*Proceedings of the 1987 Winter Simulation Conference*
A. Thesen, H. Grant, W. David Kelton (eds.)

# A SIMULATION MODEL OF PUBLIC UNIVERSITY FINANCIAL RESOURCES FOR FACULTY

John L. Ballard
Industrial and Management Systems Engineering
University of Nebraska-Lincoln
Lincoln, Nebraska 68588-0518

Thomas W. Spilker
General Dynamics Space Systems Division
San Diego, California 92123

ABSTRACT

During the previous decade it became increasingly important for public institutions of higher education to be concerned with the development and administration of budgets. A primary area of concern related to fiscal management has been the management of faculty -- specifically, the need to retain qualified faculty and to recruit new faculty in a competitive marketplace.

The paper presents a combined SLAM simulation model of university financial resources for faculty salaries which effectively describes the relationships among important variables over a specified planning horizon. The simulation model estimates budget utilization and provides information on sources of income and levels of expenditure. Also, the model makes "what if" types of analyses and tests fiscal policy alternatives.

The simulation model estimated the university resources over a five year planning horizon. A set faculty attributes is created, such that the consumption of funds can be observed from performing a normal payroll operation. Furthermore, the simulation model was used to assess twelve policy alternatives related to salary increases, the level of faculty full-time equivalents including hiring freezes, and student enrollment and its impact on tuition and fee receipts.

A summary of the major findings is:

1. The model effectively simulates growth but displays a disparity between funding and changes in faculty.

2. Hiring freezes effectively reduce cost, however, such policies can never be strictly implemented.

3. Only substantial, if not excessive, increases in tuition and fees can offset a reduction in general fund appropriations.

## 1.0 INTRODUCTION

The development and administration of budgets within a public institution of higher education has been a principal area of resource management for decades. However, the inflationary economic trends of the 1970's, the restrictive levels of funding set by legislative bodies and the prospect of declining student enrollment have all contributed to making financial resource management one of the most prominent aspects of educational administration.

During this time of economic stress and increased limitation of financial resources a primary area of concern has been the management of faculty. The availability of financial resources directly drives the institution's ability to retain qualified faculty and recruit new faculty in the marketplace.

Modeling the financial resources in an educational institution or the institution's organizational structure is nothing new. Work in this area includes resource requirements models; see Perkins and Pashke (1973), Shroeder (1974), and Honeyman and Potts (1976). Several models have been built which utilize goal programming to allocate resources. These include Lee and Clayton (1972), Shroeder (1974), Walters, Mangold and Haran (1976), Smith (1978), and Van Horn (1978). Other resource allocation models include Gerwin (1969), Halpern (1972), Koch (1973), and Cooper (1977). At the time of this modeling effort some of the most recent work in financial resource modeling was performed at Stanford University. For references see Oliver and Hopkins (1972), Hopkins (1974), Massy (1976), Hopkins and Massy (1977), and Hopkins (1979).

This paper describes a discrete event simulation model which simulates the income and expenditure of financial resources for faculty. The approach is to model the organizational structure of faculty by building a set of entities with attributes related to the variables of interest. Each entity is a faculty member within a college who is paid a salary over a twelve month period, carries a teaching load and may perform additional work in the summer. The attributes of the faculty member are adjusted during the course of the simulation. Adjustments include salary increases, changes in teaching load, promotions, and in some instances termination in the form of resignation, retirement or death. The set of faculty is also subject to programmatic change manifested by the addition or deletion of positions. Budgeted funds are expended through the use of a payroll operation which occurs monthly. Faculty are contracted on a nine month basis and paid over twelve months with the possibility of additional income from summer teaching.

Income is generated from the different sources of funding available to the institution, the principal source being the state general tax fund. The model simulates the changes in funding over a five year planning horizon. The model makes decisions based upon income and adjusts the faculty accordingly. Student enrollment is included in the model but only as a device to determine the amount of tuition and fee receipts and the level of credit hour production.

## 2.0 MODEL STRUCTURE

There are two aspects to the model structure: the nature of the simulation and how it is to be accomplished and the method of employing the SLAM II simulation language. The simulation style is to model consumption of budget by simulating the employment process for faculty and generation of income by the decisions and processes which represent public appropriations and the receipt of income from other sources such as tuition. The SLAM II language is used to its fullest capability to include the three world views of simulation upon which the language is structured; see Pritsker (1986). The employment of faculty and the decisions and processes governing income are modeled as Fortran discrete events. The levels of financial resources are modeled as continuous variables. The academic calendar which coordinates activities in the model is a SLAM network.

## 2.1 FACULTY STAFFING

The set of faculty is created as a collection of entities which continuously reside on a file during model execution. The faculty are constructed by the initial conditions routines and then adjusted during the year according to the policies and functions driving the model's behavior. Various demographic attributes are associated with each faculty member. These are listed in Table 1. Much of the demographic data regarding faculty were obtained from the Office of Institutional Research for the University of Nebraska-Lincoln. Additional data, principally related to turnover rates, hiring rates and promotions, were collected from the Office of the Vice Chancellor for Academic Affairs. Additional data was extracted from Board of Regents' agendas.

The expenditure of budgeted funds for faculty salaries is modeled by simulating a payroll operation. This is a simplified operation and includes amounts for gross salary only. Benefits costs such as insurance premiums and matching contributions for social security and retirement are not included. The payroll is processed monthly.

The adjustment to the set of faculty is programmmed to occur two times during the year: fall, and summer. The model is restricted to adjusting the set of faculty in the fall and summer because the types of transactions governing faculty are usually effective in the fall, not in the spring, and only in the summer to the extent that summer teaching and research activities occur.

Table 1: Attribute Vector for Faculty

| Element | Description |
|---|---|
| 1 | Faculty rank |
| 2 | College in which position resides |
| 3 | Budgeted annual salary |
| 4 | Position status as to filled or vacant |
| 5 | Indication if faculty member work during the summer |
| 6 | Faculty member's age |
| 7 | Faculty member's years of accumulated service |
| 8 | Number of years spent at current faculty rank |
| 9 | Indication of graduate college teaching responsibilities |
| 10 | Monthly salary on a 12 pay period basis |
| 11 | Indication as to full-time or part time position |
| 12 | Number of associated student credit hours for the current term |
| 13 | Summer salary to be added if summer teaching is involved |
| 14 | Time of the next promotion |
| 15 | Full-time equivalency of the position where full-time positions are 1.0 |

Occasionally decisions regarding a position are made in the spring but these are almost without exception implemented in the fall term.

By far, the changes that occur in the fall comprise the major portion of the model's adjustment subroutine. The general philosophy is that any vacancies to be created are created before any new faculty members are hired. The fall adjustment takes into account changes in the full-time equivalents (FTE) assigned to a college. These changes may be the result of growth or reduction in programs, not merely the normal turnover in faculty. The changes can involve administrative changes and structural changes to the respective college. However, programmatic changes involving a reduction in staff are often carried out through the process of attrition, and any amount of reduction which can be taken care of through the normal process of resignation and termination is allowed.

An important characteristic of the faculty adjustment process is that if a new vacancy is created, resulting from the resignation or termination of a faculty

member, the position is refilled immediately.This is a reasonable technique because faculty are contracted on a nine month basis. They may leave at the end of the spring term but their salary is spread over a twelve months which requires them to be retained in the model until the beginning of the fall term.

This distinction in the treatment of faculty is important because other types of positions, especially administrative positions, may remain vacant for a significant period of time until a replacement is found. This tends not to be the case with university faculty. Therefore, the concept of realizing budget savings from vacancies is different in a university environment. Vacancy savings is not realized with respect to faculty unless positions are carried within the budget as lines of budget from year to year and drawn upon for funds necessary to make changes to filled positions.

The fall adjustment to faculty creates and fills vacant positions. With respect to faculty this process is driven by resignation, termination, retirement, and death while employed. For those faculty members remaining in the system the adjustment routine processes promotions and updates attributes such as age and years of service.

The summer adjustment to faculty determines if the faculty member will teach. An appropriate adjustment to the faculty member's base salary is added during the summer months. Instructional workloads are related to faculty rank. Lower level faculty, such as instructors, are more likely to teach in the summer than the more senior faculty members, because senior faculty generally spend more time with research activities.

## 2.2 SALARY POLICY FOR FACULTY

A discrete event is used to determine new salary levels beginning in the fall term. Policy for new salaries is usually related to the level of general fund appropriations. The event represents a salary policy which is decided in the spring. The policy is implemented in the fall because the new funds are available at the beginning of the fiscal year.

Emphasis is given to increases for performance when small amounts of funds are available. A certain amount of discretionary funds is determined, however, within the model discretionary funds are distributed uniformly throughout the university as a matter of simplification. These are for the purpose of eliminating inequities among staff members and solving specific salary problems that may occur due to outside market conditions. Across-the-board amounts are awarded if there are sufficient funds.

The model does not decide the performance of the faculty member as a way of determining the pay increase. What is modeled is the fact that increases for performance are awarded to the faculty. It is assumed that performance increases occur throughout the set of colleges at similar levels.

Amounts allocated to salary increases are dispersed among the filled positions. Vacant positions are bypassed. They remain as budgeted positions but their impact is not adjusted. The model disperses all funds made available.

## 2.3 GENERATION OF INCOME

The model contains several events which represent the sources of funding for faculty. These include general funds appropriated by the legislature, cash funds which are tuition receipts, revolving funds, grants and contracts, and trust funds.

The decisions regarding the changes in these funds were developed from historical data within the university. Where possible, ten years' worth of information was used to build the process generators used in the event subroutines. Data were collected from past budgets published by the University of Nebraska Administration.

The general fund appropriation is by far the major contributor to the salaries for faculty. These are funds generated through public taxation.

Revolving funds are generated from university operations such as dormitories, the student union, continuing studies, stores operations, etc. It is assumed that income from such operations is used to fund the operations. A small portion of revolving funds is used to fund faculty.

Grants and contracts funds are derived from federal sources of funding. Typically, these funds are used to support research performed by the faculty. The funds are considered a significant portion of the total funding of faculty salaries.

Trust funds are agency funds received from outside sources. The funds are administered by the university for such outside sources. Trust funds are not considered a major contributor to faculty salaries. Historically, they have a relatively high variability from year to year.

The most complex modeling technique regarding funding sources is the procedure for generating cash income based upon tuition receipts. An event is included to establish the tuition rates and mandatory student fees charged to students. The event takes into account undergraduate and graduate students who are residents of Nebraska or who are not residents. The university's only professional school, the law school, has its own tuition rate which is also included in the model.

## 2.4 TOTAL BUDGET FOR FACULTY

The model contains an event which

computes the total budget for faculty salaries. The total budget contains amounts available from all funding sources. Once the total figure is determined it is allocated to the colleges. The percent allocated is determined from the relative amount of funds that the college already possesses. In other words, the allocation event is not used to implement programmatic changes within the institution. This is done by modeling adjustments to the set of faculty positions.

## 2.5 BUDGETED FUNDS AS CONTINUOUS VARIABLES

Subroutine STATE, which is a user defined subroutine and managed by SLAM II, was used to monitor the financial amounts as difference equations. Variables were tracked for nine colleges. Table 2 lists the topical areas for the continuous variables.

Table 2: Topical Areas for Continuous Variables

| Group | Description |
|---|---|
| 1 | Expenditure for faculty salaries (filled positions) |
| 2 | Non-expenditure of funds for faculty positions (vacant positions) |
| 3 | Cash generated in current semester or summer |
| 4 | Sources of funding |
| 5 | Amount of funds allocated to colleges |

## 2.6 UNIVERSITY CALENDAR

A network of SLAM nodes was used control the model and provide continuity among the various discrete events. The model operates on an academic year basis for a period of five years. The network proceeds through each academic year calling appropriate discrete events.

## 3.0 MODEL OPERATION AND POLICY ALTERNATIVES

The modeling task was to establish a baseline configuration which could be compared to alternative configurations which were generated through the application of different policy alternatives. The policy alternatives were applied through the use of a set of policy factors which could be modified between runs. Table 3 lists the set of policy factors available in the model. The policy factors are defined in the initial conditions routines of the model.

The policy factors are utilized singly or in combination to define policy alternatives for the model to respond to. The alternatives chosen for the study were selected to address contemporary issues faced by the administration which could be considered as either demonstrating model sensitivity or an example of a meaningful budget alternative. A total of twelve alternatives were run. These are outlined briefly.

### 3.1 POLICY 1 - FACULTY SALARY I

All increases in state general tax funds are allocated to faculty salaries. The model avoids setting aside funds for programmatic change.

Table 3: Policy Factors Set by Initial Conditions

| Factor | Description |
|---|---|
| 1 | The initial number of faculty FTE used in the model |
| 2 | The proportion of vacant positions to the total number of positions |
| 3 | The number of student credit hours per FTE faculty member |
| 4 | The level of student enrollment applied to all types of students |
| 5 | The mean and standard deviation for change in the state general fund appropriation |
| 6 | The change in tuition rates and student fees |
| 7 | The change in FTE for filled positions within all colleges |
| 8 | The change in budgeted FTE re programmatic change |
| 9 | The resignation rate among faculty |
| 10 | The mean and standard deviation for the general salary increase policy |

### 3.2 POLICY 2 - FACULTY SALARY II

Raise faculty salaries beyond amounts supported by state general tax funds. Monitor availability of funds from vacant positions.

### 3.3 POLICY 3 - GENERAL FUNDS AND CASH I

Reduce the expected amount of general tax fund increase and offset the reduction with an increase in cash from tuition.

### 3.4 POLICY 4 - GENERAL FUNDS AND CASH II

Run the same situation as policy 3 except that cash is left at the normal level. General funds are permitted to affect salary levels, but no effort is made to shift the burden to students.

### 3.5 POLICY 5 - INCREASED VACANCIES

The number of vacant positions in

proportion to filled positions is held higher than normal. The normal value is approximately 5 percent. This alternative raises the proportion to 10 percent.

### 3.6 POLICY 6 - ELIMINATION OF VACANCIES

The number of vacant positions is reduced to zero. The model may still add vacancies due to programmatic change.

### 3.7 POLICY 7 - HIRING FREEZE ON FACULTY

No additions of faculty positions are permitted. Also, any vacancies which occur are not refilled. This represents normal attrition to reduce costs without a formal reduction in force.

### 3.8 POLICY 8 - HIRING FREEZE WITH EMPHASIS ON FACULTY SALARIES

This policy is the same as policy 7 with reduced general funds and allocation of any general fund increases completely to salaries. Cash funds are not changed.

### 3.9 POLICY 9 - INCREASED STUDENT ENROLLMENT

This policy increases student levels by approximately 5 percent with a corresponding workload increase for faculty. An increase in tuition and fee receipts is realized.

### 3.10 POLICY 10 - REDUCED STUDENT ENROLLMENT

This policy is the opposite of policy 9. The enrollment levels are approximately 5 per-cent less. Tuition and fee receipts are reduced.

### 3.11 POLICY 11 - FACULTY/STUDENT RATIO

Levels of student enrollment are held to the same level, but the number of faculty is lowered. There is a corresponding increase in credit hour production.

### 3.12 POLICY 12 - FACULTY REDUCTION WITH LOWER STUDENT ENROLLMENT

This policy reflects a cutback in faculty staffing to respond to a reduction in student enrollment. It is based on the need to keep faculty to student ratios constant.

## 4.0 RESULTS

The objective of this model was to simulate university financial resources for faculty and describe the relationships among several variables which include the dynamics of staffing levels, cash flow of budgeted funds, and the impact of student enrollment on cash flow, tuition and fees.

The summary results of the study are:

1. The model effectively simulates growth in funding and expenditures over a five year period.

2. The model shows an excessive disparity between funding and changes in faculty FTE.

3. Hiring freezes effectively reduce costs. Faculty FTE decreases rapidly and results suggest that such policies can never be strictly implemented.

4. Only substantial, if not excessive, increases to tuition and fees can offset a reduction in general fund appropriations.

The results are drawn from modeling the fundamental or baseline configuration and applying the twelve policy alternatives. The alternatives can be grouped into three parts:

1. policies affecting salary increases,

2. policies related to the level of faculty FTE including hiring policy, and

3. policies related to student enrollment and the impact on tuition and fees.

### 4.1 BASELINE RESULTS

Figure 1 is the baseline output from running the model for a five year planning horizon. The growth in funding is based on two things, appropriations for salary increases and appropriations for programmatic growth.

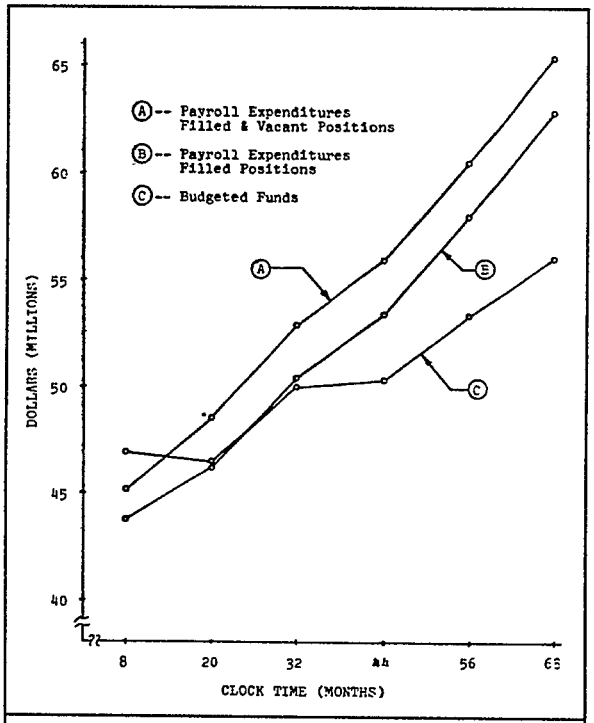


Figure 1: Base Model

Historical data was not available which split the annual appropriations into the two parts. The trend over the years had been to

establish a salary increase policy which required less than the total amount of general funds. This practice was instilled in the model by forcing salary increases on the average to run less than the total amount appropriated. The difficulty was that the manipulation of faculty FTE and budgeted funds had to be performed independently. This technique was probably the cause for the disparity between the amounts expended and the amount of budgeted funds.

Figure 1 shows expenditures for faculty and what they would be if vacancies were filled. If the budgeted funds and expenditures are viewed separately the patterns are realistic and consistent with historical data with the exception of the decrease in budgeted funds in the first year because the university had yet to actually experience a decrease.

## 4.2 FACULTY STAFFING LEVELS

Policy alternatives 5 through 8 primarily concern faculty staffing levels. Figure 2 is a graph of payroll expenditures for all four alternatives. The meaningful results come from comparing alternatives 5 and 6 to 7 and 8. Policy alternatives 7 and 8 reflect a hiring freeze among the faculty. A sizeable recoupment of funds can occur if a hiring freeze can be maintained over a period of 2 to 3 years. This particular case assumes that a legislature will not respond during the same period and reduce appropriations.

The historical data used to build the model included periods with hiring freezes and yet the institution had experienced growth. It was not evident in the data history that any sizeable recoupment of funds had ever occurred as a result of a hiring freeze. The model does not permit vacancies to be filled. The more realistic proposition is that hiring freezes may never be effectively implemented even if they are rather strictly defined. Perhaps a better interpretation is that, as positions become vacant they are reviewed by administrative personnel as to their need with the result that many positions continue to be filled.

The difference between policies 7 and 8 is simply that general fund increases are reduced for policy 8. As a result salary increases are cut. Policy alternative 8 does, however, allocate all increased appropriations to salary. This would not be an unusual situation if an institution were to experience a reduced change in appropriations.

## 4.3 STUDENT ENROLLMENT AND CASH RECEIPTS

Policy alternatives 9 and 10 are sensitivities on student enrollment and the resulting impact on the total budget due to tuition and fees received. The results are shown in Figure 3. Policy 9 is a five percent increase in enrollment levels over the basic model and policy 10 is a five percent reduction below the nominal levels.

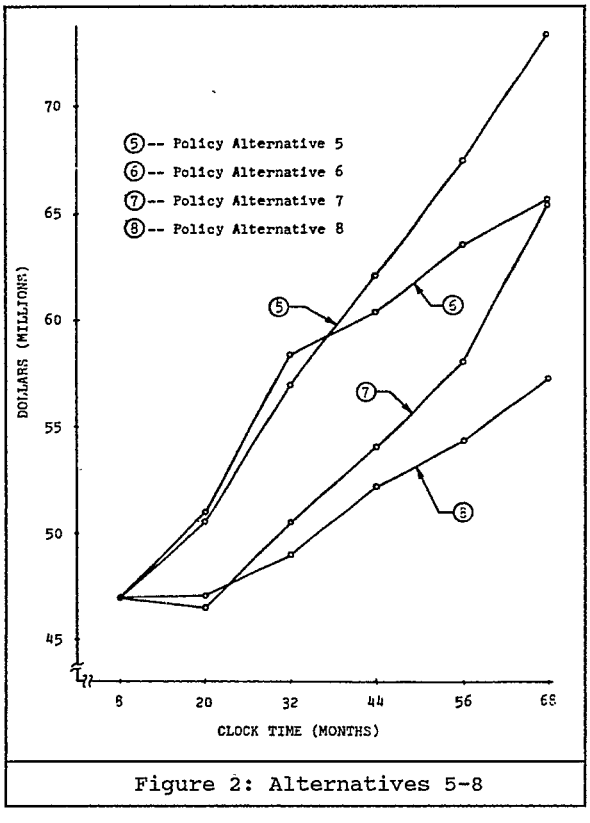


Figure 2: Alternatives 5-8

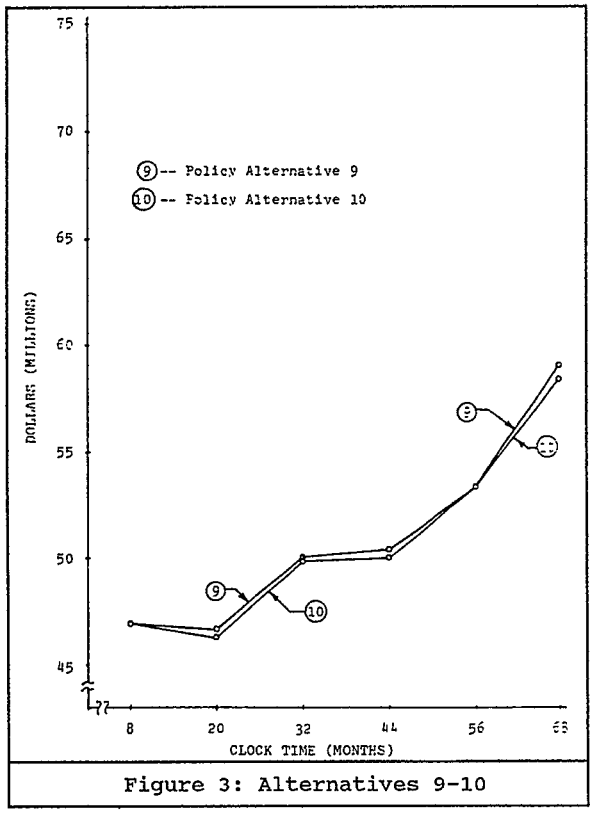


Figure 3: Alternatives 9-10

The model determines the amount of cash income by first setting tuition rates per credit hour annually and then determining enrollment levels in the fall, spring and summer. The model distinguishes among the types of students only to the extent that tuition rates differ.

Figure 3 shows that budget impact is minimal. These two alternatives are simple in concept but very important because the share of budget support between the tax paying population and the student population which takes advantage of the institutions instructional programs is a continuing issue.

The results here are probably expected because the level of cash support in relation to general fund support is lower to begin with. Cash begins at about 18 percent of the total while general funds begin at about 62 percent. However, the insensitivity of the total budgeted funds to enrollment points out the inertial properties of the allocation of support to the funding sources. A word of clarification here, the alternatives deal with enrollment not the tuition rate. The cash generated is the product of the rates in dollars per credit hour and enrollment in credit hours. Raising or lowering either term in the equation by a multiplication factor has the same effect.

The alternatives can be used to show that a decision to offset a reduction in general fund support with an increase in tuition and fees is not a viable alternative as a near term solution. The adjustment required may have to be quite substantial if not excessive.

One final point, the model does not include a response to changes in tuition which impact enrollment. If tuition is raised some people may be deterred from attending the institution. This possibility cannot occur in the model.

## 5.0 CONCLUSIONS

The important goal of this modeling effort was to develop an approach which simulated budget consumption based upon the organizational structure of the institution as opposed to another structure such as an accounting structure. This was the desirable because most financial resource issues are more likely to be dealt with through issues related to the institutions role and mission rather than the processes, such as accounting, which monitor its behavior. It is true that the model executes a payroll operation but the entities upon which the payroll acts comprise a sector of the organization, in this case faculty only. A model of this structure permits realistic consideration of alternatives: staffing levels, enrollment levels, program structure, and the processes which provide income.

The major problem was the independence between the processes which generated income and the processes which expended income. The model should not be used extensively until the environmental processes which determine income can be more closely tied to the institution's response.

## REFERENCES


Cooper, L. (1977). The determination of optimal faculty staffing for a university. Computers and Mathematics with Applications, 3,161-174.

Gerwin, D. (1969). A process model of budgeting in a public school system. Management Science, 15, no. 7, 338-361.

Halpern, J. (1972). Ratios in planning budgeting and bounds on resource requirements. Operations Research, 20, no.5, 974-983.

Honeyman, N. and Potts, J. W. F. (1976). Planning for teaching resource requirements in colleges of technology. Omega: The International Journal of Management Science, 4, no.2, 187-191.

Hopkins, D. S. P. (1979). Computer models employed in university administration: the Stanford experience. Interface, 19, no. 2, part 1, 13-23.

Hopkins, D. S. P. (1974). Faculty early retirement programs. Operations Research, 22, no. 3, 455-467.

Hopkins, D. S. P. and Massy, W. F. (1977). A model for planning the transition to equilibrium of a university budget. Management Science, 23, no. 11, 1161-1168.

Koch, J. V. (1973). A linear programming model of resource allocation in a university. Decision Sciences, 14, no. 4, 494-504.

Lee, S. M. and Clayton, E. R. (1972). A goal programming model for academic resource allocation. Management Science: Application Series, 18, no. 8, B395-B408.

Massy, W. F. (1976). A dynamic equilibrium model for university budget planning. Management Science, 23, no. 3, 248-256.

Oliver, R. M. and Hopkins, D. S. P. (1973). An equilibrium flow model of a university campus. Operations Research, 21, no. 3, 823-834.

Perkins, W. and Pashke, P. (1973). A simulation model of a higher education system of a state. Decision Sciences, 4, no. 2, 194-215.

Pritsker, A. A. B. (1986). Introduction to Simulation and SLAM II. Third Edition. Halsted Press, New York.

Schroeder, R. G. (1974). Resource planning in university management by goal programming. Operations Research, 23, no. 4, 700-710.

Smith, L. D. Planning models for budgeting teaching resources. Omega: The International Journal of Management Science, 6, no.1, 83-88.

Van Horn, J. L. (1978). A Goal Programming Model for Resource Allocation in Higher Education. Dissertation, University of Nebraska-Lincoln.

Walters, A., Mangold, J. and Haran, E. G. P. (1976). A comprehensive planning model for long range academic strategies. Management Science, 22, no.7, 727-738.

AUTHOR'S BIOGRAPHIES

John L. Ballard is an Associate Professor and Interim Chairman of Industrial and Management Systems Engineering at the University of Nebraska-Lincoln. Dr. Ballard joined the University of Nebraska-Lincoln after receiving his PhD from the University of Arkansas in 1974. His primary research interests lie in the development, evaluation, and analysis of discrete event simulation models. Dr. Ballard is a member of SCS,IIE, TIMS and ASEE.

THOMAS W. SPILKER is a senior systems engineer with General Dynamics Space Systems Division in San Diego, California. He received a B.S. in Agricultural Engineering in 1969 and an M.S. in Industrial and Management Systems Engineering in 1983 from the University of Nebraska-Lincoln. His work experience includes university administration as Assistant Director of Personnel for the University of Nebraska System. His present work is in the development of discrete event queueing models which can be used to study the manufacturing and logistics support of space based platforms and launch vehicles.