-1969.

Funds	FTE	Relative Share
1. Unrestricted Funds	940.68	53.62%
2. Restricted Institutional Funds	----	----
3. Auxiliary Activities	51.68	2.95
4. Federal Cooperative Extension	252.74	14.40
5. Agricultural Experiment Station	239.09	13.61
6. Forest Research Laboratory	50.55	2.88
7. Contract Research	220.18	12.54
Total	1,754.92	100.00%

Table 16. Breakdown of full time equivalence (FTE) of all staff by type of funds at Oregon State University for fiscal year 1969-1970.

Funds	FTE	Relative Share
1. Unrestricted Funds	981.32	52.70%
2. Restricted Institutional Funds	5.22	0.28
3. Auxiliary Activities	61.62	3.31
4. Federal Cooperative Extension	249.28	13.37
5. Agricultural Experiment Station	247.74	13.29
6. Forest Research Laboratory	53.72	2.88
7. Contract Research	264.14	14.17
Total	1,863.04	100.00%

Identification and Measurement of Output. Illustrative of the type of data which are indicative of quantitative and qualitative outputs of the process of higher education are the following:

Student Instructional Program

Full-time Equivalent Students

Student credit hours

Student contact hours (by level)

Academic awards (degrees, certificates)

Quantitative measures of intellectual achievement

Rate of employment in local community

Peer Judgments (Standing in the Cartter Report)

Characteristics of first employment

Degree of success in employment

Rate of acceptance of students as transfers

Rate of participation in community affairs

Degree of conformance to institutional objectives

Rate of salvage of disadvantaged learners

Rate of salvage of unemployables

Rate of admission to apprenticeship programs

Degree of user satisfaction

Rate of admission of graduates to graduate and professional schools

Rate of graduates placed in national fellowship programs

Rate of elections of graduates to learned societies

Rate of election of graduates to Who's Who

Research Program

Research findings and applications

(new knowledge and technical advancement)

Awards for research findings

Rate of graduates continuing in research scholarship

External Service Program

Solutions to community and regional problems: industrial, social, economic (research output can apply here, also)

Many student instructional program output indicators apply here to University Extension activities (Bartram *et al.*, 1968).

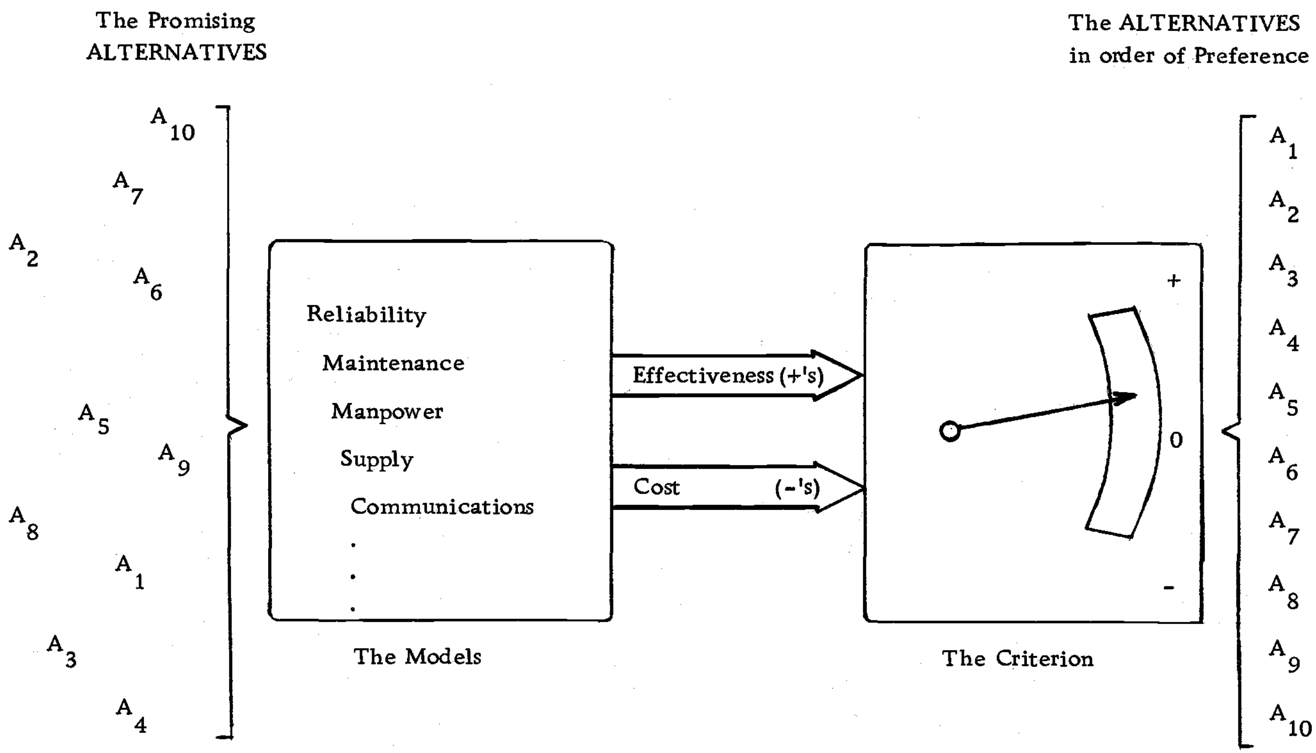


Figure 12. The structure of analysis (Lyden and Miller, 1967).

Input	Components	Functions	Output
<u>People</u> Working force Students <u>Expenditures</u> Facilities Equipment Supplies <u>State of the Art</u> Existing knowledge	Students Staff Faculty Facilities Knowledge	Instruction Research Extension Creative Activity Supporting Services	Public Service Research Education Creation of knowledge Services

Figure 13. University activities (Birch, 1969).

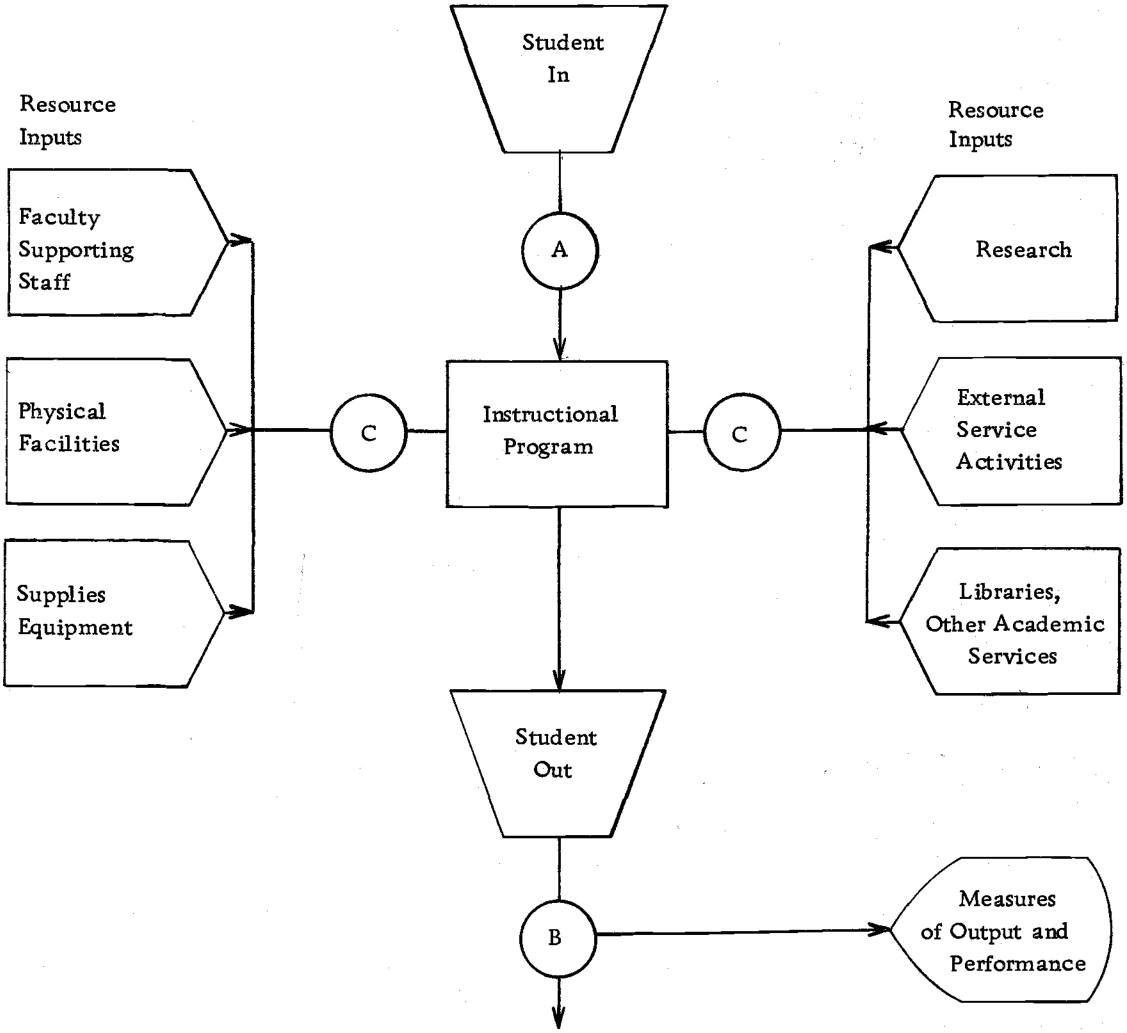


Figure 14. Student instruction model (Bartram et al., 1968).

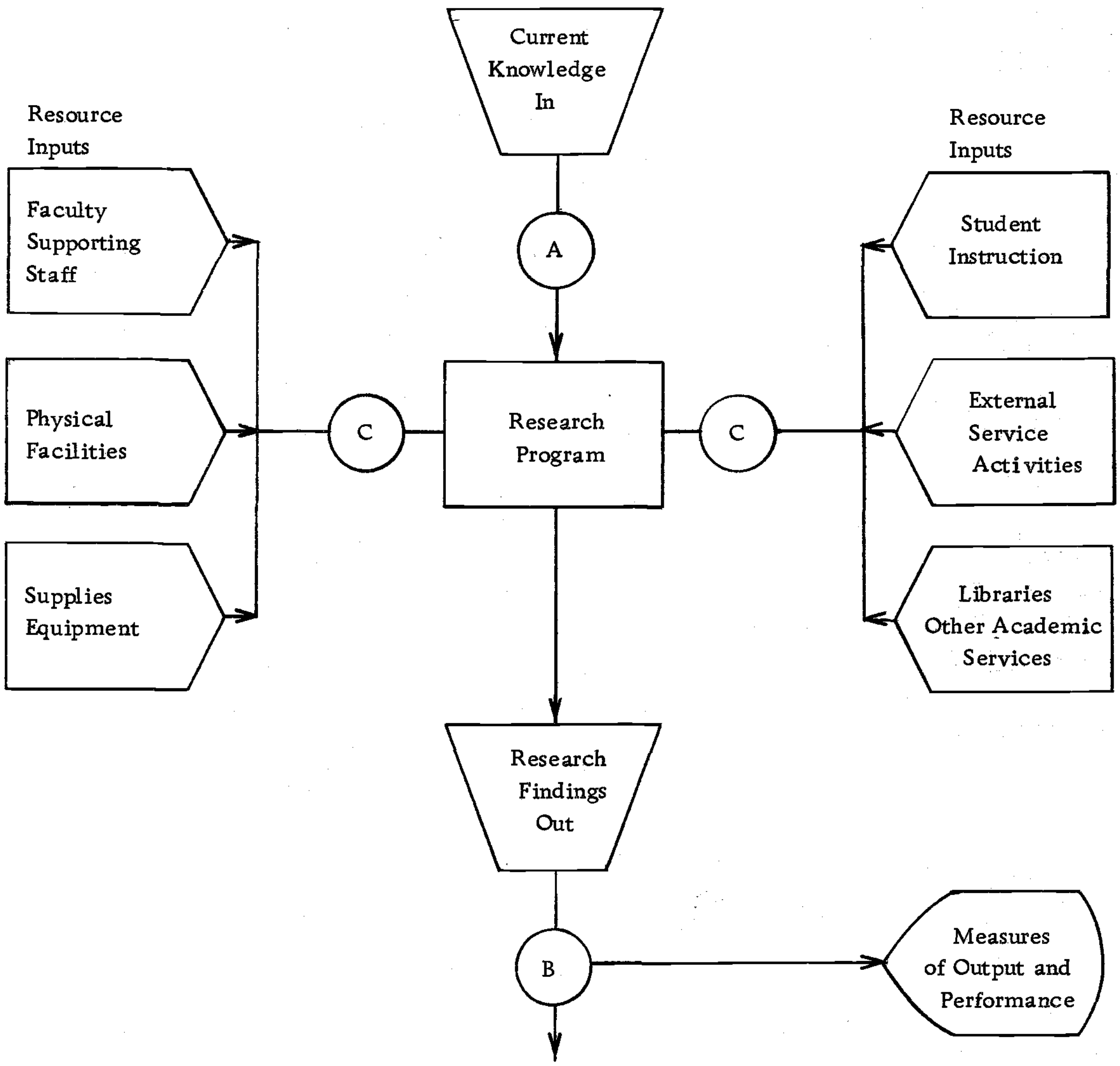


Figure 15. Research model
(Bartram et al., 1968).

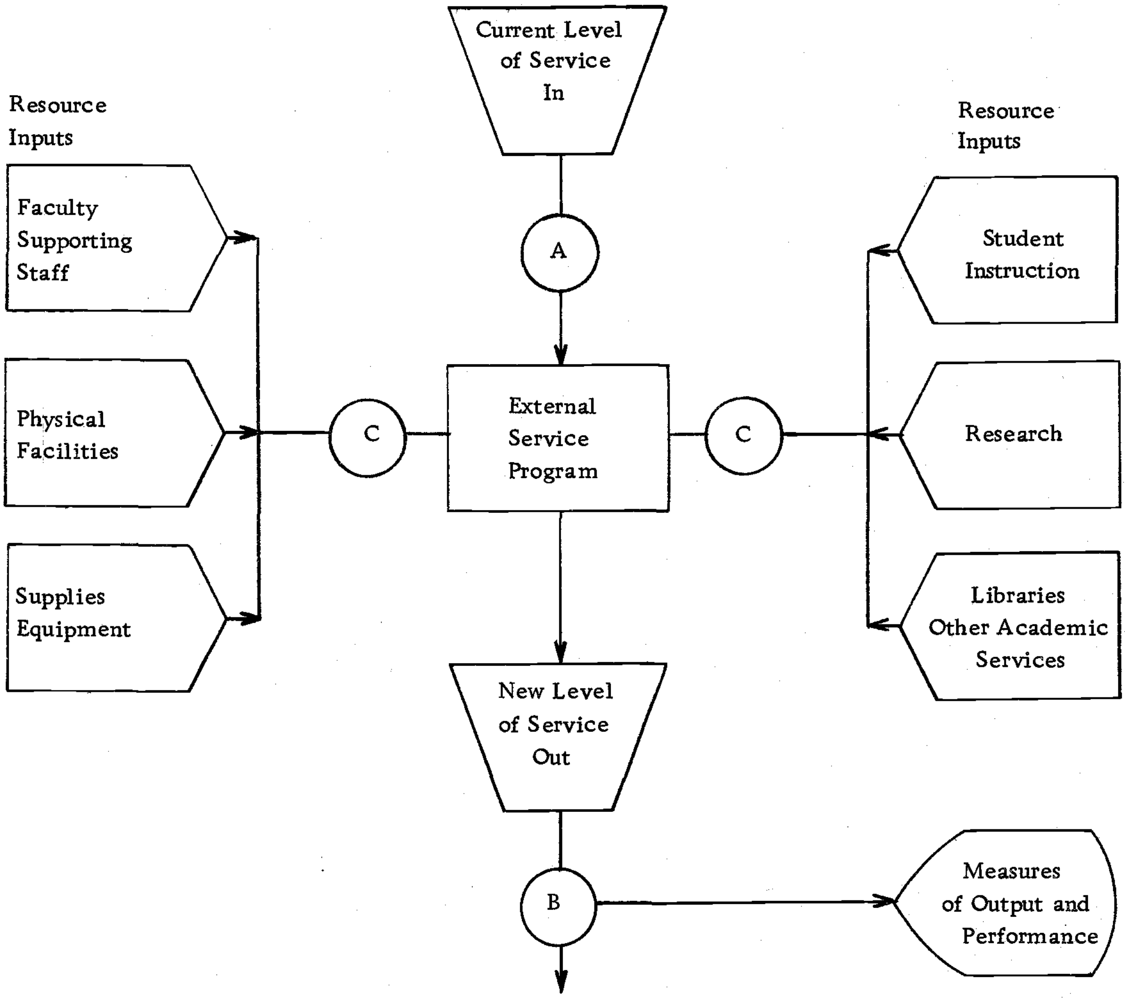


Figure 16. External service model
(Bartram et al., 1968).

Table 17. General format of input-output table indicating classifications of personnel inputs and departmental outputs (Herman E. Koenig, 1969).

	Instruction								Research Outside Services					Management			
Input \ Output	Thesis Direction	Graduate Counseling	Undergrad Counseling	900 Level Instruction	800 Level Instruction	300 & 400 Level	100 & 200 Level	Course Development	Contract Research	Dept. Spon. Research	Consultation & Reviews	Lectures & Seminars	Proposal Prep.	Dept. Management	College Management	University Management	Professional Development
Professor																	
Assoc. Prof.																	
Asst. Prof.																	
Inst.																	
Grad. Asst.																	
Undergrad Asst.																	
Technicians																	
Secretary																	
Hourly Labor																	
Other																	

Table 18. Input-output table compiled from faculty survey. Coefficients in table represent total full-time equivalents (FTE) of manpower by rank or job classification devoted to each category of output (Herman E. Koenig, 1969).

Total outputs in units indicated		No. Candidates (15)	No. Students (100)	No. Students (340)	Student Credit Hours (82)	Student Credit Hours (332)	Student Credit Hours (2308)	Student Credit Hours (0)	Course Credits (10)	F.T.E. Profs. (3.34)	F.T.E. Profs. (0.64)	F.T.E. Profs. (1.0)	F.T.E. Profs. (0.37)	F.T.E. Profs. (0.40)	F.T.E. Profs. (1.38)	F.T.E. Profs. (0.62)	F.T.E. Profs. (0.09)	F.T.E. Profs. (0.60)
Total Inputs in F.T.E.	Output / Input	Thesis Direction	Graduate Counseling	Undergrad Counseling	900 Level Instruction	800 Level Instruction	300 & 400 Level	100 & 200 Level	Course Development	Contract Research	Dept. Spon. Research	Consultation & Reviews	Lectures & Seminars	Proposal Prep.	Dept. Management	College Management	University Management	Professional Development
6	Professor	0.70	0.17	0.05	0.20	0.95	1.42		0.28	1.05		0.1	0.20	0.25	.80	0.20	.05	0.18
7	Assoc. Prof.	0.27	0.16	0.06	0.50	0.95	2.40		0.35	1.09	0.50	0.8	0.12	0.10	0.31	0.37	0.04	0.12
6	Assist. Prof.	0.40	0.14		0.13	0.60	2.15		0.41	1.20	0.14	0.1	0.05	0.05	0.27	0.05		0.30
0	Inst.																	
20	Grad. Asst.						8.0			12.0								
	Undergrad Asst.																	
3	Technician					0.5	2.0			0.5								
4	Secretary		0.2	1.0	0.2	0.2	1.0			0.2	0.2		0.1	0.1	0.8			
	Hourly Labor																	
	Other			1.0														
	Column Total	1.37	0.67	1.11	1.03	3.2	16.9		1.04		0.84	0.29	0.47	0.5	2.18	0.62	0.09	0.60

Table 19. Cost Effectiveness Calculations (Firmin et al., 1967).

CRITERION		1	2	3	4	5	$\sum$	Total Program Cost	Cost/ Effectiveness Ratio
RELATIVE IMPORTANCE		0.10	0.15	0.20	0.50	0.05	1.00		(000's)
PROGRAM	Score-Type								
A	Raw	0.60	0.70	0.10	0.10	0.30			
	Weighted	0.060	0.105	0.020	0.050	0.015	0.250	$ 50,000	$200
B	Raw	0.30	0.40	0.50	0.50	0.40			
	Weighted	0.030	0.060	0.100	0.250	0.020	0.460	$150,000	$326
	Raw								
	Weighted								

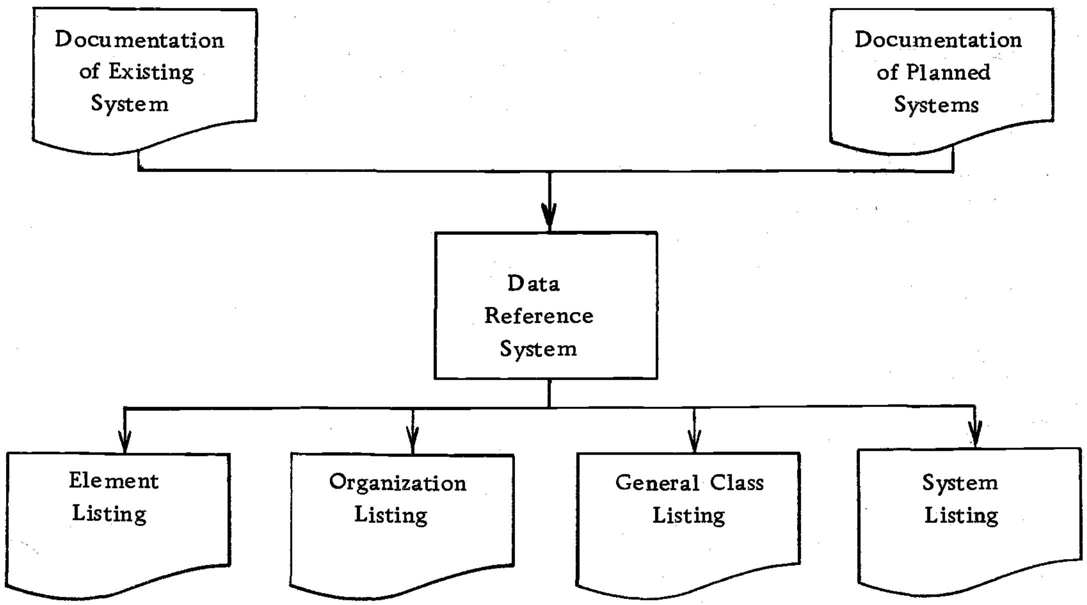


Figure 17. Data reference system

WHAT: A reference guide for OSU information systems.

WHERE: System provides a centralized record of MIS elements and status at OSU.

WHY: The Data Reference System provides a compilation of records on existing and planned management information systems; thus, reducing unnecessary duplication of effort when collecting data and providing source of data when needed.

WHO: Coordinated through the Office of Business Affairs and the Office of Institutional Research.

HOW: Existing and planned systems are described and documented by the responsible agency. Data is then compiled and made available to participating organizations.

WHEN: The system is operational and being updated as new systems are proposed or existing systems modified (Birch, 1969).

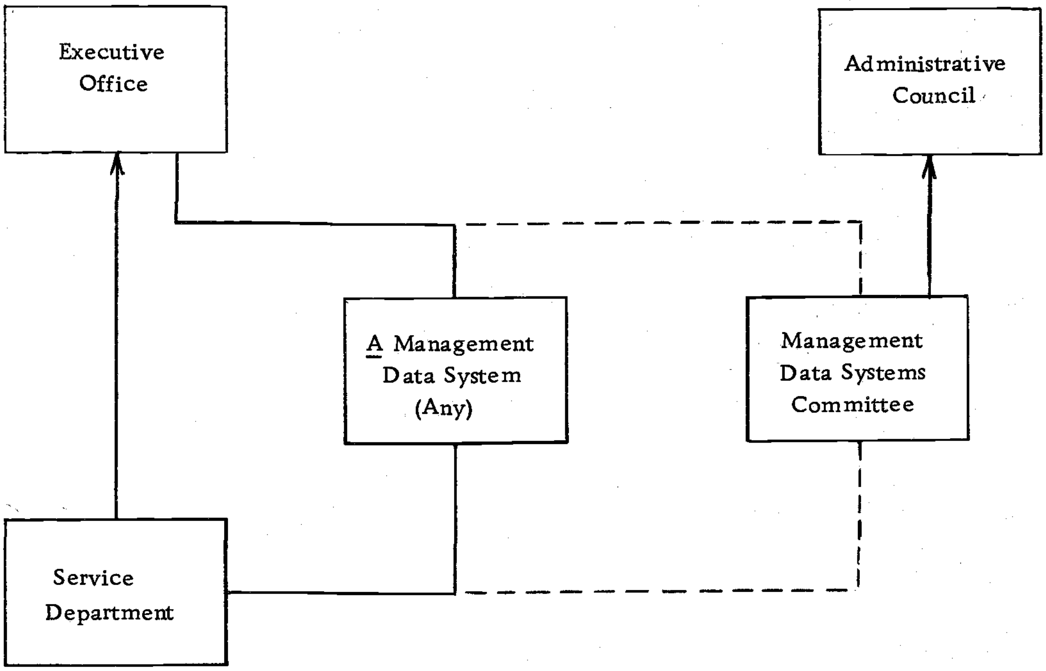


Figure 18. Management Data Systems Committee (Oregon State University).

WHAT: Management Data Systems Committee

WHERE: An overall review and jurisdiction over mechanized management information systems at Oregon State University.

WHY: To institute and maintain proper controls on the accessibility, storage and processing of University data.

WHO: Primary responsibility is through the members of the Committee on Management Data Systems reporting to the Administrative Council.

HOW: The method and procedures of committee activity is outlined in the Administrative Council minutes of February 5, 1969. A procedural form, the Request/Clearance Report, is to be completed when access to data is required by other than the responsible department.

WHEN: The system is currently operational. Future responsibilities are primarily in the policy and planning levels as affecting proposed data systems (Birch, 1969).

Table 20. Transition matrix for academic progression (Firmin et al., 1967).

	Freshmen	Sophomores	Juniors	Seniors	5th Year	Graduate I	Graduate II	Graduate III	Bachelor	Masters	Doctoral	Dropped
Freshmen	$\delta_{1,1}$	$\delta_{1,2}$	0	0	0	0	0	0	0	0	0	$\delta_{1,12}$
Sophomore	0	$\delta_{2,2}$	$\delta_{2,3}$	0	0	0	0	0	0	0	0	$\delta_{2,12}$
Juniors	0	0	$\delta_{3,3}$	$\delta_{3,4}$	0	0	0	0	0	0	0	$\delta_{3,12}$
Seniors	0	0	0	$\delta_{4,4}$	$\delta_{4,5}$	0	0	0	$\delta_{4,9}$	0	0	$\delta_{4,12}$
5th Year	0	0	0	0	$\delta_{5,5}$	0	0	0	$\delta_{5,9}$	0	0	$\delta_{5,12}$
Graduate I	0	0	0	0	0	$\delta_{6,6}$	$\delta_{6,7}$	0	0	$\delta_{6,10}$	0	$\delta_{6,12}$
Graduate II	0	0	0	0	0	0	$\delta_{7,7}$	$\delta_{7,8}$	0	$\delta_{7,10}$	$\delta_{7,11}$	$\delta_{7,12}$
Graduate III	0	0	0	0	0	0	0	$\delta_{8,8}$	0	0	$\delta_{8,11}$	$\delta_{8,12}$
Bachelor	0	0	0	0	0	0	0	0	0	0	0	$\delta_{9,12}$
Masters	0	0	0	0	0	0	0	0	0	0	0	$\delta_{10,12}$
Doctoral	0	0	0	0	0	0	0	0	0	0	0	$\delta_{11,12}$
Admissions or Dropped	$\delta_{12,1}$	$\delta_{12,2}$	$\delta_{12,3}$	$\delta_{12,4}$	$\delta_{12,5}$	$\delta_{12,6}$	$\delta_{12,7}$	$\delta_{12,8}$	$\delta_{12,9}$	$\delta_{12,10}$	$\delta_{12,11}$	$\delta_{12,12}$

$$\sum_{j=1}^{12} \delta_{i,j} = 1 \quad \text{for } i = 1, 2, \ldots, 12$$

for simplicity the model assumes:

$$\delta_{i,\, i+1} + \delta_{i,\, 12} = 1 \qquad i = 1,\ 2,\ 3$$

$$\delta_{i,i} = 0 \quad i = 1,\ 2,\ \ldots,\ 8$$

$$\delta_{12,\, 12} = 0$$

Table 21. The initial tableau of LP formulation of Churchman-Ackoff's procedure for evaluation of outcomes.

TABLEAU AFTER 0 ITERATIONS

"B"	X1	X2	X3	X4	X5	X6	X7
0	1.00	-1.00	-1.00	-1.00	-1.00	1.00	0
0	1.00	-1.00	-1.00	-1.00	0	0	1.00
0	1.00	-1.00	-1.00	0	-1.00	0	0
0	-1.00	1.00	1.00	0	0	0	0
0	0	1.00	-1.00	-1.00	-1.00	0	0
0	0	-1.00	1.00	1.00	0	0	0
0	0	0	-1.00	1.00	1.00	0	0
0	-1.00	1.00	0	0	0	0	0
0	0	-1.00	1.00	0	0	0	0
0	0	0	-1.00	1.00	0	0	0
0	0	0	0	-1.00	1.00	0	0
19.00	1.00	1.00	1.00	1.00	1.00	0	0
1.00	0	0	0	0	1.00	0	0
0	-7.00	-4.00	-2.00	-1.50	-1.00	0	0
0	-1.00	-1.00	-1.00	-1.00	-2.00	0	0

Table 22. The final tableau of LP formulation of Churchman-Ackoff's procedure for evaluation of outcomes.

TABLEAU AFTER 12 ITERATIONS

"B" ::	X1 :	X2 :	X3 :	X4 :	X5 :	X6 :	X7 :
1.00 ::	0	0	0	0	0	1.00	-1.00
1.00 ::	0	0	0	0	0	0	1.75
1.00 ::	0	0	0	0	0	0	0
2.00 ::	0	0	0	0	0	0	-1.00
1.00 ::	0	0	0	0	0	0	0
2.00 ::	0	0	0	0	0	0	1.75
9.00 ::	1.00	0	0	0	0	0	.50
5.00 ::	0	1.00	0	0	0	0	-0.25
3.00 ::	0	0	1.00	0	0	0	.75
1.00 ::	0	0	0	1.00	0	0	-1.00
1.00 ::	0	0	0	0	1.00	0	0
0 ::	0	0	0	0	0	0	-1.00
4.00 ::	0	0	0	0	0	0	.75
91.50 ::	0	0	0	0	0	0	2.50

Table 23. Computer output for the study of the effect of family background variables on college graduation.

DO YOU WISH TELETYPE OUTPUT ? YES;

ANALYSIS OF VARIANCE. . . . . GRAD

LEVELS OF FACTORS

D	2
C	2
B	2
A	2

GRAND MEAN 33. 00000

SOURCE OF VARIATION	SUMS OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARES
D	2209. 000	1	2209. 000
C	1722. 250	1	1722. 250
DC	1892. 250	1	1892. 250
B	289. 000	1	289. 000
DB	64. 000	1	64. 000
CB	12. 250	1	12. 250
DCB	30. 250	1	30. 250
A	289. 000	1	289. 000
DA	169. 000	1	169. 000
CA	2. 250	1	2. 250
DCA	6. 250	1	6. 250
BA	1. 000	1	1. 000
DBA	49. 000	1	49. 000
CBA	30. 250	1	30. 250
DCBA	6. 250	1	6. 250
TOTAL	6772. 000	15	

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*****OSU*******DEPT OF INDUSTRIAL ENGINEERING*****
*                                               *
*    MARKOV CHAIN SIMULATION OF GRADUTION OF    *
*    ENGINEERING STUDENTS AT OSU                *
*                                               *
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THERE ARE 6 STATES
THE RUN WILL BE 250 LONG
THE INITIAL STATE IS 0
THE SEED IS 0
THE SNAP INTERVAL IS 50

TRANSITION PROBABILITY MATRIX
(ROUNDED TO TWO DECIMAL PLACES)

0	1.00	0	0	0	0
0	0	.64	0	0	.13
0	0	0	.95	0	.01
0	0	0	0	.81	.09
.91	0	0	0	0	.05
1.00	0	0	0	0	0

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*****OSU*******DEPT OF INDUSTRIAL ENGINEERING*****
*                                                *
*    MARKOV CHAIN SIMULATION OF GRADUTION OF     *
*    ENGINEERING STUDENTS AT OSU                 *
*                                                *
**************************************************

TIME=  200.00
FREQUENCY DISTRIBUTION

     PERCENT    0       10       20       30       40       50       60       70       80       90       100
                .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
(STATE   0)     XXXXXXXXXXXXXXXXXXXX.   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
 SOCIETY        .   19.00%    .  X.   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .     38.00
                XXXXXXXXXXXXXXXXXXXX.   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
                .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
(STATE   1)     XXXXXXXXXXXXXXXXXXXXXXXXXXXXX   .   .   .   .   .   .   .   .   .   .   .   .   .
 FRESHMAN       .   28.50%    .   .   .  X  .   .   .   .   .   .   .   .   .   .   .   .   .     57.00
                XXXXXXXXXXXXXXXXXXXXXXXXXXXXX   .   .   .   .   .   .   .   .   .   .   .   .   .
                .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
(STATE   2)     XXXXXXXXXXXXXXXX    .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
 SOPHOMORE      .   16.00%   .X     .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .     32.00
                XXXXXXXXXXXXXXXX    .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
                .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
(STATE   3)     XXXXXXXXXXXXXXXXX   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
 JUNIOR         .   17.00%    . X   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .     34.00
                XXXXXXXXXXXXXXXXX   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
                .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
(STATE   4)     XXXXXXXXXXXXX   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
 SENIOR         .   .   .  X  13.00%    .   .   .   .   .   .   .   .   .   .   .   .   .   .   .     26.00
                XXXXXXXXXXXXX   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
                .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
(STATE   5)     XXXXXXX .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
 DROPOUT        .   .X  .   6.50%   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .     13.00
                XXXXXXX .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .   .
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*****OSU*******DEPT OF INDUSTRIAL ENGINEERING*****
*                                                *
*    MARKOV CHAIN SIMULATION OF GRADUTION OF     *
*    ENGINEERING STUDENTS AT OSU                 *
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TIME=  250.00
FREQUENCY DISTRIBUTION

     PERCENT   0         10        20        30        40        50        60        70        80        90        100
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(STATE   0)    XXXXXXXXXXXXXXXXXXX .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
 SOCIETY       .    18.40%    .  X .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   46.00
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(STATE   1)    XXXXXXXXXXXXXXXXXXXXXXXXXXXXX .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
 FRESHMAN      .    28.00%    .    .    .  X .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   70.00
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(STATE   2)    XXXXXXXXXXXXXXXXX   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
 SOPHOMORE     .    16.80%    .X   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   42.00
               XXXXXXXXXXXXXXXXX   .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
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(STATE   3)    XXXXXXXXXXXXXXXXXX  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
 JUNIOR        .    17.60%    . X  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   44.00
               XXXXXXXXXXXXXXXXXX  .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
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(STATE   4)    XXXXXXXXXXXXXXX.    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
 SENIOR        .    14.00%   X.    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   35.00
               XXXXXXXXXXXXXXX.    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
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(STATE   5)    XXXXXX    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .
 DROPOUT       .    X    .    5.20%    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .    .   13.00
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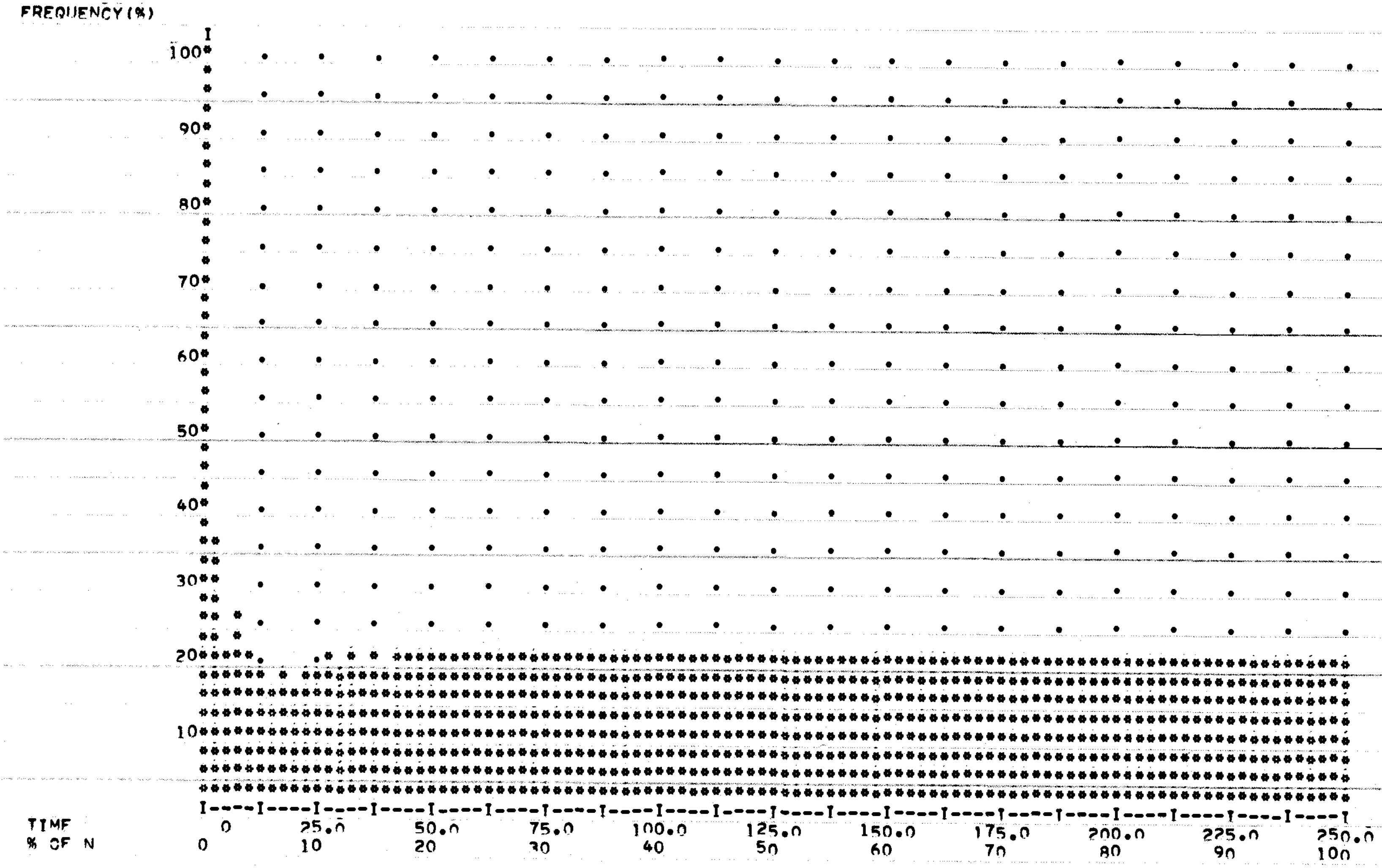
*****OSU*********DEPT OF INDUSTRIAL ENGINEERING*****

MARKOV CHAIN SIMULATION OF GRADUTION OF
ENGINEERING STUDENTS AT OSU

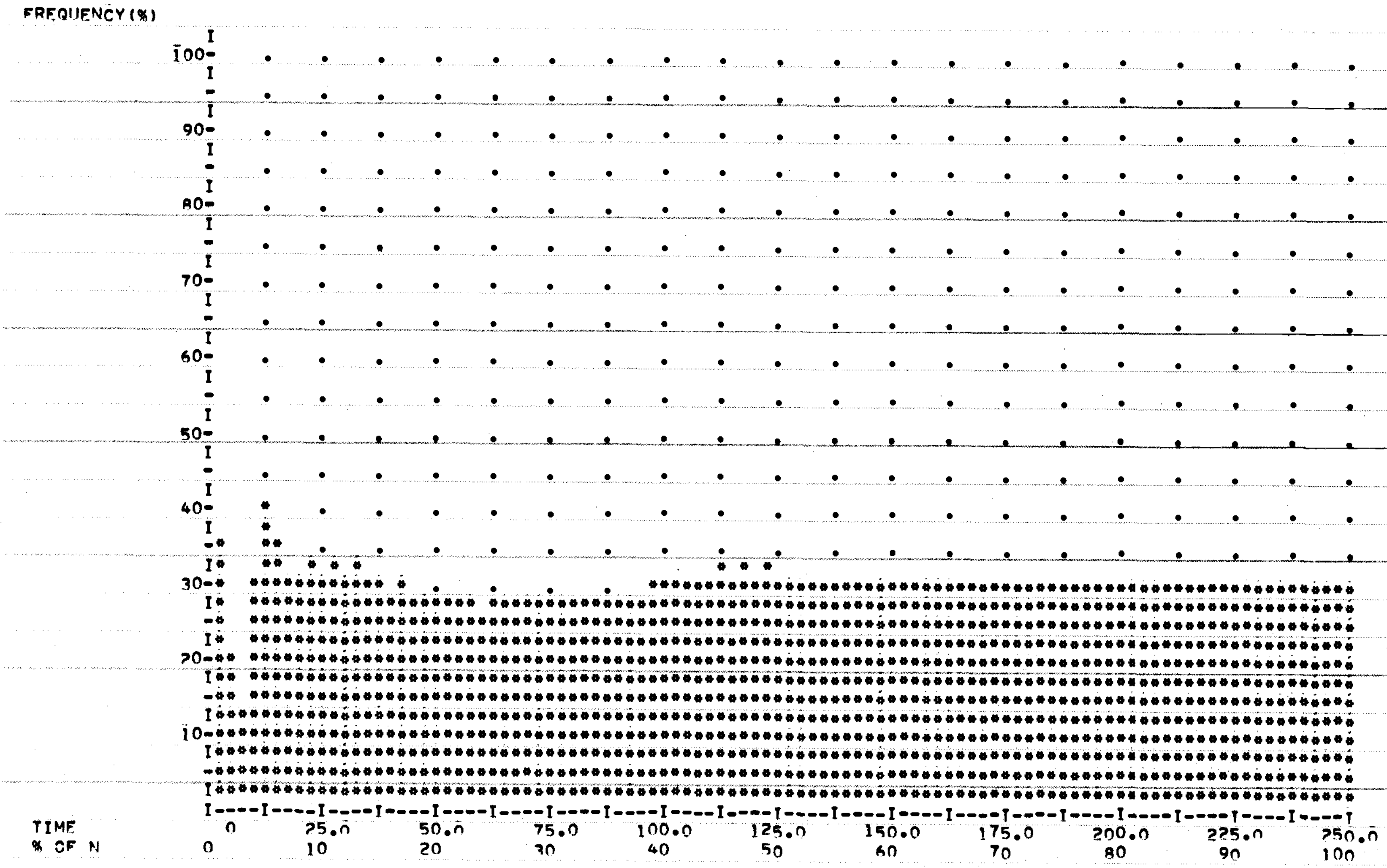
*** STATE 0 ***SOCIETY ***



*****OSU********DEPT OF INDUSTRIAL ENGINEERING*****

MARKOV CHAIN SIMULATION OF GRADUTION OF ENGINEERING STUDENTS AT OSU

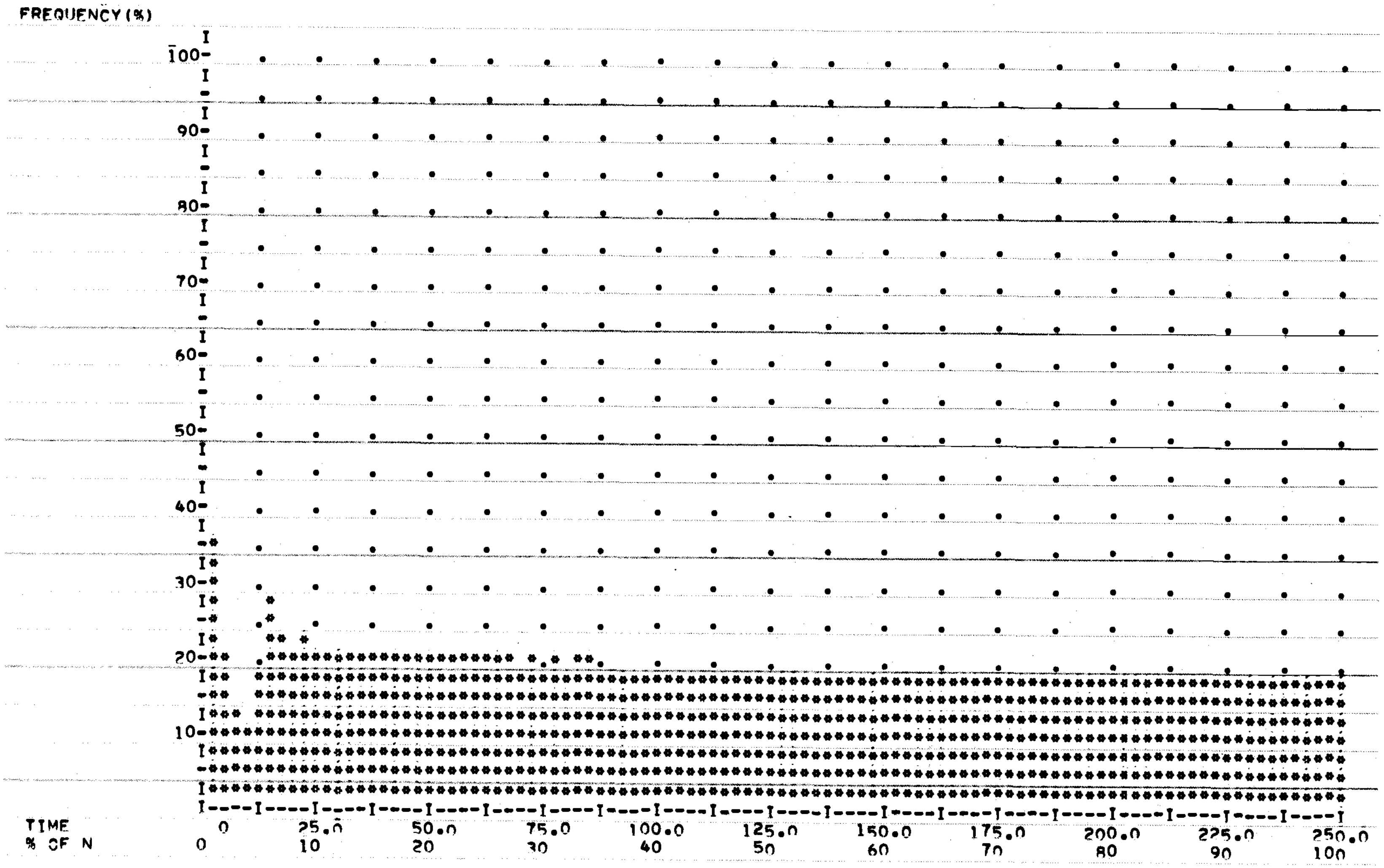
*** STATE 1 ***FRESHMAN ***



*****OSU*******DEPT OF INDUSTRIAL ENGINEERING*****

MARKOV CHAIN SIMULATION OF GRADUTION OF
ENGINEERING STUDENTS AT OSU

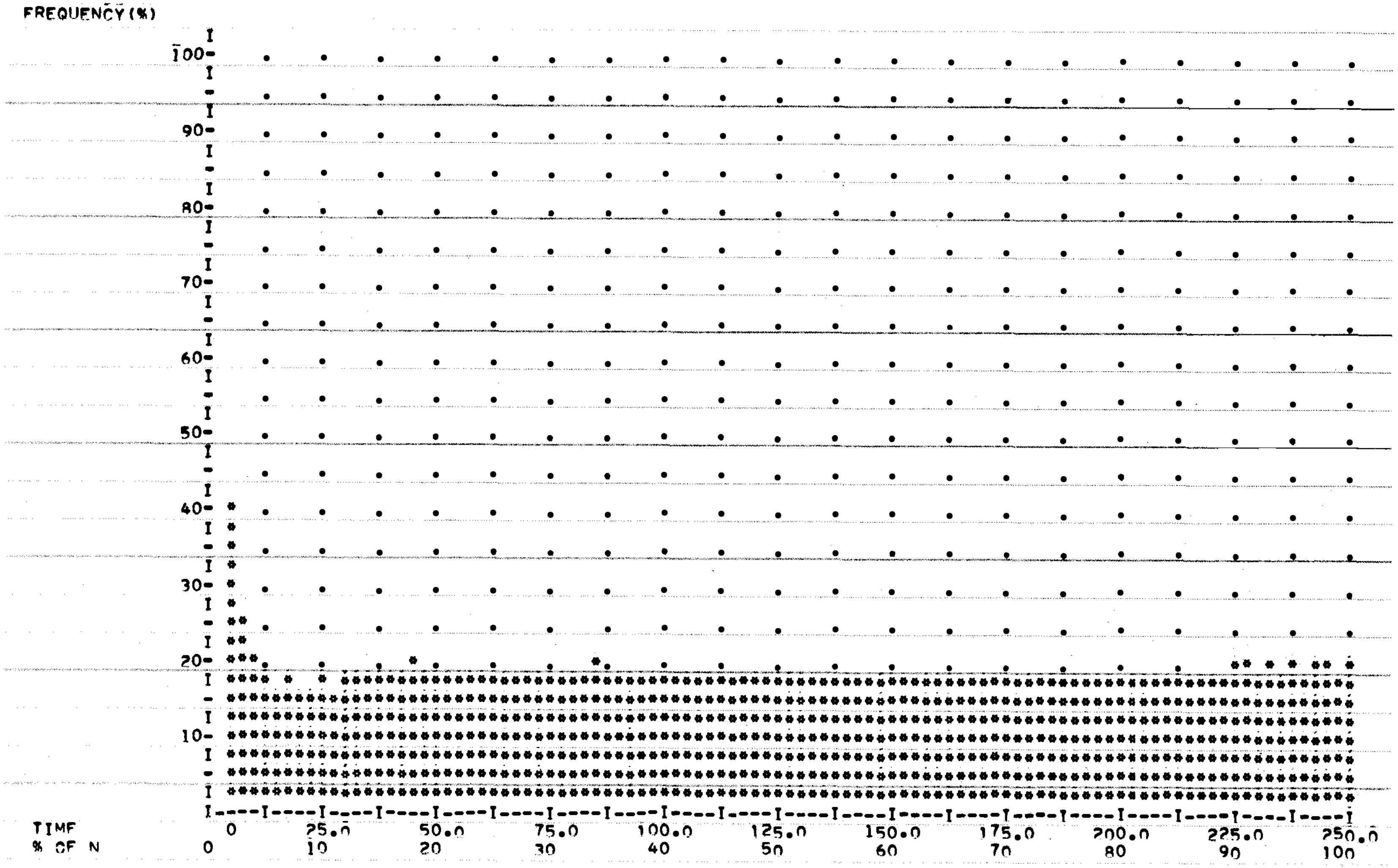
*** STATE 2 ***SOPHOMORE ***



*****OSU*******DEPT OF INDUSTRIAL ENGINEERING*****

MARKOV CHAIN SIMULATION OF GRADUTION OF
ENGINEERING STUDENTS AT OSU

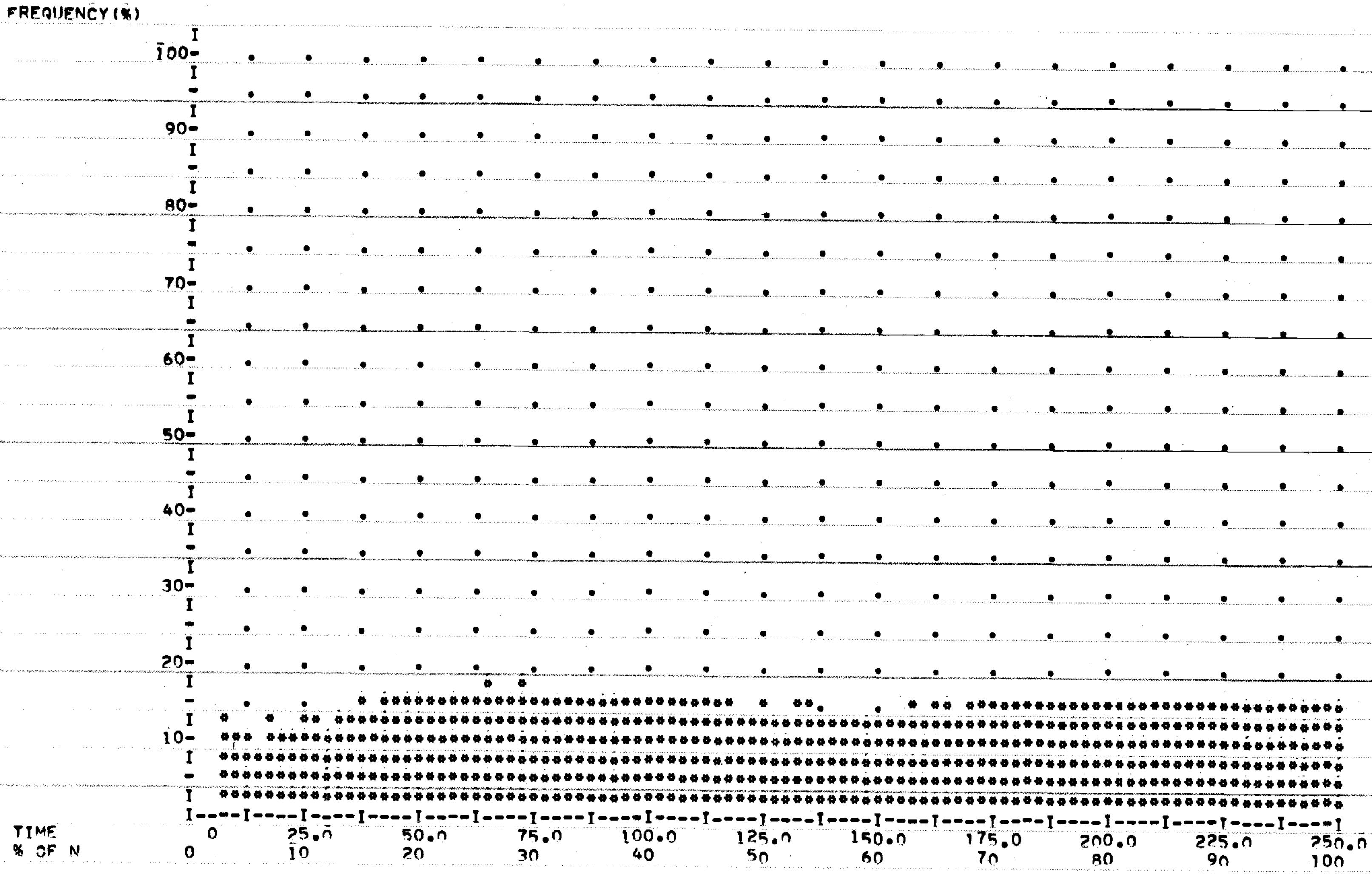
*** STATE 3 ***JUNIOR ***



*****OSU********DEPT OF INDUSTRIAL ENGINEERING*****

MARKOV CHAIN SIMULATION OF GRADUTION OF
ENGINEERING STUDENTS AT OSU

*** STATE 4 ***SENIOR ***



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*****OSU********DEPT OF INDUSTRIAL ENGINEERING*****
*                                                 *
*    MARKOV CHAIN SIMULATION OF GRADUTION OF      *
*    ENGINEERING STUDENTS AT OSU                  *
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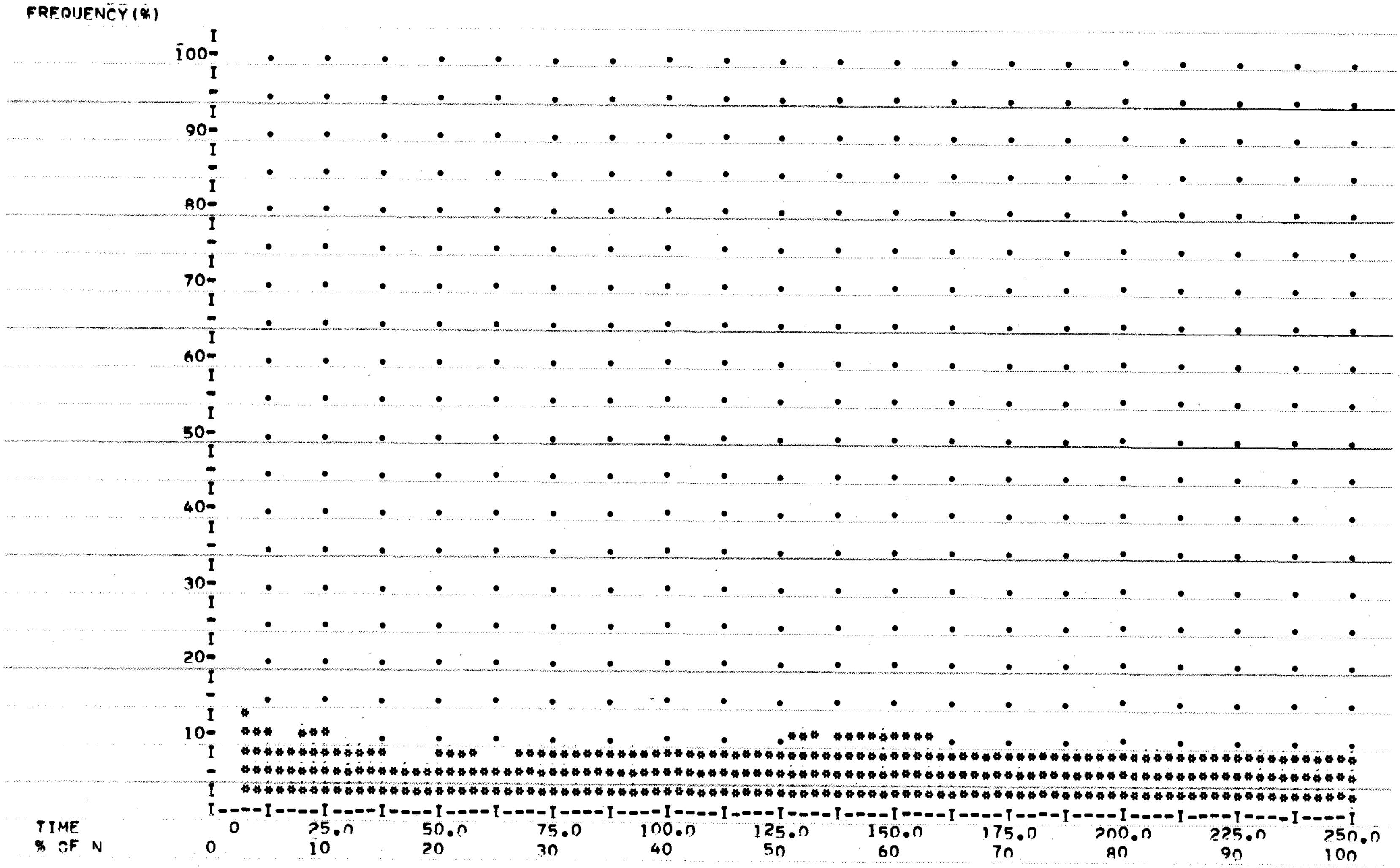
*** STATE 5 ***DROPOUT ***



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SENIOR
SOCIETY
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