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I am submitting herewith a thesis written by Jerome David Wegener entitled "Development of a Computer Simulation Model as a Management Aid for a Small College." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Education, with a major in Curriculum and Instruction.

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DEVELOPMENT OF A COMPUTER SIMULATION MODEL AS A MANAGEMENT AID FOR A SMALL COLLEGE

A Dissertation

Presented for the

Doctor of Education

Degree

The University of Tennessee

Jerome David Wegener

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ABSTRACT

The purpose of this study was to develop a computerized model of a small private college that would be of use in the financial management of the institution. In addition, the computer programs were to be executable on a small on-campus digital computer.

A review of the pertinent literature indicated that many small private colleges were in financial trouble at the beginning of the 1970s. Although a number of management tools have been developed and implemented at large universities, there have been few applications of these methods at small institutions. Despite the many good features of such management tools as cost analysis, PPBS, and simulation, they are not panaceas.

Small schools are, in addition, often without funds to implement some of the more expensive management tools. An important feature of the model developed in this study is its capability of being operated on a small computer such as are found on many small college campuses. The model developed was limited to the expenditures for classroom instruction, the largest single line item in the college's budget.

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The model was developed mathematically, and then programmed in FORTRAN. It consisted of two main stages: a descriptive mode and a predictive mode. In the descriptive mode, the enrollments of all the students in various majors and departments were broken down and stored in matrix form. From the instructors' salaries, cost per departmental hour and per course were developed and displayed. Year by year comparisons have proved useful to college administrators in preparing budgets for future years.

The predictive mode relied on past enrollments in the various departments and majors. Future enrollments were projected utilizing the cohort survival method, and answers to various suppositions determined. Typical results included an extraordinary large increase or decline in Freshman enrollment, the effect of introducing new majors, and the effect of closing out departments.

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CHAPTER I

INTRODUCTION

The financial management of an institution of higher education is not an easy task. Never was this more true than in the years just before and after 1970 when colleges and universities were simultaneously confronted with spiraling costs and restricted funding. The overall financial picture declined to such an extent that this period was termed the "new depression" in higher education by the Carnegie Commission on Higher Education.[1]

This financial slump came on the heels of a period of tremendous growth in higher education. Enrollments in colleges and universities increased greatly during the 1960s. In the decade from 1960 to 1970, higher education enrollments increased 212 percent in public institutions and 38 percent in private institutions.[2] Educational expenditures also increased greatly during this period, much of it

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[1]Carnegie Commission on Higher Education, Priorities for Action: Final Report of the Carnegie Commission on Higher Education (New York: McGraw-Hill, 1973), p. 4.

[2]Ronald B. Thompson, Projections of Enrollments in Public and Private Colleges and Universities (Washington, D.C.: American Association of Collegiate Registrars and Admissions Officers, 1970).

due to inflation. According to H. R. Bowen expenditures increased by 5.5 percent per year. When expressed in constant dollars, this amounted to 3 percent per year. He concluded that, at this steady rate, "the cost per student doubles every 23 years."[3]

Income also increased: in the decade ending 1967-68, the income of colleges and universities tripled.[4] Near the end of the 1960s, however, signs of financial stress began to become apparent and the flow of funds from various sources ceased to rise at the rapid rate that had been experienced in the first half of the decade.

The rate at which enrollments had been rising from year to year also declined. For example, the rate of increase from 1970 to 1971 was 2.9 percent whereas, the rate from 1965 to 1966 has been 7.8 percent.[5] This slowdown in enrollment may be attributed primarily to financial and social conditions. Many potential students were finding that personal financial needs required them to start to work rather than continue their schooling. Many also became

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[3]Howard R. Bowen, "Can Education Become More Efficient," Educational Record, LIII (Summer, 1973), p. 191.

[4]Earl F. Cheit, The New Depression in Higher Education (New York: McGraw-Hill, 1971), p. 5.

[5]United States Office of Education, Projections of Educational Statistics to 1981-82 (Washington, D.C.: Government Printing Office, 1973), p. 33.

disillusioned with the type of values propagated by the higher education system. The termination of the draft had also removed the pressure on young men to enroll in college as a means of escape or postponement of military service. This decline in enrollment also meant less funds whether in the form of per student allotments in the case of public colleges and universities or as tuition from students in private ones.

Cheit summarized the characteristics of the financial problem facing higher education as follows:

> The essence of the problem is that costs and income are both rising, but costs are rising at a steady or slowly growing rate, depending on the period and the measure used, whereas income is growing at a declining rate. The rate of growth of expenditures may decline at any given year . . . but the longer range trend has been toward a growing rate of costs. . . . This financial problem arose immediately after a decade of unprecendented growth in higher education. But, contrary to what might be expected, that growth had not protected the school but may well have made them more vunerable to a downturn. Many were undercapitalized, overextended, moving into enlarged areas of responsibility without permanent financing, or still raising quality standards.[6]

During all this time, expenses were rising. Expenditures per full time equivalent student as given by the U. S. Office of Education rose (in terms of 1971-72 dollars) from $1676 in 1961-62, to $2367 in 1971-72, an

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[6]Cheit, op. cit., pp. 137-138.

increase of 4.1 percent. The increase was even more dramatic in private institutions, from $1797 in 1961-62 to $2888 in 1971-72, an increase of 6.0 percent.[7] It was to the small private college that this study was directed.

I. BACKGROUND OF THE PROBLEM

The fact that many small colleges were in financial trouble was pointed out in a study by Jellema. He indicated that many of these institutions were showing deficits in 1969 equal to 26 percent of the book value of their assets.[8] In a follow-up study, the same author predicted the failure of as many as 100 of these institutions in the near future.[9] According to the U. S. Office of Education 64 private four-year institutions of higher education had been forced to close or to merge with other institutions during the period from 1969 to 1973.[10] In his survey of 431 private colleges, Jellema showed that, in addition to financial difficulties,

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[7] USOE, op. cit., p. 3.

[8] William W. Jellema, The Red and the Black: Special Preliminary Report on the Financial Status, Present and Projected of Private Institutions of Higher Learning (Washington, D.C.: Association of American Colleges, 1970).

[9] William W. Jellema, Redder and Much Redder: A Follow-up Study to "The Red and the Black" (Washington, D.C.: Association of American Colleges, 1971).

[10] USOE, Education Directory: Higher Education (Washington, D.C.: Government Printing Office, 1969 to 1974).

these smaller schools showed declines in percentage increase in enrollment during the period of 1965-1972 even though that was a period of generally increasing enrollments.[11] He later stated that private schools showed no gain in 1971, and actually declined in enrollment 1.7 percent in 1972.[12]

Another survey of 48 private four-year liberal arts colleges revelaed that most were characterized by worsening financial conditions with no help in sight.[13] The researchers felt that colleges had experienced more inflation than the economy as a whole while producing only slightly more growth.

In many instances where colleges and universities had continued to operate in or near the black, methods for sustaining financial solvency included tuition increases and boosted rates of admission. While this brought about some short-term financial improvement, administrators at private institutions felt that increases in student fees had reached

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[11]William W. Jellema, The Numbers Game: A Study of Enrollment Patterns in Private Colleges and Universities (Washington, D.C.: Association of American Colleges, 1972).

[12]William W. Jellema, From Red to Black? (San Francisco: Jossey-Bass, 1973), p. 65.

[13]Hans H. Jenny and Richard C. Wynn, The Turning Point: A Study of Income and Expenditure Growth Distribution of 48 Private Four-year Liberal Arts Colleges (Wooster, Ohio: College of Wooster, 1972).

a saturation point; that is, they were driving away students from middle-income families and creating conditions on some campuses such that only the very rich and very poor could afford to attend.[14]

These indications of a particularly high incidence of financial difficulty among private institutions, along with an acceleration of the decline in the proportion of enrollment in private institutions during these years, suggested that the survival of many of our private institutions of higher education was in jeopardy. In his study, Cheit estimated that 42 percent of all private institutions were headed for financial difficulty and that 30 percent had already achieved this dubious distinction.[15]

These colleges had attempted to stem the tide by utilizing various methods of budget cutting, saving in as many ways as they could. As Jellema pointed out:

> Behind these mounds of deficits . . . lie the broken remains of curtailed operations, of innovations untried, and of creativity curbed. If these cutbacks had not been made, the deficits must surely have been higher.[16]

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[14]Cheit, op. cit., p. 13.

[15]Ibid, pp. ix-x.

[16]Jellema, The Numbers Game, p. 113.

However, there were limits to the amount of budget cutting that such small colleges could perform.

> One of the paradoxes of making liberal arts colleges more efficient is that rich institutions with large total budgets can afford the luxury of cost-cutting. They have built-in extravagances which can be removed without serious jeopardy to their basic programs. Poor institutions, on the other hand, have no such discretionary marginal resources. Even though they need desperately to cut costs, they cannot do so without jeopardizing their quality, their accreditation, or even their existance.[17]

A review of financial and enrollment statistics such as those mentioned points to the need for better management practices and for more efficient methods of running the smaller institutions of higher education. As a whole, the higher education community had been frequently criticized for failing to observe principles of effective management. Graese pointed out that "educational institutions must continue to be classed among the more backward of organizations insofar as administrative procedures are concerned."[18] Meeth stated that the cause of the economic dilemma in private colleges was poor management. Although many college presidents indicated the need for planning based on careful

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[17]Howard R. Bowen and Gordon K. Douglass, Efficiency in Liberal Education (New York: McGraw-Hill, 1971), p. 93.

[18]Charles E. Graese, "University Management: A Total Review," Management Controls, XV (April, 1968), p. 75.

institutional analysis, he found that it was not widely practiced in private higher education.[19]

In listing some of the problems faced by small colleges, Mayhew indicated that one was the lack of key personnel in the areas concerned with planning and with the controlling of expenses.[20] In addition, procedures for studying the interaction of the various sectors of the college which could shed additional light on the manner in which the colleges operated were not always readily available to such administrators. Methods of systematic analysis had been put to use by large state universities and state-wide coordinating bodies, but they had had somewhat limited application in small private colleges. This was due primarily to the cost of implementation and to the lack of a machine readable data base. If the latter was not available, it could be expensive in time and staff to get it ready. If the institution has not invested effort in some type of management information system, this task can be quite formidable. Perhaps it should be pointed out that even in some large institutions where large-scale models had been used, there were indications that the time and expense involved had not always been

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[19] L. Richard Meeth, Quality Education for Less Money (San Francisco: Jossey-Bass, 1974), p. 160.

[20] Lewis B. Mayhew, The Smaller Liberal Arts College (New York: Center for Applied Research in Education, 1962).

justified in terms of the extent of their utilization.[21]

That many of the private colleges were in financial difficulty was pointed out above. Each year, an additional number are forced to shut their doors. A number of authors have deplored this fact. For example, Drucker has pointed out:

> I consider the health of the independent college to be one of the most important needs of our society. . . . (They provide) diversity which is the single most important strength of our system of higher education.[22]

Even state systems began to question whether they could afford to allow the independent colleges to disappear. State coordinating boards are considering the contributions that the private institutions make to the state as a whole and the cost that would be involved to the states should the private institutions cease to exist. For example, a study made by the state of Tennessee indicated that private colleges were an asset far too valuable to be ignored in long-range planning for higher education in the state.[23] The

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[21]Jerome F. Wartgow, "An Assessment of the Utilization of Computer Simulation Models in the Administration of Higher Education" (unpublished Doctoral dissertation, University of Denver, 1972).

[22]Peter F. Drucker, "What Principles of Management can the President of a Small College Use to Improve the Efficiency of His Institution," Selected Issues in College Administration, ed. Earl J. McGrath (New York: Teachers College Press, 1967), p. 71.

[23]John S. Diekhoff and Ida Long Rogers, A Study of Private Higher Education in Tennessee (Nashville: Tennessee Council of Private Colleges and the Tennessee Higher Education Commission, 1970).

report mentioned that because of their diverse backgrounds and general life styles, the private colleges allowed students a wider choice of the type of education they might pursue than if there were only public institutions for them to choose from. In addition, as a result of their relatively small size, private institutions presented a better opportunity for close student-faculty relationship and thus more opportunity for personalized education for the students.

Despite the fact that their number is dwindling, four-year college institutions account for nearly 25 percent of the institutions of higher education. However, since they are generally small in size, they account for only 8 percent of the students. Their median size is 846.[24] Since many of them were suffering as a result of the "new depression" in finances, better methods of planning for the future were indicated.

> The need for intelligent and effective short- and long-term planning in education is more urgent than ever before. Only through careful planning can colleges and universities expect to become reasonably successful in responding to the financial, social and political crises of the 1970s and 1980s.[25]

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[24]Carnegie Commission on Higher Education, New Students and New Places (New York: McGraw-Hill, 1971).

[25]Committee for Economic Development, The Managing and Financing of Colleges (New York: CED, 1973), p. 48.

II. STATEMENT OF THE PROBLEM

Christian Brothers College is a small Catholic-affiliated college located in Memphis, Tennessee. While the student enrollment rose to 1162 in 1968-69, after that year it gradually decreased, reaching 820 in 1973-74. Since the largest share of operating capital came from tuition, this decrease in enrollment created a tighter and tighter financial situation. Cutbacks in expenditures were made. Tuition was raised several times during that interval. Departmental budgets and faculty raises were kept to a minimum. Much work was put into development and a number of new sources of money were found.

In making their decisions, the administrators of the college, although using the best information that they could gather, felt that there was need for much improvement. Since the expenditure for classroom instruction was by far the largest single line item in the budget (approximately fifty percent of the total expenditures) the college administrators desired to have a method to examine this line item in detail. A method was desired by which they could determine and compare the amount of money that was actually expended for the various courses and in the various departments.

The college had installed a small digital computer in 1961 that was used primarily for instruction. Having been upgraded somewhat through the years, the system consisted of an IBM 1130 with a 16,000 word memory, three disk drives and a line printer. Such a system is similar to that found on many small campuses throughout the country. Although the primary use of this computer was instructional, a modest management information system had been developed. It was used by the registrar's office, the alumni and development office, and the business office. While not a completely integrated system, it had been found to be quite adequate by its users. The data base from this system furnished the input for the model developed in this study.

The purpose of this study was to develop a cost analysis model of the college using the on-campus computer that would enable the college administration to determine, in any given term, what percent of the instructional budget was expended in each course, in each instructional department, and in each major field. In addition to preparing this descriptive model, an additional purpose of this study was to adapt the model in such a manner that it could be used in making modest predictions concerning the expenditures for classroom instruction in the future. The procedures developed, though specific to Christian Brothers College, were to be general

enough so as to be applicable to other small colleges equipped with similar modest computing equipment.

III. SCOPE AND LIMITATIONS OF THE STUDY

As indicated above, the work of this study consisted of two phases. The first phase was concerned with preparation of the descriptive model. On the one hand, the input for this was faculty salaries and other instructional department expenses and the registration records of the students over the past several years on the other. Utilizing the interrelationships of these quantities, the model was able to output the cost per student credit hours taken by the students in the various major programs. The expectation was that by displaying the breakdown of expenditures per student credit hour according to the departments that produced them and the student and course levels at which they were consumed, the administrators of the college would be better able to determine which programs should receive more support and which programs less in terms of budgeting for the next year.

As indicated, there was no attempt to include total institutional expenditures, but the study was limited to those for classroom instruction. These expenditures by department can be related directly to the number of student credit hours produced. Other line items in the budget

would have to be allocated indirectly to instruction through some special formulas. No effort was made in this study to set up such allocation formulas.

The second phase of the study consisted in preparing the model to operate in the predictive mode. The model was not a complete resources requirements prediction model. Its purpose was not to predict the number of laboratory stations, lecture rooms, or classroom buildings needed. It was limited again to the expenditures for classroom instruction. When used in the predictive mode, the model was to have capability of showing what would be the instructional expenditures necessary for some future enrollment, given the past mix of students and faculty loads. These assumptions must be kept in mind when the results are interpreted. Changes in the student mix and in the faculty productivity may also be entered and their effect on expenditures noted.

IV. DEFINITION OF TERMS

As previously noted, the student credit hour (SCH) was the basic output variable in this expenditure analysis model. While not to be considered a true output of higher education, it is the quantity generally used in cost studies in the same manner as credits are used to specify how much a student has learned. In her research, Frisbee made a rather thorough examination of different cost studies and found

that the SCH was by far the most commonly used unit.[26] Although he did find some slightly different terms used, Witmer,[27] in a thorough review of cost studies, concluded that the SCH is the most often used unit. A similar result was reported by Drehmel.[28] On this subject, Bogue commented as follows:

> Though the current ferment in studying the linkage between inputs and outputs in higher education may produce more sophisticated and appropriate indicators of instructional activity than the proximate criterion of student credit hours, it is probable that the study of unit costs in instruction will continue to be an important factor in the decision-making at all levels in higher education in the immediate future.[29]

The definition of student credit hour, and that of other terms used in this study are:

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[26]Joan Frisbee, "Analysis of Instructional Program Costs in a Small Liberal Arts College" (unpublished Doctoral dissertation, University of Tennessee, 1970).

[27]David R. Witmer, "Cost Studies in Higher Education," Review of Educational Research, XLII, No. 1 (1972), pp. 99-127.

[28]Elwood W. Drehmel, "Cost and Budget Parameters in Higher Education" (unpublished Doctoral dissertation, University of Minnesota, 1970).

[29]E. Grady Bogue, "An Inquiry into the Relationship Between Instructional Cost Patterns and Assumptions Influencing Analysis of Basic Data in Unit Cost Studies," Institutional Research and Institutional Policy Formulation, ed. Clifford T. Stewart (Denver, Colorado: Association for Institutional Research), p. 90.

1. Student credit hour (SCH). The amount of credit earned by a student upon successful completion of a course that meets one hour per week for the length of one semester.

2. Full time equivalent (FTE) enrollment. The sum of full time students (those taking 12 hours or more) and the equivalent number of part time students (those taking less than 12 hours). This equivalence is calculated by adding the number of hours taken by part time students and dividing by 12.

3. Full time faculty member. One teaching 12 hours. Occasionally because of scheduling problems in a particular semester, a full time instructor may be assigned an hour or two more or less than the standard 12. Such a person is still considered full time. The proportion of the work load that is spent in each course is calculated by dividing the credit hours for this course by the instructor's total credit hour load.

4. Part time faculty member. One teaching less than 12 hours. The number of such hours normally ranges from 1 to 9. The full time equivalency of such a person is found by dividing the number of hours assigned by 12.

5. Full time equivalent faculty. The sum of all full time faculty members plus the full time equivalent of those part time faculty members.

6. Major or major program. A program of studies in some branch of knowledge. Upon the successful completion of this program, the student is awarded a bachelor's degree.

7. Department or teaching discipline. An organizational entity consisting of faculty and other resources designed to impart knowledge of a particular kind to the students enrolled. In some cases, several disciplines may be combined into a single department. For example, the disciplines of history and political science are combined into the single department of history. This is done both as a method of organization and as a method of conserving time and computer facilities when operating the model.

8. Productivity. The ratio between the total number of SCH and the number of full time equivalent faculty members in a particular department.

9. Credit hour matrix. A table containing the total number of student credit hours broken down according to major program and student level as well as by instructional discipline and course level.

10. Induced course load matrix. A table containing the average number of SCH taken at various course levels in each department or discipline by the typical or average student in each major and at each student level.

V. PROCEDURE

The equations which describe mathematically the interrelationship of students enrolled in various major programs and the instructional departments were derived. These equations are examined in Chapter III. Additional equations for calculating the average faculty salary and productivity in each department and for determining the manner for allocating the expenditures for each course were also derived.

These equations were then programmed for the IBM 1130 computer. FORTRAN, the commonly available programming language, was used. This would enable the programs to be compatible with other similar machines having a FORTRAN compiler.

A considerable task in implementing any model is gathering the data on which it will operate. This had been simplified by the requirements for this model. The data consisted of the enrollments of the students in various major fields along with faculty and other expenditures by department. The former were already in machine readable form in the registrar's office. The latter were obtained from the business office either in the form of the official audit for the past years or of the budget for the current or future years.

In order to accommodate the programs to the small memory of the IBM 1130, each was written in a modular fashion. That is, many small programs and subprograms were used rather than several large ones. The large amounts of data used were stored on magnetic disks on-line to the computer, and the portions utilized as needed.

VI. IMPORTANCE OF THE STUDY

While analytical methods which are assisted by technological tools are designed to be aids to college administrators, there are limitations and precautions that must be taken when using these techniques. In this section, some of the advantages and limitations of these methods will be pointed out.

Advantages of Using Quantitative Methods

Unit-expenditure studies such as the one prepared in this study are an important step in increasing efficiency in the use of a college's resources. As Russell has pointed out:

> One of the points at which unit-expenditure data have proved valuable in institutional administration is in the preparation of the budget. The calculation of expenditures for instructional salaries per student registered affords data that are useful in judging departmental requests for the support of the instructional program.[30]

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[30] John Dale Russell, The Finance of Higher Education (rev. ed.; Chicago: University of Chicago Press, 1954), p. 150.

Such studies are a restraint on introducing new programs. In the circumstances of financial stress indicated above, it is probably not wise for colleges to open new programs unless they are fully cost justified. With the method developed, it will be possible to estimate rather accurately the costs of new curricula on the basis of varying enrollments.

As Harris has pointed out, colleges as a rule are not inclined to estimate their unit costs for services already being given.[31] The unit costs of running a curriculum or even of offering a particular course can vary considerably from year to year. What may be a justifiable expenditure one year is not necessarily justifiable at a given time later. Unless attempts are taken to make the cost estimates accurate, administrators must rely on their intuition in determining which courses or departments will receive priority in the allocation of resources and funds. In every college, some factors are given more weight than others; some are emphasized while others are minimized in order to provide what the administrators feel is the best program attainable with the available resources. The quality and cost of a particular educational program reflect the

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[31] Seymour E. Harris, Higher Education: Resources and Finance (New York: McGraw-Hill, 1962).

success of the administrators in dealing with the institutional variables. The better knowledge they have of these variables, the better they will be able to apportion resources to the various programs. "When the judgments of the decision-makers are uninformed or weak the quality of education will fall and cost will rise."[32]

Without the kinds of information presented, decisions may be uninformed, casual, and sometimes even unrelated to the overall purposes for which the college exists. Although some types of economies may be educationally undesirable, a more discriminating use of the limited resources available to most institutions must be made if their quality is to be maintained at a competitive level. The procedures developed in this study should enable even a small institution to make careful and detailed examinations of its expenditures on a year to year or on a semester to semester basis.

In addition, the use of such information should lead to a more thorough examination of the relationship between cost and quality. Indeed, it should foster the development of a more complete program of academic management that could

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[32]Thad L. Hungate, L. Richard Meeth, and William R. O'Connell, "The Quality and Cost of Liberal Arts College Programs," Cooperative Long-Range Planning in Liberal Arts Colleges, ed. Earl J. McGrath (New York: Bureau of Publications, Teachers College, Columbia University, 1964), p. 10.

provide the basis for a qualitative assessment of both personnel and program performance.

Precautions in Using Quantitative Methods

While the purpose of preparing accurate quantitative data on the running of their institutions is to assist administrators, it is by no means certain that having such additional information will make them more comfortable in dealing with fiscal problems. Quantitative measurement in the field of educational policy has its own pitfalls. There is the danger that quantitative standards will tend to drive out qualitative criteria altogether. This is often quite true of cost analysis studies. As Wilson remarked, "an obsession with costs can lead us to know the price of everything and the real value of nothing in education.[33]

It must be remembered that, even when refined to the utmost, cost analysis figures are always a crude instrument for measuring the effectiveness of an institution of higher education. Such figures may be useful in increasing the efficiency of the operation, but as Fincher remarked, effectiveness and efficiency are not the same thing.[34] Such data

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[33]Logan Wilson, Shaping American Higher Education (Washington, D.C.: American Council on Education, 1972), p. 201.

[34]Cameron Fincher, "Planning Models and Paradigms in Higher Education," Journal of Higher Education, XLIII (December, 1972), 754-767.

give no information about the relative performances of various professors or departments, but only some enlightenment with regard to the expenditures they require. The relation between expenditure and educational effectiveness is loose and tenuous at best. Excellent education takes place in some low-budget institutions and second-rate education in some high-budget ones. Unfortunately, many people feel more secure when their decisions are based on quantitative rather than qualitative information.

It is also important to remember that unit-expenditures summarize cost for present or past years. Extreme care must be used when attempting to apply them to future situations about which there can only be conjecture.

Numbers are not magic nor do they tell the whole story. However, they can be useful. If they are properly understood and interpreted, they can be combined with other information to give a reasonably complete picture. While qualitative considerations are usually understood to imply judgments that are more subjective than objective, there is no reason for these judgments to be uninformed or capricious. In addition, it must be recognized that even when the end result is a number, an essentially subjective decision may have been made in the selection of the method for producing that number. Bowen has summarized these ideas as follows:

> Admittedly, the outcomes of education are difficult to assess. The process must involve mainly the judgment of competent observers backed up by rather ambiguous objective facts. But merely because something is not easy to measure does not excuse administrators from carefully appraising cost-effectiveness.[35]

VII. PLAN OF THE STUDY

In this chapter, the background and circumstances leading to the decision to inaugurate the present study are given. Various statistics were used to show that small private colleges were in definite financial trouble and in need of better management tools to alleviate this difficulty. Reasons for choosing the particular cost analysis model are stated. The procedure, as well as definitions of terms as used in this study, are included. A section is devoted to the advantages of using such quantitative data as well as to certain precautions that must be exercised in using them to examine the efficiency and effectiveness of a college.

Chapter II is devoted to a review of literature concerning modern management techniques, including some of the important modeling systems available at the present time. These include commercially available systems as well as some individually proposed systems.

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[35]Bowen, "Can Education Become More Efficient," p. 192.

In Chapter III the mathematical equations needed to describe the system under study are derived and examined.

The methods of implementation and programming these equations to make the model operable on a small computer are presented in Chapter IV.

Chapter V contains the conclusions and recommendations coming out of this research.

CHAPTER II

REVIEW OF RELATED LITERATURE

As a result of the rather serious financial difficulties in which colleges and universities have found themselves during the past several years, administrators of such institutions have been increasingly on the alert for new tools and techniques to assist them in managing their operations more efficiently. A variety of new administrative and managerial tools for use in higher education have been adapted from ideas developed initially to administer large business organizations and federal agencies. They are an outgrowth of advances in computer science, cost accounting and other disciplines. The purpose of such tools is to give academic decision-makers better information on which to base their judgments.

The first section of this chapter contains a review of some of these modern management techniques which have been adapted to educational administration. The methods discussed are those which, as a general rule, involve large amounts of data and are therefore most easily handled by means of a computer. The methods are presented in more or less the order in which they were implemented. While each method is not entirely derived from the ones that preceded it, there

is a certain sense of development through the various methods leading to that of computer simulation.

The second section of this chapter contains a discussion of some of the large-scale models that have been prepared. A number of these are available commercially. The third section of this chapter presents some smaller, individual research studies involving models and cost analysis.

I. MODERN AIDS TO EDUCATIONAL MANAGEMENT

From the sciences of systems analysis and operations research have come a number of new methods that have been put to use in business and more recently in education. Within modern management techniques, the system approach is the one that has been strongly recommended to managers of small colleges as well as to those in large institutions. This approach is a method of thinking that attempts to interrelate all variables, base decisions on reliable data, systematically evaluate outcomes of programs and plan for the future. The study of a system's structure, parts, interactions and processes is referred to as systems analysis or operations research. While these terms are frequently used interchangeably, Immegart and Pilecki characterized the latter as being more objective or mathematical in its approach, with the former being more subjective or

heuristic.[1] With regard to educational management, Shoemaker pointed out that when the systems approach is used in resource allocation, questions are asked such as what resources are required, to what extent, and with what degree of goal achievement. It is then that alternate goals and objectives can be considered.[2]

Better information about costs and income is essential if decisions are to be made that increase efficiency. Educators have done little to evaluate the cost of programs in terms of resources required against what is produced. Educational managers were encouraged to make such studies by the Carnegie Commission on Higher Education when it indicated that cost benefit analysis or cost effectiveness was the most important step in effective resource use.[3]

But as Harris has pointed out, colleges and universities, unlike industries, have neglected to use cost studies. The reason he gave is obvious: industry relates its prices to costs.[4] Although colleges do not base prices on costs,

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[1]Glenn L. Immegart and Francis J. Pilecki, An Introduction to Systems for the Educational Administrator (Reading, Mass.: Addison-Wesley, 1973), p. 113.

[2]William A. Shoemaker, Systems Models and Programs for Higher Education (Washington, D. C.: Academy for Educational Development, 1973).

[3]Carnegie Commission on Higher Education, The More Effective Use of Resources: An Imperative for Higher Education (New York: McGraw-Hill, 1972).

[4]Seymour E. Harris, Higher Education: Resources and Finance (New York: McGraw-Hill, 1962), p. 503.

there is some relationship between them. Educators normally resist such things as cost analyses in the belief that educational outputs cannot be measured. Usually the argument is as follows:

> As is the case with all organizations that produce intangible products and employ a large number of highly skilled professional staff members to achieve their goals, the output of institutions of higher education does not readily lend itself to quantitative measurement. Judgments about many aspects of institutional productivity must ultimately be based on qualitative rather than quantitative standards of achievement and, in the absence of agreed-upon objective criteria, must ultimately be highly subjective in character.[5]

While it is true that the productivity of educational institutions is difficult to quantify, advocates of cost studies claim that it is better to use imperfect measures than none at all. On the other hand, careful investigators have also pointed out the dangers of being too dependent on such numerical results and have indicated that the administrator must still make the final judgment. Meanwhile, a fair amount of research has been conducted to determine better methods for measuring the outputs of higher education.[6]

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[5]Francis E. Rourke and Glenn E. Brooks, The Managerial Revolution in Higher Education (Baltimore: The Johns Hopkins Press, 1966), pp. 18-19.

[6]Ben Lawrence, George B. Weathersby, and Virginia Patterson, eds., The Outputs of Higher Education: Their Identification, Measurement and Evaluation (Boulder, Colorado: Western Interstate Commission on Higher Education, 1970).

Quantitative facts admittedly do not reveal the quality of education. These data do not portray the purposes of institutions, nor do they reveal the qualification of faculty members or measure their dedication to teaching. They do not analyze the quality of the student produced. However, descriptive analyses of data related to curriculum, teaching loads, student loads and costs do provide facts from which the administrators of the institution can make an analysis of its educational condition and examine the prospects for future development.

Russell felt that one of the important criticisms could be disposed of immediately by abandoning the word "costs" with its connotation drawn from industrial processes, and substituting the term "unit expenditures."[7] This suggested term would be a more accurate description of the concept involved. Of interest here is a method of translating expenditures into terms by which comparisons will be possible.

Cost studies can be made with pencil and paper. However, because of the amount of detail and the large arrays of numbers involved, their conclusions can be reached much more quickly by using a digital computer. Such machines have found a great deal of use in both business and in

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[7]John Dale Russell, The Finance of Higher Education (Revised Edition; Chicago: University of Chicago Press, 1964).

education. One of the early applications of these devices as an aid to educational management is what is termed a "management information system." The term management information system (MIS) refers to the processes and procedures by which raw data are organized into information useful for administrative decision making. These systems are commonly computer based since the repetitive task of tabulating and aggregating large quantities of detailed information can be handled most efficiently by these data processing machines. Sophisticated computer technology permits the "merger and synthesis of large masses of data and the manipulation of these data to form analyses and predictions."[8] What is now considered a landmark study outlining the conceptual structure for an integrated data system for a college or university was prepared under the direction of Rev. R. J. Henle of St. Louis University and sponsored by the National Science Foundation.[9] A similar but less detailed design was prepared by Siegmann.[10]

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[8]Thomas Mason, "Developing and Using Information Systems," Institutional Research in the University, ed. Paul L. Dressel (San Francisco: Jossey-Bass, 1971), p. 80.

[9]R. J. Henle, Systems for Measuring and Reporting the Resources and Activities of Colleges and Universities (Washington, D.C.: Government Printing Office, 1965).

[10]R. M. Siegmann, Information Systems in Universities (Atlanta: Georgia Institute of Technology, 1969).

According to Bogard, an MIS for an institute of higher education should meet three basic needs: (1) it must provide administrators with information about the day-to-day operations of the institution; (2) it must provide the information needed to develop the planning capability required for both long- and short-term planning by means of analytic techniques; and (3) it must provide the reporting capabilities required by the societal and economic pressures for accountability.[11]

While not always a part of a management information system, the budget of a college or university is the fundamental document for financial planning. Budgets have customarily been used for fund accounting in higher education. This is in accord with the recommendation of the American Council on Education in its publication College and University Business.[12] Such budgets are prepared in standard line item style, a method which has received some criticism. Williams pointed out some of the deficiencies of this system as follows:

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[11]Lawrence Bogard, "Management in Institutions of Higher Education," Papers on Efficiency in the Management of Higher Education, ed. Carnegie Commission on Higher Education (New York: McGraw-Hill, 1972), p. 25.

[12]American Council on Education, College and University Business Administration (Revised edition; Washington, D. C.: American Council on Education, 1968).

> Conventional budgetary formats provide very little information of value for decision making. They cover short time frames, provide no clue to what is being done, point up no relations between teaching and research, provide no guide to graduate and undergraduate levels, and exhibit no information on costs except in a relatively inaccurate aggregate sense; moreover, they may contribute to obscuring rather than sharpening management decisions.[13]

Newer concepts of budgeting, however, stress the role that the budget can play in decision making about future courses of action. A close relation between desirable programs and resource allocation is the goal of the planning, programming, budgeting systems (PPBS) approach. The appeal of PPBS lies in its concept of (1) selecting specific objectives and systematically analyzing, in terms of costs and benefits, various courses of action to attain those objectives—planning; (2) deciding on specific courses of action (programs) and providing for review and control—programming; and (3) translating planning and programming decisions into specific financial plans—budgeting.[14]

Frank Dilley identified higher education's need for a system such as PPBS, which relates expenditures to results. He has commented that:

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[13]Harry Williams, Planning for Effective Resource Allocation in Universities (Washington, D.C.: American Council on Education, 1966), pp. 15-16.

[14]Loyd D. Andrew and Leon Robertson, "PPBS in Higher Education: A Case Study," Educational Record (Winter, 1973), p. 60.

> . . . as matters now stand . . . objectives are not spelled out; sophisticated measures of accomplishment are not generally in use; unit costs are known only vaguely, if at all; and under the pressure of the yearly budget no one has time to plot out alternatives, let alone scrutinize them.[15]

It should be pointed out that the word planning in PPBS is not the conventional planning in which one sets goals with little thought for their attainment. Nor is program budgeting a cost-benefit analysis that sacrifices goal accomplishments for minimum cost considerations. While there is definite quantification involved, it is not necessary that all objectives be spelled out in numerical terms. However, specific activities must be planned to attain those goals.

Basically, PPBS is a method of organizing cost data in such a manner that they can be used to analyze different courses of action in terms of cost and utility. In contrast to conventional budgets which indicate only general categories and tell little about plans and objectives, program budgets and their associated planning activities indicate specific objectives and methods for their attainment.[16] It provides educators with a design for the scientific planning and allocation of scarce educational resources among

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[15]Frank B. Dilley, "Program Budgeting in the University Setting," Educational Record, XLVII (Fall, 1966), pp. 476-477.

[16]John Pfeiffer, New Look at Education: Systems Analysis in Our Schools and Colleges (New York: Odyssey Press, 1968), p. 18.

competing ends. Since the emphasis is upon outputs, cost effectiveness, rational planning, long range objectives, and analytical tools for decision making, PPBS illuminates the relationships between current programs and ultimate objectives. It is, of course, necessary to point out that PPBS is not a panacea for all the ills brought on by poor management, nor is it a remedy for institutions that cannot hope for the resources necessary to achieve their chosen objectives.[17] Even the Defense Department, where PPBS was originated, often has problems of cost overruns despite the use of this scientific tool.

Modeling or cost-simulation is another new administrative technique. In normal use, it is an attempt to predict and plan for the future by projecting what will happen over time to an institution operating under various assumptions. Once an institution has good program budget information based on current and historical data that shows the cost of credit hours by discipline and level, it is helpful to project these data into the future to determine what would happen to the institution under certain different conditions.

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[17] Harry J. Hartley, Educational Planning, Programming, Budgeting: A Systems Approach (Englewood Cliffs, N.J.: Prentice Hall, 1968), p. 75.

Models as used in industry can be classified in various ways.[18] These include physical models which are used to a great extent in architecture. Analog models are frequently used to illustrate a new process such as the flow of electricity being used to simulate the flow of real fluids. The type of model of interest in the present study is termed a mathematical model. In this form, mathematical symbols and equations are used to describe the status of variables in a system and the way in which the variables change and interact.

Such models have three chief uses in education. The first is to furnish an unambiguous, highly specified and quantified description of the major elements of an institutional system and the interrelationships which prevail among those elements. The second use is to provide a reliable means of predicting the outcomes that result when one or more of the variables in the system is changed. The third use of modeling is to help the institution make optimal use of resources based on carefully specified objectives.[19]

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[18]James R. Emshoff and Roger L. Sisson, Design and Use of Computer Simulation Models (New York: Macmillan, 1970), p. 6.

[19]Donald C. Lelong, "Allocating and Utilizing Resources," Institutional Research in the University, ed. Paul L. Dressel (San Francisco: Jossey-Bass, 1971), pp. 236-237.

A number of mathematical models have been developed to aid in the management of educational institutions. Several are on the market and have been in use for the past couple of years. A review of some of the more important versions is presented later in this chapter. Most of these are of the second type; that is, they are programmed to make projections concerning the future of the institution by responding to what are termed "what if" type questions. Proponents of such simulation models point to their "flexibility" and their ability to handle large quantities of data. This leads to "continuous planning . . . and the comparison of multi-year reports."[20] They are capable of being used in both the descriptive and projective modes. Judy, one of the pioneers in this field, indicated that little work has been done on forms that operate in the optimal mode.[21]

Beginning about 1965, the art of computer simulation was applied to problems of the management of institutions of higher education. Cost simulation models have been developed

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[20]George Mowbray and Jack B. Levine, "The Development and Implementation of CAMPUS: A Computer-Based Planning and Budgeting System for Universities and Colleges," Educational Technology, XI (May, 1971), p. 31.

[21]Richard W. Judy, "Simulation and Rational Resource Allocation in Universities," Efficiency in Resource Utilization in Education, ed. Organization for Economic Cooperation and Development (Paris: OECD, 1969), p. 274.

at a number of universities as well as by some commercial consulting firms. Large-scale simulation models are generally quite expensive to produce and use. They require a great deal in terms of man-hours as well as machine time for debugging and for test runs. Once developed, there is the additional expense that each user must bear in putting these models into operation on a given campus. The development costs for several of the models that are described below have been borne by the federal government so that these particular ones are comparatively inexpensive to obtain. The operational costs are still quite high. Hopkins has estimated that even for the simple version, costs may run to $15,000 per year in analyst, programmer and computer time.[22]

II. LARGE-SCALE MODELS

While several of the models to be discussed below were undertaken under the auspices of a particular university, those that have found the most widespread use have been prepared by commercial consulting firms or special agencies funded by foundations or government grants. Even those models designed to operate at a particular institution have,

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[22]David S. P. Hopkins, "On the Use of Large-Scale Simulation Models for University Planning," Review of Educational Research, XLI, No. 5 (1971), p. 473.

because of the large scale of the program and because of possible applications to other schools, also received financial support of such agencies as the National Science Foundation.

The discussion that follows is devoted to those models that are either in fairly common use or have produced a good deal of discussion and sometimes adaptation because of their design. It is by no means an inclusive report. Casasco reported on the existence of approximately 40 computerized planning and management techniques.[23]

The CAMPUS Model

CAMPUS is the acronym for "Comprehensive Analytical Methods of Planning University Systems." This particular model is considered the pioneering effort among large-scale simulation in higher education performed at the University of Toronto. In December, 1964, the Commission on the Financing of Higher Education in Canada undertook to investigate the feasibility of a university system simulation model and commissioned a pilot study.[24] That such a project could be successfully carried out was reported to the Commission

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[23]Juan A. Casasco, Planning Techniques for University Management (Washington, D.C.: American Council on Education, 1970).

[24]Judy, op. cit., p. 261.

by Judy and Levine, after determining the availibility of sufficient data, applicable methods to be derived from operations research, and computing capabilities sufficient to handle the large number of variables involved.[25] With regard to the latter, Sceviour, who was one of the coworkers on the project, reported that at that time, the University of Toronto had one of the largest and most sophisticated computer systems in Canada.[26] A formal discussion of the design and application of this model is given by Levine.[27] A number of the original workers in the project have joined to form the firm Systems Research Group (SRG) which continues the development of the model and markets the most recent versions.

CAMPUS has gone through several revisions and versions (presently including CAMPUS VIII), as well as adaptations to specific institutions. A particularly adaptable version, called CAMPUS/CONNECT, employs individual terminals attached

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[25]Richard W. Judy and Jack B. Levine, A New Tool for Educational Administrators (Toronto: University of Toronto Press, 1965).

[26]W. F. Sceviour, "A Computer Simulation Model for Planning Instructional Facilities at the University of Toronto" (unpublished Master's thesis, University of Toronto, 1968), p. 3.

[27]Jack Bernard Levine, "University Planning and Budgeting Systems Incorporating a Microanalytical Model of the Institution" (unpublished Doctoral dissertation, University of Toronto, 1969).

through telephone lines to a large-scale computer. It contains a computer aided instruction software package which assists the user to experiment with, to alter and to interpret the model without having had any previous programming experience.

The basic logic of CAMPUS revolves around the specific activities found in a college or university. An example of what is meant by such activities would be a course with two weekly contact hours of lecture and three weekly contact hours of lab. Since they require different types of resources in terms of personnel and space, the lecture and the lab are treated as separate activities. This detailed level of activities enables the model to be very flexible with regard to the type of output reports that can be generated. It also enables planning at the most elemental organizational level and involves all organizational levels in the planning process. However, the price that must be paid for this extreme detail is (1) the massive amount of detailed data required at the activity level and (2) the large-scale computer memory required to accommodate it. Different versions of CAMPUS allow varying amount of aggregation with accompanying loss of detail.

The model is capable of performing a variety of simulations for the user through its elaborate input and output routines. The user can specify precisely which data

are to be supplied as inputs (whether as user-estimated parameters or as decision variables), which parameters are to be estimated from time series analysis using regression or exponential smoothing, and which are to be calculated and reported as output. For example, enrollment in future years can be estimated by the user and supplied as input, or the figures can be projected by the student flow module which is an optionally used part of the model. The user is able to specify whether he wishes to know average or marginal costs. The model can compute resource requirements and costs at any level of aggregation that the user specifies whether by program, by department or by individual activity.

It is the activity concept which gives CAMPUS its great flexibility in handling practically any level of aggregation or disaggregation. It is a debated question whether or not the reliability and utility of the output of the model for institutional decision making is sufficient to justify the expense involved in accumulating and storing the detailed data needed and for updating it in order to keep the model current.

In the version called CAMPUS/CONNECT, the computer program is resident on a large time-sharing utility with each user terminal equipped with cathode ray tube display, printer and keyboard. These give the user access to the program and to the data prepared for the model. The data of

each user is stored on protected files at the central computer facility and continuously updated.

In order to gain some idea of the size of CAMPUS, the following data should be considered. CAMPUS VIII is capable of handling 350 major programs, 100 academic departments, and 4000 activities. Included in its capabilities are 9 instructional types, 8 student levels, and 10 faculty ranks. Over 100 space types may be specified.

Running such a large simulation model can be quite expensive. Judy estimated the cost of adaptation and initial implementation at a university would be between $25,000 and $125,000, with the time for implementation ranging from 6 to 12 months. A similar task at a community college is estimated to cost from $15,000 to $50,000 with the corresponding time of implementation ranging from 3 to 6 months. In addition, the annual cost of operating such a system, for adapting and maintaining the software, is estimated to range from $10,000 to $20,000.[28] Alexander reported that the developmental costs in implementing CAMPUS VI at the University of Colorado from March 1972 to February 1973 amounted to

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[28]Richard W. Judy, Some Applications of Management Science to Institutions of Higher Education (Toronto: Systems Research Group, 1971).

$101,000.[29] Hussain and Mason estimated the cost of preparing a complete set of reports using CAMPUS VIII ranges from $200 to $500.[30] Less detailed versions could cost substantially less. Despite its often high costs, CAMPUS has had numerous applications in this country.

The Resource Requirements Prediction Model

One of the leaders in the development of new administrative techniques for higher education is the National Center for Higher Education Management Systems (NCHEMS) located in Boulder, Colorado. It is operated by the Western Interstate Commission for Higher Education (WICHE) and supported primarily by contracts with the U. S. Department of Health, Education and Welfare and by grants from major foundations. NCHEMS has been developing a series of interrelated systems for planning and management in higher education. The "Resource Requirements Predication

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[29] Madelyn D. Alexander, "The Implementation of CAMPUS/COLORADO," Tomorrow's Imperatives Today, ed. Robert G. Cope (Vancouver, British Columbia: Association for Institutional Research, 1973), p. 91.

[30] K. M. Hussain and Thomas R. Mason, "Planning Models in Higher Education: A Comparison of CAMPUS and RRPM," Tomorrow's Imperatives Today, ed. Robert G. Cope (Vancouver, British Columbia: Association for Institutional Research, 1973), p. 82.

Model" (RRPM) is the cost simulation package that has been developed.[31]

Like CAMPUS, RRPM is a long-range planning model designed to aid higher level management in rapidly determining the resource implications of alternative policy and planning changes. It is designed to aid decision-making by providing quantitative estimates of the total set of resource requirements for the institution. The RRPM system consists of a set of generalized computer routines which may be used to simulate mathematically the resource requirements associated with operating an institution of higher education for a specified period of time. According to Judy, the prototype for RRPM was the cost simulation model developed by Weathersby at the University of California in the late 1960s.[32]

As with CAMPUS, RRPM has gone through several versions. Although version 1.6 is the one currently available, version 1.3 had been previously released. The intermediate programs were basically experimental and test versions. In addition to RRPM, the task force at NCHEMS has prepared a Program Classification Structure (PCS) that is meant to be applicable

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[31]K. M. Hussain, A Resource Requirements Prediction Model (RRPM-1): Guide for the Project Manager (Boulder, Colorado: NCHEMS at WICHE, 1971).

[32]Judy, Some Applications of Management Science, p. 37.

to all of higher education.[33] Auxiliary modules with appropriate software have been developed to complement or aid in running RRPM. These consist of the Student Flow Model, the Cost Finding Principles and Procedures, the Faculty Activity Analysis procedures and the Induced Course Load Matrix generator.

The central computational facet of RRPM is the induced course load matrix (ICLM). In this matrix, each column represents the credit hour load induced by an average major in the different levels of courses that are offered by the various departments. There are a number of difficulties associated with using the ICLM as it propagates how an average major on the average distributes his or her course activity in an average semester. In addition to dealing with so many averages, there is the additional question of the reliability and stability of majors. There may be little homogeniety within majors in terms of course activity, and homogeniety within majors is an essential point of the ICLM.

RRPM is enrollment driven, that is, its predictions are based on assumed new enrollment distributions over a number of years. New freshman and transfer enrollment are treated

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[33]Warren W. Gulko, Program Classification Structure (Boulder, Colorado: NCHEMS at WICHE, 1971).

as input variables while other enrollments are computer by the student flow module. Variations in the number of student credit hours produce the cost involved in the number of faculty required and also a number of indirect costs that are allocated to the various programs by means of a group of empirical equations. The constants used in these equations may be varied by the user. Space allocation is not included in RRPM-1.6 although it had been in version 1.3. This makes the later version easier to implement, and it requires less data and a smaller amount of computer memory.

As for the cost of RRPM, the software and accompanying documentation are available from NCHEMS for $50. While a small amount of consulting service is available, each institution is responsible for the full implementation on its own campus. The introductory materials present a method for calculating the approximate cost of such implementation.[34] Using this chart, it is estimated that the development and maintenance cost of implementing RRPM-1.6 at a university would cost approximately $10,000 while a similar task at a community college would cost about $6,000.

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[34]Warren W. Gulko and K. M. Hussain, A Resource Requirements Prediction Model (RRPM-1): An Introduction to the Model (Boulder, Colorado: NCHEMS at WICHE, 1971), p. 16.

RRPM-1.6 is capable of handling 200 major programs and 200 academic departments. It does not consider activities but will accept up to 7 course levels, 5 instruction types, 7 student levels and 6 faculty ranks.

Since it has been developed under federal contract, RRPM, along with other NCHEMS products, is likely to find rather widespread utilization. Many major campuses have already implemented it. The state of California has mandated the use of its format as standard in preparing budget requests. Other states are said to be considering doing likewise. Because of these facts, it would seem to be important for administrators and planners at all institutions of higher education in the United States to have some familiarity with the NCHEMS products.

The SEARCH Model

SEARCH ("System for Evaluating Alternative Resource Commitments in Higher Education") is the end product of the collaboration of the consulting firm of Peat, Marwick, Mitchell and Company with eight small colleges. Beginning with a seminar held in 1968, the project was also known as the Computer-Assisted Planning for Small Colleges project (CAP:SC). The first phase involved the formation of planning committees at each college to develop an organized approach to long-range planning and to design a common analytical

framework to accommodate the planning information needs of the colleges. This phase lasted about one year.

The participating colleges then agreed to proceed with the second phase, the design of the mathematical structure of the simulation model and development of the computer program by the consulting firm. From this point, the project received considerable foundation support. The colleges then decided to proceed to the third phase, the implementation in the local environment. The work on these two last phases spread over another two years.

SEARCH is a generalized simulation of a college as an interactive system. It encompasses students, programs, faculty, facilities and finances, functionally relating each of these aspects to the others so that it can simulate the behavior of a college as an operating system. Beginning with the actual state of the institution, it simulates its future state at yearly intervals for up to ten years, based upon a continuation of present operating policies and decisions, as well as alternative policies and decisions which the planners wish to explore.[35]

An unusually complete treatment of cost and income generation distinguishes this model from the other general

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[35]Peat, Marwick, Mitchell & Co., SEARCH: A College Planning Model (New York: PMM, 1972).

costing models. Most of the relationships in the dynamics of the model are definitional and therefore exact, but many are estimated. Most of these estimates are based on the intuition of the user although statistical curve fitting is occasionally used. For example, regression analysis is used in the estimation of the course demand pattern.

The level of aggregation is high. This is appropriate for long-range planning and is justified because any lower level of aggregation would reduce the matrix to a collection of mostly ones and zeroes for a small college such as those represented by the eight associated with the CAP:SC project. The program has been written to operate on large scale, time-sharing computer systems, thus avoiding the constraints resulting from limited computer capability on campus. Operated in the time-sharing mode, SEARCH allows the user to interact with the model between simulation runs by modifying the data base and rerunning the simulation in an interactive search for the plan which best meets the needs of the institution.[36] The program also has the capability of being run in a batch-processing mode. SEARCH will enable the user to obtain a report on any state variable for any future year

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[36]Peat, Marwick, Mitchell & Co., Computer Model SEARCH: Systems for Evaluating Alternative Resource Commitments in Higher Education (New York: PMM, 1971).

within a ten-year time frame. Each college also has the capability of selecting logical groupings of variables for arrangement into preformatted reports in areas such as enrollment, program, school, facilities, finances, etc.

The project was envisioned as the means of achieving a total methodology for long-range planning. The two major objectives for reaching this goal were first, to train key administrators and planning officers in the concepts, techniques, and organization of overall institutional planning; and secondly, to design and implement a mathematical simulation to make possible the exploration of a wide range of planning alternatives by enabling the planners to project expected resources, resource demand, and institutional characteristics quickly and easily. Those in the project report that the second objective was more successfully achieved than was the first. The consultants were more successful than were the institutions.

When the project was first undertaken, the growth syndrome was still very much characteristic of college thinking and along with it the idea that planning was planning for growth. The discovery that this is not true may have been one of the major factors in cooling enthusiasms for implementation of the planning project. Some administrators apparently had difficulty accepting the idea that college planning can, at least in part, be a science rather

than an art. The model became a restricting force giving too much weight to narrow fact, without enough allowance for reasoned speculation. This can be a common failing when using any model.

The lack of enthusiasm mentioned, as well as personnel turnover, gradually lessened the participation of the original collaborating colleges. For some, results did not come fast enough, and the model appeared to be too rigid for the intended experimentation. While the original participants may have dropped it, other schools have made satisfactory use of the model. The fee varies according to the size of the institution, but normally runs from $10,000 to $25,000.

HELP/PLANTRAN

The "Higher Education Long-Range Planning" (HELP) program was developed by Midwest Research Institute under contract to the Kansas City Regional Council on Higher Education.[37] The current version is known as PLANTRAN II. While not a model in the sense of those discussed previously, the HELP/PLANTRAN program enables college administrators to construct a mathematical model of their institution, to simulate its behavior over a period of years under various

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[37]Richard Salmon, Duane Dieckman, and Jeanne Robertson, A Computer Simulation Modeling Tool to Assist Colleges in Long-Range Planning (Kansas City, Mo.: Midwest Research Institute, 1969).

hypothetical conditions and with its help arrive at policy decisions.

The PLANTRAN system is not a model but a sort of computer language consisting of a series of simple arithmetical calculations and projection techniques.[38] It does not require a planning process or a sophisticated information system. Collection of the variables to be included in a model, the relationships among the variables and the projections which are to be made are all under the control of the model builder. Since PLANTRAN is essentially a calculation tool, it is a different concept from CAMPUS, RRPM, and SEARCH, which are models of higher education environments.

In relation to the large-scale models, the PLANTRAN system requires much less of a commitment to planning and to the development of an adequate information system. The requirements of the other models force individuals on the campuses to develop information and assumptions which must be included in the models before they are operative. From this standpoint, PLANTRAN is a more flexible and simplified system. While it is expected to be used primarily as a budget simulator, other variables can also be used. Mini-models can be constructed to isolate and analyze specific

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[38]Midwest Research Institute, An Introduction to PLANTRAN II (Kansas City, Mo.: MRI [n.d.]).

problems or planning areas. Many interactions of the model can be included in one computer run. This is probably the system's strongest characteristic. As many as 4,000 variables are possible. It is also possible to build models at the lowest level of disaggregation and then aggregate the results. Models constructed with PLANTRAN are easy to understand and interpret, although there is always the danger of oversimplifying a model or omitting significant variables or relationships. The level of complexity and sophistication of the system is limited and not easily adapted to the complex mathematical calculation generally associated with sophisticated modeling and simulation techniques.

PLANTRAN is marketed by Midwest Research Institute. The program sells for $9,600. This price includes a certain amount of training and consulting services. However, the computer time during which the runs are made, is an additional cost. The system is able to be operated on a medium to large size computer. Perhaps the most important effect of using this system is the developing of an awareness of the need for more detailed and long-range policy analysis for the school in question.

The Michigan State University Model

The "System Model for Managing, Planning and Resource Allocation in Institutions of Higher Education" was

developed at Michigan State University by Herman Koenig and his associate in the department of electrical engineering.[39] They utilized what is termed the state-space approach which develops out of systems study.

The state-space approach provides a dynamic view of interdependence of the subsystems of an educational system through the possible application of control theory techniques and methods of dynamic decomposition. Any quantitative method for analysis of a system is based on a set of equations which show the interdependence among the component variables which characterize the system. If the set of equations is all algebraic in form, the model is called a static model. If the set contains at least one differential or difference equation of any order, it is called a dynamic model. If all the differential or difference equations are of the first-order, it is called a state-space model.[40] A state-space model is very easy to treat mathematically and computationally.

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[39] H. E. Koenig, M. G. Keeney, and R. Zemach, A Systems Model for Management Planning and Resource Allocation in Institutions of Higher Education (East Lansing, Michigan: Michigan State University, 1968).

[40] Karl A. Fox, Economic Analysis for Educational Planning: Resource Allocation in Nonmarket Systems (Baltimore: Johns Hopkins University Press, 1972), p. 244.

The model is developed as an explicit function of a system structure that consists of a demand sector and of various production sectors. The demand sector describes the demands placed on the system by the students in various academic programs. The production sectors of the model describe the allocation of resources in terms of both man-hours of faculty and staff and support facilities. The basic sectors of the university system are modeled as unconstrained components, that is, the model demand sector is developed as though there were no constraints imposed on the demand sector by the production sectors and vice versa. When the two sectors operate as an integrated unit, constraints are imposed on the flow rate and unit values which, when expressed mathematically, couple the two components together to form the state-space model of the complete system. This establishes an interrelationship between a set of inputs, outputs and internal states as a function of a set of control variables.[41]

In terms of user intervention, this model is not as flexible as either CAMPUS or RRPM. However, it is fairly comprehensive, including students, faculty, support needs,

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[41]M. G. Keeney, H. E. Koenig, and R. Zemach, "State-space Models of Educational Institutions," Efficiency in Resource in Education, ed. Organization for Economic Cooperation and Development (Paris: OECD, 1969).

services, facilities and costs. A credit distribution matrix relates students by field to course demands. No attempt is made to quantify any measure of output other than costs and degrees awarded, limiting the usefulness of the model in institutional decision-making. Some of its more attractive features are its amenability to decomposition or suboptimization by sector and its analysis of the sensitivity of outputs to varying parameters. In order to facilitate implementation of this model, users must overhaul the data system of the institution since much of the data needed is not generally available in the form required. Because of this, the model has not received a wide acceptance.

The Tulane University Model

Researchers at Tulane University sponsored by the National Science Foundation, developed the "University Cost Structure and Behavior Cost Simulation Model."[42] This model does not represent a total system. It is essentially a resource costing model designed specifically for a nine year period. The main objective of the model is to provide a useful tool for university policy makers for planning, controlling and evaluating university operations. Used as an

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[42]P. A. Firmin, et al., University Cost Structure and Behavior Cost Simulation Model (New Orleans: Tulane University, 1967).

analytical tool, the model compares interdepartmental costs. As a prediction tool, it simulates cost levels for five years in the future based on the present year and four past years.

Data for the first five years on student enrollment, faculty by rank and pay scale, teaching load, faculty salaries and section size are analyzed by linear regression to generate projections for the next four years. Faculty salaries are calculated according to a rather elaborate scheme. Input to the model are academic pay schedules according to the AAUP scale for the nine year period. Based on the student mix for the initial five years and expected entering enrollments for the final four, the number of faculty by rank are predicted along with the corresponding costs. Support and facilities costs are not computed by such elaborate procedures but are based on fixed ratios of the faculty salaries just computer.

The model is well-suited to suboptimization at the divisional or departmental level because these contributions to total expenses are itemized. Its strongest feature is its faculty salary allocation procedure. Another feature that is incorporated into this model is the ability to project price indices for the last four years of the study. Since it does not utilize a structure describing the interrelationship of all of the variables, it is not useful for

predicting resource allocations. Its chief use is as a predictor of faculty costs as a function of price indices. Although it has been used somewhat at Tulane, it has not found much implementation outside of that university.

III. INDIVIDUAL RESEARCH STUDIES

During the past several years, a number of individual research studies on modeling have been reported. In some cases, these have been theoretical studies, but others have actually been implemented. In both instances, some have involved a small school or a single department in a larger institution.

Vaughn Kenneth Grace Study, 1969

This research study involved a single department. Entitled "A Systems Model for University Resource Allocation," this model used the college of engineering at Oklahoma State University as a basis.[43] The systems theory concept of component structure was used to separate the model into two sectors, the student sector and the production sector.

In the student sector, the student population is described as it is distributed throughout the various

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[43]Vaughn Kenneth Grace, "A Systems Model for University Resource Allocation" (unpublished Doctoral dissertation, Oklahoma State University, 1969).

departments and levels. In addition, the demands that the students make on the various departments in the form of credit hour enrollments is also included. The production sector contains the unit cost equations for instruction, research and extension. By combining these two sectors through constraint equations, a complete systems model of the college results.

In addition to the component structure concept, the author also made use of the state-space approach. The model is in many ways similar to one prepared at Michigan State University[44] except that it is not as involved, and is applied only to a single college. They both utilize concepts derived from control theory and they both have been developed in departments of engineering. Programming was done, and the model put into actual operation on the school's computer.

The author feels that the model used here on one college is easily adaptable to the complete university. Since it has utilized the state-space variable approach, he feels it is in a convenient form for future extensions and applications. It is by far the most sophisticated of the individual research models reviewed. It has the problem of requiring data not readily available at most schools. This difficulty was obviated in the author's case since the data

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[44] Koenig, Kenney and Zemach, op. cit.

has been accumulated in the college in question. In addition, the claims of the author are quite broad, and it is doubtful that the model can solve all of the problems of a college or university.

George Merrill Van Dusen Study, 1961

Entitled "Application of a Computer Simulation Model to Logistical Decisions in a University," this research study did not develop a new model but utilized a modeling system that had been developed to represent the school of engineering at Michigan State University.[45] The purpose of the research was to convince academic administrators of the usefulness of such techniques.

In carrying out the study, interviews were conducted with 13 administrators. These yielded a broad range of responses and from them were developed detailed and specific alternatives that could be used to achieve generalized objectives. The interviews brought out a number of points. Administrators desired more descriptive data than they presently had. With this they felt that they would be capable of better decisions. Of particular significance were enrollment trends and financial data. The administrators

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[45]George Merrill Van Dusen, "Applications of a Computer Simulation Model to Logistical Decisions in a University" (unpublished Doctoral dissertation, Michigan State University, 1969).

felt that too many of their decisions were made in isolation from the rest of the campus, and they wanted better communication and knowledge of other parts of the university. New programs were often initiated or old ones extended without thorough evaluation of present programs or of the effects the new ones might have.

In order to determine if the model could help these administrators in solving the problems they had indicated in the interviews, the author designed several experiments to be tried out on the model. The model consisted of a large computer program into which the researcher put the data that had been previously gathered. The experiments included varying enrollments, not only of incoming freshmen but of upper classmen as well; changing graduation requirements for some of the majors; and increasing salaries for the faculty. The author concluded that the model handled these questions accurately and that there was actual help to be gotten for the problems that had been raised in the interviews. Of particular value was the illustration of the interrelationships of the various parts of the college which were easily seen as the model was operated.

This study emphasized the usefulness of management techniques such as simulation models in aiding decision-makers in their tasks. The author tended to be somewhat overly optimistic about the amount of help that can be

gained. The report failed to emphasize the tenuous nature of many of the results of modeling experiments and the importance of being aware of the assumptions that went into the model before utilizing the results.

Dennis James Harrison Study, 1970

The purpose of this research study, entitled "A Mathematical Model for Determination of College and University Facilities Needs," was to project the additional facilities that would be needed to accommodate forecasted increases in enrollments.[46] This work, done at the University of Georgia, used data on the number in various programs and the type of facilities that would be needed. The latter information included data on the square footage of the various types of space and on the size that should be allocated to particular activities.

The model developed consisted of a single algebraic equation that purports to give the relationship that exists between the space factors and the expected enrollments. The author claimed to have verified the equation by utilizing past data and by comparison with other factors.

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[46]Dennis James Harrison, "A Mathematical Model for Determination of College and University Needs" (unpublished Doctoral dissertation, University of Georgia, 1970).

The difficulty with such a model is that it purports to perform a rather large and difficult task using only a simple linear equation. While there are definite relationships between the variables, it is doubtful that a simple equation can point out all of the various relationships. The author also claims that it may be used for parameters other than just the space allocation for which it has been derived. This statement is rather difficult to accept. Also, in the statement of the problem, an increase in enrollments was forecast, but no mention was made of the decline in percentage increase that has been experienced in the past several years and which is predicted to continue for some time to come.

William J. Arthur Study, 1969

The research report, "A Financial Planning Aid for Private Colleges," was developed utilizing principles that have been in use in the management of manufacturing and sales organizations.[47] The author is disenchanted with large simulation models with their volumes of computer output. He set out to establish a simple formula that would tell college administrators whether their financial

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[47]William J. Arthur, A Financial Planning Model for Private Colleges: A Research Report (Charlottesville, Va.: University Press of Virginia, 1973).

resources will support the myriad plans proposed by faculty members and others on the college staff.

The study, done at the school of business at the University of Virginia, draws from emerging concepts of business strategy formulations as well as planning, programming, budgeting techniques. It attempts to set up a quantitative measurement that a college president can use to easily establish in his own office by gathering certain facts on enrollment, space utilization and the financial matters at his institution.

The equation makes use of what is called the "utilization ratio." Combining terms involving dormitories and their utilization, enrollments, class space and its utilization, the operating costs of auxiliary enterprises, tuition and endowment funds, the formula is not quite as easy to use as might have been expected from the introduction. Once the formula is set up, variables in the equation can be varied until a proper and sought after utilization ratio has been achieved, at least on paper. With the values that are present in this formulation, the administrator can then make the decisions that are necessary.

With this model, there is also the problem of a too simple formula being used to answer complicated questions. On the plus side for this study, the equation derived is more comprehensive than the one in the previous research

study. The author is careful to point out the limitations in the use of such systems, noting that such financial data often has little to do with excellence in an institution of higher education.

CHAPTER III

MATHEMATICAL DEVELOPMENT OF THE MODEL

In this chapter, the equations used in this study in determining unit expenditures for instruction are examined. The costing approach is straight-forward—total direct instructional expenditures divided by the number of output units is equal to the unit cost.

As mentioned in Chapter I, the unit of output used in this study is the student credit hour. In some studies, student contact hours have been used. This is appropriate when analyzing the load placed on instructional facilities. However, for this study which is concerned with direct instructional expenditures, student credit hours seem more appropriate. The expenditures in question, faculty salaries, are based on the number of credit hours taught. Even when time is released from teaching, as for example to chair a division, such time is usually equated with some number of credit hours in order to estimate the number of hours by which the instructor's teaching load is diminished.

In studying expenditures, a common practice in many small colleges is to indicate the cost per student at the end of each year. This number is arrived at by dividing the total expenditures for that year by the number of

students enrolled. However, this method does not give any indication of the variations that exist in the various programs offered by the college. In order to better understand the inner workings of the college and to aid in increasing efficiency, such expenditure breakdowns are needed.

In setting up a unit expenditure or unit cost procedure such as the one presented in this study, it is important to recognize the dual nature of the instruction producing activities in an institution of higher learning. Departments or teaching disciplines produce learning units, student credit hours, which are taken by students majoring in the various programs of the college. For example, all course offerings in chemistry comprise the chemistry discipline instruction program, but chemistry majors also take some courses in mathematics, English, etc., in addition to courses in chemistry, to constitute a degree program in chemistry. Thus, the expenditure for a discipline instruction program must be examined in terms of its contribution to a major degree program. This distinction between a discipline instruction program and a major program is fundamental and must be kept clear and explicit. A discipline or departmental instruction program is concerned with instructional activities in a specific field of knowledge. A degree program is concerned with the learning activities in which a student engages during the pursuit of a degree. In other

words, it is the curricula mix which leads to the award of a specific degree.

Such detailed breakdowns as the one to be presented here are not frequently found on small campuses because of the large number of data elements required. A computer is a real necessity in conducting such studies. In the examples of the method given in Chapter IV, student credit hours were broken down into 6592 elements. This large number remained even after a certain amount of aggregation. As these are stored in a four dimensional matrix, the method is somewhat difficult to visualize and illustrate. For this reason, a reduced version using a two dimensional matrix will be presented and illustrated first. This was the way this study originated.

I. TWO DIMENSIONAL APPROACH

In setting up a study involving a two dimensional matrix, costs of the student credit hours taken by students in major i taking courses in department j are calculated. These are represented mathematically by the matrix $C = [c_{ij}]$.

To make the transition from unit costs by department to unit costs by major field of study, information on the distribution of courses taken by students in the different majors is required. This information is obtained from

student registration data. The data are arranged to show the total number of student credit hours taken by students in major $\underline{i}$ taking instruction in department $\underline{j}$. These data are represented by the matrix $H = [h_{ij}]$. This will be referred to as the credit hour distribution matrix.

Let the number of majors in each field i be represented by m_i. The average number of credit hours taken in each department $\underline{j}$ by students in major $\underline{i}$ may then be represented by

$$\overline{H} = [\overline{h}_{ij}] \text{ where } \overline{h}_{ij} = h_{ij} \div m_i$$

This distribution of average credit hours is often referred to as the induced course load matrix. It describes the distribution of the average load placed on the instructional department by students pursuing various degrees.

From the credit hour matrix H, the total number of student credit hours generated by a particular department may be calculated as follows:

$$h_{.j} = \sum_i h_{ij}$$

Let the expenditure per department j be represented by d_j. Then the average cost per student credit hour generated is given by:

$$\bar{d}_j = d_j \div h_{.j}$$

Multiplying the components of the average credit distribution matrix by the appropriate cost per departmental hour determines the cost of the student credit hours taken on the average by students in the various majors. Symbolically,

$$C = [c_{ij}] \text{ where } c_{ij} = \bar{h}_{ij} \cdot \bar{d}_j$$

This matrix will be referred to as the average expenditure matrix. The average cost per student majoring in field i can be determined by summing these unit costs over the field in question. Symbolically,

$$c_{.j} = \sum_i c_{ij} = \sum_i (\bar{h}_{ij} \cdot \bar{d}_j)$$

This average cost per major presents a better picture of the operations of the college than does the average cost per student mentioned earlier in the chapter. This is also in

accord with the acknowledged fact that some majors are more expensive than others.

In addition, the average expenditure matrix enables the administrators of the college to examine the comparative cost of instruction given in the various departments as well as the comparative use made of it.

II. FOUR DIMENSIONAL APPROACH

The two dimensional procedure discussed above does not take into consideration the spread of courses taken by students in various years of study nor of the level at which various courses are taught. Combining these two additional variables with the two used previously, major and department, the four dimensional procedure that is the basis of this study will be discussed.

The year of the student is important in examining the curricular mix since, as the student progresses through the course of study, more requirements in the major field are taken in order to build up the necessary background in the field. In addition, in the earlier years of college, the student normally takes courses to fulfill the general education requirements included in the program. These are often referred to by the departments in question as service courses.

The level of each course is also an important variable since there can be a difference in the cost of producing courses at the various levels. This may be true either because instruction in upper division courses involves the more highly paid professors or because the enrollments in these courses are less than those in the lower division courses. Generally, the higher cost of upper division courses is apt to be due to a combination of these two causes.

In order to determine the expenditure per course, both the salary and teaching load of the individual instructor must be known. The fraction of the instructor's time spent on a specific course is determined by dividing the credit hours of the course by the total credit hour load of the instructor. Multiplying this fraction by the instructor's salary gives the expenditure for this course. This expenditure per course in department j at level l may be represented by x_{jln}, where n is the subscript referring to the number of courses at that level taught in the particular department. Let the number of student credit hours produced in that course be represented by r_{jln}. Then the cost per student credit hour in that course may be calculated by:

$$\bar{x}_{jln} = x_{jln} \div r_{jln}$$

The cost of producing a student credit hour in department $\underline{j}$ at level $\underline{l}$ may then be calculated using the following equation

$$\bar{d}_{jl} = \Sigma_n (x_{jln} \cdot r_{jln}) \div \Sigma_n r_{jln}$$

This value of the average cost per student credit hours generated, however, includes only the contribution due to instructor salaries. In addition to this, the expenditure for the divisional chairman's salary and support salaries. These expenditures will be allocated to the departmental costs in proportion to the total number of student credit hours generated in the division. This will increase each $\bar{d}_{ij}$ by a small amount. In addition, other expenditures in the departments, such as for equipment and travel, may be incorporated in a similar manner.

Using registration data, the credit hour distribution matrix is again calculated. In this case, the course level $\underline{l}$ and the student level $\underline{k}$ are incorporated into the calculations. The matrix will be represented by

$$H = [h_{ijkl}]$$

Let m_{ik} represent the number of students majoring in field $\underline{i}$ who are presently at student level $\underline{k}$. The average credit hour distribution matrix $\overline{H}$ may then be calculated as follows:

$$\overline{h}_{ijkl} = h_{ijkl} \div m_{ik}$$

This is the induced course load matrix referred to previously. Using it as well as the cost per departmental credit hour, the average cost matrix may be calculated:

$$c_{ijkl} = \overline{h}_{ijkl} \cdot \overline{d}_{jl}$$

This gives the average amount expended for the student credit hours taken by a student majoring in field $\underline{i}$ who is presently in year or class $\underline{k}$, and who is taking a course or courses in department $\underline{j}$ taught at level $\underline{l}$.

Using this matrix, college officials are able to examine in detail and compare the cost of instruction in the various departments. Incorporated into it are the varying enrollments in the different programs as well as the scale of expenditures required by the faculties in various departments.

With this detailed data stored, it is a simple matter to make summary calculations according to major, department, year or level. For example, the average cost per major $\underline{i}$ at student level $\underline{k}$ can be found by summing the values for the various departments and course levels as follows:

$$c_{i.k.} = \sum_{j} \sum_{l} c_{ijkl}$$

This represents the cost of educating one student in a particular field for one year. Judicious use of these numbers can be helpful in preparing for the following years. While this is not the marginal cost per student (the cost of adding one more such student), this average cost can be used within limits to approximate the marginal cost.

Other calculations that are frequently useful include those for determining the average faculty salary and the faculty productivity for each department. Letting the full time equivalent faculty in each department be represented by f_j, the average faculty salary $\underline{s}$ in department $\underline{j}$ is given by

$$s_j = \sum_{l} \sum_{n} x_{jln} \div f_j$$

In a similar manner, the productivity $\underline{p}$ in department $\underline{j}$ is calculated according to the following equation:

$$p_j = \sum_i \sum_k \sum_l h_{ijkl} \div f_j$$

These values are useful in making comparisons between departments.

III. THE PREDICTIVE MODE

In order to set up the predictive mode of the model which may be used to estimate future instructional expenditures, three fundamental sets of data are required. The first of these is the set of average credit hours taken by students in the various majors and at the various levels. These are contained in the induced course load matrix $\bar{H}$. Secondly, faculty productivity by department is required. The third required set of data consists of the enrollment figures m_{ik} giving the number of students in each major $\underline{m}$ and student level $\underline{k}$

The induced course load matrix $\bar{H}$ and the faculty productivity p_j are obtained from a run of the descriptive phase of the model. Normally, the most recent sets of data for a comparable time period would be used. The fundamental assumption of the predictive model is that these two sets of data remain constant over time. It would not be very difficult to make adjustments in some of these values, but such changes were not considered in this study.

Enrollment figures, on the other hand, are considered to vary between periods. Freshmen enrollments in each major field are considered exogenous variables and are input for each iteration. However, upper division enrollments are based on previous totals. There are a number of ways by which enrollments may be projected over a given period of time.[1] The method used for this model is referred to as the "cohort survival ratio" method. In this method, the ratio of students who move from one level to the next is averaged over a period of years. These calculated ratios are then applied to one set of enrollment figures in order to calculate the upperclassmen enrollment for the next period.

Letting t represent the time period or academic term, the enrollment in t any given time in any major field j and student level k will then be represented by:

$$m_{ik}\ (t)$$

While the freshmen enrollment for a given period is input to the model, the enrollment for the other student level is calculated according to the following formula:

$$m_{i,k+1}(t+1) = m_{ik}(t) \times R_k \quad (k = 1,2,3)$$

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[1] L. J. Lins, Methodology of Enrollment Projections for Colleges and Universities (Washington, D.C.: American Association of Collegiate Registrars and Admissions Officers, 1960); D. Kent Halstead, Statewide Planning in Higher Education (Washington, D.C.: U. S. Government Printing Office, 1974).

where R_k represents the ratio of students at k who continue on to level k + 1 for the next year.

Once the enrollment figures for an upcoming period have been determined, the new credit hour matrix

$$H(t + 1) = [h_{ijkl} (t + 1)]$$

is then calculated here,

$$h_{ijkl}(t + 1) = \bar{h}_{ijkl}(t) \times m_{i_k} (t + 1)$$

The total student credit hours produced in each department are found by summing:

$$h_{.j.l}(t + 1) = \sum_i \sum_k h_{ijkl} (t + 1)$$

Dividing these totals by the productivity per department produces the number of full time equivalent faculty that is predicted for the upcoming period:

$$f_j(t + 1) = h_{.j.l} (t + 1) \div p_j$$

Total faculty salaries per department are calculated by multiplying the FTE faculty just determined by the value of the average salary for that department:

$$s_j(t + 1) = f_j(t + 1) \times \bar{s}_j\ (t)[1 + Q]$$

where Q is a fraction that is entered at the start of each iteration and represents the percent raise to be given to the faculty for the period in question. Total departmental expenditures are calculated as follows:

$$d_j(t + 1) = \sum_j s_j(t + 1)$$

The addition of these predicted departmental expenses results in the amount to be expended for classroom instruction during the upcoming period.

These calculations may be repeated over any number of periods. Comparisons may be made regarding total or departmental expenditures. In interpreting such predicted results, the college administrator must carefully keep in mind the assumptions which underlie their calculations.

CHAPTER IV

PROGRAMMING AND IMPLEMENTATION OF THE MODEL

The chief purpose of this study was to develop a computerized cost analysis model of a small college that could be run on the college's on-campus computer. The use of an on-campus computer has a twofold purpose. First, it makes the model more accessible to the college administrators, more available for running. Second, the use of an on-campus computer for developing and running the model puts less economic stress on the college's budget than would the renting of time on a service bureau computer.

The chief difficulty found in using such a computer was the limitation such a machine placed on the size of the model and on the amount of data that could be incorporated. The first section of this chapter will deal with the programming considerations which were utilized in order to accommodate large quantities of data to the memory of a small computer.

The cost analysis model was constructed and operated in two phases. In the first of these, the model was used to present a description of the college. That is, unit costs for a particular time period were calculated and displayed. The implementation of this phase of the model is described

in the second section of this chapter, along with examples of the types of information supplied by this descriptive model.

The third section of the chapter deals with the second or prediction phase of the model. The manner in which this is built upon the descriptive phase, as well as the validation process, is discussed.

I. PROGRAMMING CONSIDERATIONS

The computer used in this study was an IBM 1130 with 16,000 words of main memory. Briefly, this indicates that, if the memory were used solely for the purpose of holding numbers, 16,000 integers or whole numbers could be stored. Because of the internal method used to keep track of the decimal point, only a third as many numbers involving fractions or decimals could be so stored.

However, in addition to the storage of data, this same memory must be used to store the program as well. The more complicated and lengthy the program, the more memory is involved, thus limiting the amount of data that can be stored in the computer's memory. To overcome this shortcoming, large volumes of data were stored on magnetic disk, a secondary storage medium connected directly to the main memory. Portions of this data were called into memory by the program as they were needed. In addition to using this technique to

save memory locations, many small programs were utilized, thus allowing comparatively more data to be kept in the computer's memory at one time. Bringing the data in and out of the computer's memory requires a certain amount of time. In this study, it was felt better to sacrifice some time in the interests of making the storage arrays large enough to be meaningful.

The programs were written to accommodate matrices involving 25 major fields and 20 instructional departments. Such a 25 × 20 matrix was utilized for each combination of student level and course level, thus making the complete matrix a four dimensional one. As the FORTRAN compiler for the IBM 1130 allows a maximum of three dimensions, only one student level could be kept in main memory at one time. One pass through the student data was required for each student level. As each pass was completed, that portion of the matrix was stored on disk and calculations for the next level began.

The four student levels and four course levels were increased by one to allow an area for totals. Thus the matrix built into the program had dimensions of 25 × 20 × 5 × 5, a total of 12,500 elements. A subarray of 25 × 20 × 5 was brought into primary storage, operated on, and then placed in secondary storage. This was particularly necessary when calculating the average credit hour or cost matrices.

As these elements included fractions, 7500 memory locations were required as opposed to the 2500 necessary in the credit hour matrix. Although programmed for 25 majors and 20 departments, 22 majors and 17 departments were actually used in this study.

The matrices just discussed were stored in output files in the secondary storage medium, magnetic disk. In addition to these output files, certain input files were required. The principle one of these consisted of a file of student data. As there was neither room nor requirements for a complete set of data on each student, abbreviated files were constructed which contained merely the level and major of each student, along with a list of the course numbers taken during a particular semester. An auxiliary file connected with this contained the requisite data on each course, namely, the level of the course, the instructor, the department and the number of credit hours. As mentioned above, it was necessary to go through these files several times in order to accommodate all of the elements required to construct the credit hour matrix and the other data derived from it.

II. THE DESCRIPTIVE PHASE

The descriptive phase of the model consists of calculating and displaying the breakdown of costs involved

in a single semester. The first step in this process consists of calculating the elements of the credit hour matrix. In order to do this, the enrollment data on each student must be retrieved in order to obtain major field and student level, as well as the list of courses taken. For each of the latter, course level and the number of credits are determined. Each of the proper cells in the credit hour matrix are then incremented and the next student's data is retrieved and operated on in a similar manner. Table I illustrates a typical output of this step. The numbers of full time equivalent majors in each field as well as at each level are also accumulated. This data is shown in Table II. In addition, the total number of student credit hours produced by each department and at each course level are gathered. Sample output of this type is shown in Table III.

In the next step, the average credit hour of induced course load matrix is calculated. As mentioned previously, this indicates the average number of hours taken in each department by an average major. Typical data output by this step is shown in Table IV. While all of the elements of this matrix are useful in later steps, it is of particular interest to examine the total number of hours taken by a typical major at each level. A typical display of this data is shown in Table V.

TABLE I

Portion of a credit hour matrix showing the number of credit hours taken by Freshmen in 100 level courses, Semester I, 1973-74.

	Instructional Departments						
MAJOR	BIOL	BUS	CHEM	CH E	C E	ENGR	ENG
ACCT	0	72	0	0	0	0	72
ECON	0	0	0	0	0	0	0
MKMN	4	48	0	0	0	0	45
BUS	8	78	6	0	0	0	72
ENGR	0	0	4	0	0	3	3
CH E	0	0	20	0	0	15	9
C E	0	0	28	0	0	24	24
E E	0	3	59	0	0	48	45
M E	0	0	48	0	0	39	39
BIOL	113	6	62	0	0	0	90
CHEM	0	0	12	0	0	3	12
MEDT	37	3	27	0	0	0	18
MEDR	11	12	0	0	0	0	9
MATH	3	3	4	0	0	0	3
NSCI	8	0	8	0	0	0	6
PHYS	0	0	4	0	0	0	3
ENG	0	0	0	0	0	0	9
HIST	4	0	0	0	0	0	42
HUM	23	3	19	0	0	0	69
MTHA	4	0	0	0	0	0	3
RAC	0	0	0	0	0	0	6
ARTS	4	0	4	0	0	0	12
TOTALS	219	228	305	0	0	132	591

TABLE I (continued)

	Instructional Departments						
MAJOR	EDUC	E E	LANG	HIST	HUM	MATH	M E
ACCT	0	0	6	36	78	70	0
ECON	0	0	0	0	0	0	0
MKMN	0	0	0	15	54	37	0
BUS	0	0	9	24	93	49	0
ENGR	3	3	27	0	0	4	0
CH E	0	0	0	0	15	24	0
C E	0	0	0	9	6	36	0
E E	0	0	0	0	27	64	0
M E	0	0	0	3	24	52	0
BIOL	0	0	0	21	43	71	0
CHEM	0	0	0	0	0	16	0
MEDT	0	0	3	6	16	18	0
MEDR	0	0	0	3	3	3	0
MATH	0	0	0	0	6	8	0
NSCI	0	0	0	0	3	8	0
PHYS	0	0	0	0	3	4	0
ENG	0	0	6	3	3	6	0
HIST	0	0	24	90	36	9	0
HUM	0	0	3	9	180	27	0
MTHA	0	0	3	3	0	4	0
RAC	0	0	0	0	0	3	0
ARTS	0	0	3	3	18	7	0
TOTALS	3	3	84	225	608	520	0

TABLE I (continued)

	Instructional Departments			
MAJOR	PHYS	RAC	P E	TOTALS
ACCT	0	0	22	356
ECON	0	0	0	0
MKMN	0	0	15	218
BUS	0	3	24	366
ENGR	0	0	1	48
CH E	4	0	5	92
C E	4	9	9	149
E E	0	18	17	281
M E	0	15	14	234
BIOL	0	24	21	451
CHEM	8	6	3	60
MEDT	0	3	8	139
MEDR	0	0	3	44
MATH	0	0	1	28
NSCI	0	0	0	33
PHYS	4	0	1	19
ENG	0	0	0	27
HIST	0	0	15	220
HUM	0	12	21	366
MTHA	0	0	1	18
RAC	0	9	1	19
ARTS	0	3	4	58
TOTALS	20	102	186	3226

TABLE II

Full time equivalent students by student level, Semester I, 1973-74.

	Student Level				
MAJOR	FR	SO	JR	SR	TOTAL
ACCT	24	22	12	19	76
ECON	0	3	1	2	6
MKMN	15	25	17	21	77
BUS	24	17	5	3	49
ENGR	4	2	1	0	7
CH E	6	5	2	5	18
C E	9	6	1	14	30
E E	17	17	15	30	79
M E	14	8	7	12	40
BIOL	28	10	4	8	50
CHEM	3	0	0	0	3
MEDT	9	8	3	4	24
MEDR	3	4	0	0	7
MATH	2	0	1	3	5
NSCI	2	1	1	0	4
PHYS	1	1	3	1	6
ENG	2	13	3	10	28
HIST	15	26	22	24	86
HUM	23	18	12	10	63
MTHA	1	4	5	4	14
RAC	1	5	2	3	11
ARTS	4	8	1	0	12
TOTAL	207	203	118	173	695

TABLE III

Distribution of student credit hours produced by each department, Semester I, 1973-74.

	Course Level				
DEPT.	100	200	300	400	TOTAL
BIOL	436	76	51	76	639
BUS	405	729	717	336	2187
CHEM	622	118	40	3	783
CH E	72	27	3	26	128
C E	0	0	21	170	191
ENGR	195	129	141	45	510
ENG	627	471	183	42	1323
EDUC	0	0	168	125	293
E E	0	20	177	198	395
LANG	252	219	0	0	471
HIST	474	303	114	261	1152
HUM	1536	120	477	42	2175
MATH	921	144	294	24	1383
M E	0	30	57	103	190
PHYS	90	0	297	169	556
RAC	90	0	297	169	556
P E	265	0	0	0	265

TABLE IV

Portion of an average credit hour matrix showing the average number of credit hours taken by typical Freshmen in 100 level courses, Semester I, 1973-74.

	Instructional Departments						
MAJOR	BIOL	BUS	CHEM	CH E	C E	ENGR	ENG
ACCT	0.00	2.82	0.18	0.00	0.00	0.00	2.73
ECON	0.00	3.00	0.00	0.00	0.00	0.00	0.00
MKMN	0.00	2.79	0.21	0.00	0.00	0.00	2.79
BUS	0.14	3.41	0.21	0.10	0.00	0.00	2.48
ENGR	0.31	0.69	1.46	4.62	0.00	1.15	0.46
CH E	0.00	0.00	4.00	0.00	0.00	2.63	0.38
C E	0.00	0.00	4.00	0.00	0.00	3.00	0.33
E E	0.00	0.00	3.69	0.00	0.00	3.00	0.69
M E	0.00	0.00	3.14	0.00	0.00	2.79	0.43
BIOL	3.70	0.00	3.88	0.00	0.00	0.00	2.55
CHEM	0.00	0.00	4.00	0.00	0.00	0.00	3.00
MEDT	3.60	0.00	4.00	0.00	0.00	0.00	2.10
MEDR	1.33	3.00	0.00	0.00	0.00	0.00	3.00
MATH	0.00	1.50	2.00	0.00	0.00	0.00	1.50
NSCI	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PHYS	0.00	0.00	4.00	0.00	0.00	0.00	3.00
ENG	0.00	0.38	0.00	0.00	0.00	0.00	1.88
HIST	0.14	0.00	0.00	0.00	0.00	0.00	2.43
HUM	0.52	0.13	2.09	0.00	0.00	0.00	2.48
MTHA	1.33	0.00	1.33	0.00	0.00	0.00	3.00
RAC	1.50	0.00	0.00	0.00	0.00	0.00	3.00
ARTS	0.00	0.00	1.14	0.00	0.00	0.00	2.57

TABLE IV (continued)

	Instructional Departments						
MAJOR	EDUC	E E	LANG	HIST	HUM	MATH	M E
ACCT	0.00	0.00	0.18	0.82	3.00	2.76	0.00
ECON	0.00	0.00	3.00	0.00	0.00	3.00	0.00
MKMN	0.00	0.00	0.00	0.86	3.21	2.57	0.00
BUS	0.00	0.00	0.31	0.62	2.90	3.00	0.00
ENGR	0.00	0.00	0.00	0.23	1.38	1.62	0.00
CH E	0.00	0.00	0.00	0.00	4.88	3.50	0.00
C E	0.00	0.00	0.00	0.00	5.33	4.00	0.00
E E	0.00	0.00	0.00	0.00	4.15	4.12	0.00
M E	0.00	0.00	0.00	0.00	4.29	3.79	0.00
BIOL	0.00	0.00	0.00	0.00	0.30	4.21	0.00
CHEM	0.00	0.00	0.00	0.00	0.00	4.33	0.00
MEDT	0.00	0.00	0.00	0.30	0.40	3.00	0.00
MEDR	0.00	0.00	0.00	0.00	1.00	3.17	0.00
MATH	0.00	0.00	1.50	0.00	3.00	4.50	0.00
NSCI	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PHYS	0.00	0.00	0.00	0.00	1.00	4.00	0.00
ENG	0.00	0.00	1.50	0.75	2.25	0.75	0.00
HIST	0.00	0.00	2.14	7.57	1.00	0.14	0.00
HUM	0.00	0.00	0.00	0.78	6.04	1.00	0.00
MTHA	0.00	0.00	1.00	2.00	0.00	4.67	0.00
RAC	0.00	0.00	0.00	0.00	1.50	1.50	0.00
ARTS	0.00	0.00	0.43	0.64	5.36	1.36	0.00

TABLE IV (continued)

MAJOR	Instructional Departments			
	PHYS	RAC	P E	TOTAL
ACCT	0.00	0.00	0.82	13.31
ECON	0.00	0.00	0.00	9.00
MKMN	0.00	0.21	0.93	13.57
BUS	0.00	0.10	0.86	14.13
ENGR	0.00	0.00	0.31	12.23
CH E	0.00	0.00	0.88	16.27
C E	0.00	0.00	1.00	17.66
E E	0.00	0.12	0.96	16.73
M E	0.00	0.21	0.93	15.58
BIOL	0.00	0.00	0.76	15.40
CHEM	0.00	3.00	1.00	15.33
MEDT	0.00	0.00	0.70	14.10
MEDR	0.00	0.00	1.00	12.50
MATH	0.00	0.00	0.50	14.50
NSCI	0.00	0.00	0.00	0.00
PHYS	0.00	2.00	1.00	15.00
ENG	0.00	0.00	0.25	7.76
HIST	0.00	0.00	0.67	14.09
HUM	0.00	0.13	0.91	14.08
MTHA	0.00	0.00	1.00	14.33
RAC	0.00	3.00	0.50	11.00
ARTS	0.00	0.64	0.86	13.00

TABLE V

Total number of student credit hours taken by an average major at each level, Semester I, 1973-74.

	Student Level				
MAJOR	FR	SO	JR	SR	AVERAGE
ACCT	15.12	17.36	17.66	16.93	16.53
ECON	15.00	15.60	0.00	15.50	15.52
MKMN	15.69	16.56	17.10	17.27	16.68
BUS	15.06	16.91	15.73	15.00	15.67
ENGR	13.84	17.00	0.00	0.00	14.46
CH E	17.14	18.00	18.00	15.00	16.60
C E	18.00	16.50	16.33	19.40	18.21
E E	17.66	15.76	15.82	16.09	16.42
M E	16.42	15.67	16.29	15.20	15.94
BIOL	15.79	16.83	11.16	16.18	16.39
CHEM	17.33	16.00	0.00	0.00	17.00
MEDT	14.10	15.19	13.80	17.00	14.58
MEDR	15.00	15.67	0.00	0.00	15.33
MATH	17.50	17.00	15.75	16.50	16.44
NSCI	0.00	17.00	0.00	0.00	17.00
PHYS	15.00	17.22	16.50	11.00	14.88
ENG	16.52	17.26	18.13	16.15	17.01
HIST	15.23	17.00	17.36	15.85	16.51
HUM	15.12	17.00	17.61	14.25	16.61
MTHA	15.33	17.65	15.00	18.00	16.87
RAC	14.00	17.50	18.00	11.00	15.00
ARTS	14.72	15.73	0.00	0.00	15.28

As was described in Chapter III, with teacher salaries included in the model, the cost per student credit hour in each department and at each level is calculated. A typical set of these values is shown in Table VI. A supplemental display for this section of the model gives the cost of each course and of the student credit hours generated in this course. A small sample of this output is shown in Table VII.

Once the cost of producing student credit hours in each department has been calculated, these values may be combined with the average credit hour matrix to determine the average expenditure incurred by a typical major. This has been referred to as the average cost matrix, and a sample of such data is shown in Table VIII. Of greater interest is the summary cost of each major at each level as is illustrated in Table IX.

Displays such as those which have been described and illustrated in this section have made it much easier for the college administrators to examine the breakdown of the expenditures for classroom instruction. Comparisons are easily made between departments and programs. Additionally, after the model has been run through several years of data, comparative results may be displayed which indicate the variations in expenditures and output over the years. Tables X and XI show such comparative data.

TABLE VI

Cost in dollars of producing a student credit hour at each level in each department, Semester I, 1973-74.

	Course Level				
Dept.	100	200	300	400	Weighted Average
BIOL	24.97	32.62	38.78	27.21	27.25
BUS	15.99	17.74	17.43	22.01	18.13
CHEM	23.91	39.79	48.24	140.35	27.99
CH E	35.58	129.14	532.20	111.89	82.43
C E	-	-	113.30	47.07	54.36
ENGR	37.19	27.94	36.63	54.32	36.21
ENG	21.52	11.04	22.90	53.59	19.00
EDUC	-	-	7.18	20.88	13.02
E E	-	121.84	38.47	54.44	50.70
LANG	14.88	16.88	-	-	15.81
HIST	17.96	9.06	13.99	18.32	15.31
HUM	12.34	8.29	20.99	20.81	14.18
MATH	20.97	13.36	19.45	62.40	20.57
M E	-	59.92	102.47	114.37	102.20
PHYS	-	41.12	-	246.81	52.64
RAC	17.31	-	20.76	17.40	19.18
P E	21.20	-	-	-	21.20

TABLE VII

Portion of table showing cost per course and cost per student credit hour produced in each course, Semester I, 1973-74.

Catalog Number	Enrollment	Cost of Course	Cost Per Sch.
BIOL 104	21	2135.63	33.89
BIOL 211	19	1859.49	32.62
BUS 101-A	34	2336.88	22.91
BUS 101-B	45	1440.19	10.66
BUS 101-C	31	1289.41	13.86
BUS 218	31	2071.91	22.27
CHEM 113-A	18	1709.56	31.65
CHEM 113-B	36	1904.47	17.63
C E 413	15	2138.30	47.51
E E 415	7	1601.30	76.25
ENGR 201	35	2368.37	22.55
ITAL 101	17	1278.39	25.06
MATH 305	31	1746.68	18.78
M E 432	7	2079.67	99.03
PHIL 317	20	1218.40	20.30

TABLE VIII

Portion of average cost matrix showing the cost of student credit hours taken in 100 level courses by typical Freshmen majors, Semester I, 1973-74.

	Instructional Departments						
MAJOR	BIOL	BUS	CHEM	CH E	C E	ENGR	ENG
ACCT	0.00	45.09	4.30	0.00	0.00	0.00	58.75
ECON	0.00	47.97	0.00	0.00	0.00	0.00	0.00
MKMN	0.00	44.01	5.02	0.00	0.00	0.00	60.04
BUS	3.50	54.53	5.02	3.56	0.00	0.00	53.37
ENGR	7.74	11.03	34.91	164.38	0.00	42.77	9.90
CH E	0.00	0.00	95.64	0.00	0.00	97.81	8.18
C E	0.00	0.00	95.64	0.00	0.00	111.57	7.10
E E	0.00	0.00	88.23	0.00	0.00	111.57	14.85
M E	0.00	0.00	75.00	0.00	0.00	103.76	9.25
BIOL	92.39	0.00	92.77	0.00	0.00	0.00	54.88
CHEM	0.00	0.00	95.64	0.00	0.00	0.00	64.56
MEDT	89.89	0.00	95.64	0.00	0.00	0.00	45.19
MEDR	33.21	47.97	0.00	0.00	0.00	0.00	64.56
MATH	0.00	23.99	47.82	0.00	0.00	0.00	32.28
NSCI	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PHYS	0.00	0.00	95.64	0.00	0.00	0.00	64.56
ENG	0.00	6.08	0.00	0.00	0.00	0.00	40.46
HIST	3.50	0.00	0.00	0.00	0.00	0.00	52.29
HUM	12.98	2.08	49.97	0.00	0.00	0.00	53.37
MTHA	33.21	0.00	31.80	0.00	0.00	0.00	64.56
RAC	37.46	0.00	0.00	0.00	0.00	0.00	64.56
ARTS	0.00	0.00	27.26	0.00	0.00	0.00	55.31

TABLE VIII (continued)

	Instructional Departments					
MAJOR	EDUC	E E	LANG	HIST	HUM	MATH
ACCT	0.00	0.00	2.60	14.73	37.02	57.88
ECON	0.00	0.00	44.64	0.00	0.00	62.91
MKMN	0.00	0.00	0.00	15.45	39.61	53.89
BUS	0.00	0.00	4.61	11.14	35.79	52.91
ENGR	0.00	0.00	0.00	4.13	17.03	33.97
CH E	0.00	0.00	0.00	0.00	60.22	73.40
C E	0.00	0.00	0.00	0.00	65.77	83.88
E E	0.00	0.00	0.00	0.00	51.21	86.40
M E	0.00	0.00	0.00	0.00	52.94	79.48
BIOL	0.00	0.00	0.00	0.00	3.70	88.28
CHEM	0.00	0.00	0.00	0.00	0.00	90.80
MEDT	0.00	0.00	0.00	5.39	4.94	62.91
MEDR	0.00	0.00	0.00	0.00	12.34	66.47
MATH	0.00	0.00	22.32	0.00	37.02	94.37
NSCI	0.00	0.00	0.00	0.00	0.00	0.00
PHYS	0.00	0.00	0.00	0.00	12.34	83.88
ENG	0.00	0.00	22.32	13.47	27.77	15.73
HIST	0.00	0.00	31.84	135.96	12.34	2.94
HUM	0.00	0.00	0.00	14.01	74.53	20.97
MTHA	0.00	0.00	14.88	35.92	0.00	97.93
RAC	0.00	0.00	0.00	0.00	18.51	31.46
ARTS	0.00	0.00	6.40	11.49	66.14	28.52

TABLE VIII (continued)

	Instructional Departments				
MAJOR	M E	PHYS	RAC	P E	TOTAL
ACCT	0.00	0.00	0.00	17.38	237.83
ECON	0.00	0.00	0.00	0.00	155.52
MKMN	0.00	0.00	3.64	19.72	241.98
BUS	0.00	0.00	1.73	18.23	254.39
ENGR	0.00	0.00	0.00	6.57	332.43
CH E	0.00	0.00	0.00	18.66	353.91
C E	0.00	0.00	0.00	21.20	385.16
E E	0.00	0.00	2.08	20.35	374.69
M E	0.00	0.00	3.64	19.72	343.87
BIOL	0.00	0.00	0.00	16.11	348.13
CHEM	0.00	0.00	51.93	21.20	324.13
MEDT	0.00	0.00	0.00	14.84	318.80
MEDR	0.00	0.00	0.00	21.20	245.75
MATH	0.00	0.00	0.00	10.60	268.40
NSCI	0.00	0.00	0.00	0.00	0.00
PHYS	0.00	0.00	34.62	21.20	312.24
ENG	0.00	0.00	0.00	14.20	253.07
HUM	0.00	0.00	2.25	19.29	249.45
MTHA	0.00	0.00	0.00	21.20	299.50
RAC	0.00	0.00	51.93	10.60	214.52
ARTS	0.00	0.00	11.08	18.23	224.43

TABLE IX

Cost per major at each student level, Semester I, 1973-74.

MAJOR	Student Level FR	SO	JR	SR	WEIGHTED AVERAGE
ACCT	277.53	310.20	317.56	296.80	279.34
ECON	274.92	271.38	-	256.95	268.61
MKMN	229.96	289.19	300.31	311.13	294.77
BUS	280.12	321.58	265.45	263.07	293.21
ENGR	665.58	505.23	-	-	636.09
CH E	397.95	603.28	642.42	662.62	533.51
C E	410.74	558.35	608.37	836.22	635.55
E E	407.41	518.73	565.45	652.47	536.56
M E	400.10	718.25	823.08	1106.56	722.72
BIOL	373.26	377.54	523.96	398.04	394.82
CHEM	375.13	351.79	-	-	369.34
MEDT	336.77	331.77	315.61	356.43	331.27
MEDR	293.55	316.16	-	-	304.82
MATH	325.35	428.74	378.62	461.25	390.58
NSCI	-	348.58	-	-	348.58
PHYS	324.98	550.87	479.27	445.39	435.86
ENG	286.24	298.11	318.27	276.76	294.84
HIST	249.60	293.12	267.27	259.15	270.83
HUM	229.41	298.37	325.03	231.12	300.23
MTHA	294.16	334.67	282.56	328.16	321.85
RAC	275.69	332.25	323.74	185.48	173.27
ARTS	261.51	300.95	-	-	280.50

TABLE X

Comparison of average expenditures for various majors over a three year period.

MAJOR	Year 1971-72	1972-73	1973-74
ACCT	653.16	620.50	577.47
ECON	723.47	588.07	502.32
MKMN	678.75	628.77	649.23
BUS	643.29	627.92	592.14
ENGR	986.86	909.46	882.98
CH E	1297.58	1504.13	1256.67
C E	1125.96	1386.15	1329.05
E E	1028.65	1242.51	1041.53
M E	1132.78	1563.05	1421.32
BIOL	1034.25	965.46	772.36
CHEM	1180.46	871.87	888.53
MEDT	1047.72	889.99	784.21
MEDR	970.36	745.38	497.95
MATH	794.05	780.81	591.78
NSCI	-	-	2126.43
PHYS	838.86	892.15	862.26
ENG	711.48	590.00	527.04
HIST	680.86	622.93	514.46
HUM	-	687.00	617.05
MTHA	785.63	713.83	634.36
RAC	789.15	600.70	699.74
ARTS	716.81	564.38	439.00

TABLE XI

Comparison of total student credit hours produced by each instructional department over a three year period.

Depart-ments	Year					
	1971-72		1972-73		1973-74	
	Sem I	Sem II	Sem I	Sem II	Sem I	Sem II
BIOL	418	400	544	447	639	520
BUS	1420	1464	2223	1875	2187	1770
CHEM	740	635	717	589	780	546
CH E	140	120	155	90	128	41
C E	256	372	241	275	203	205
ENGR	823	637	596	445	510	348
ENG	1331	1263	1369	1338	1323	1268
EDUC	354	414	361	309	289	254
E E	628	693	514	581	395	467
LANG	444	390	504	495	471	453
HIST	1242	1455	1230	1056	1134	910
HUM	984	1173	2234	2060	2175	2059
MATH	1706	1340	1526	1095	1383	979
M E	341	303	211	191	178	205
PHYS	383	356	290	249	232	215
RAC	638	569	630	720	574	553
P E	175	156	277	278	265	251

III. THE PREDICTIVE PHASE

The predictive phase of the model was built upon the descriptive phase. The data that was gathered for use in the descriptive phase as well as many of the calculated values were used in setting up the predictive phase.

The principle set of calculated values taken from the descriptive phase was the induced course load matrix. This set of average credit hours taken by typical majors in various departments is calculated each time the descriptive phase is used. The matrix utilized for predictions may be saved from any one of these runs. However, the one calculated from the most recent period was used in this study. It was considered to contain the most representative set of departmental loadings to be projected into the future. In addition to the induced course load matrix, the enrollment figures for the past several years were required. A special program was written to calculate the average survival ratio for the upper classes in each major field. The values used in this study are exhibited in Table XII. These are ratios averaged over a three year period. Some of the values are greater than one indicating that students have, in certain cases, changed majors. The predictive program was built to operate in a cyclical fashion. These ratios enabled the program to deduce new enrollment figures based on the

TABLE XII

Survival ratio of the various majors averaged over a period of three years.

Major	Freshmen to Sophomore	Sophomore to Junior	Junior to Senior
ACCT	0.62	0.82	1.37
ECON	0.74	0.65	1.00
MKMN	1.01	0.79	0.95
BUS	0.51	0.38	1.00
ENGR	0.31	0.00	0.00
CH E	0.58	0.75	1.20
C E	0.66	0.84	1.11
E E	0.78	0.82	1.26
M E	0.79	0.72	1.21
BIOL	0.56	0.43	1.71
CHEM	0.56	0.33	1.00
MEDT	0.74	0.85	0.37
MEDR	0.48	0.33	0.00
MATH(S)	0.76	0.36	1.38
NSCI	0.74	0.65	1.20
PHYS	0.75	0.72	1.33
ENG	0.86	0.66	1.20
HIST	0.78	0.59	1.44
MATH (A)	0.60	0.40	1.33
RAC	0.78	0.40	1.25
ARTS	0.67	0.15	0.00

previous period's enrollment. For each new period, Freshmen enrollment was read in. Decisions concerning the prediction of incoming Freshmen classes were not handled by the model.

The new enrollment figures were combined with the induced course load matrix in order to calculate the total number of student credit hours that would be needed by that enrollment. These were summed by department to determine the load that would be placed on the instructional departments.

Additional data from the base run of the descriptive phase were entered into the calculations. These included (1) the productivity per department and (2) the average faculty salary per department. The productivity constants were used along with the calculated departmental credit hours to determine the number of full time equivalent faculty that would be required by the enrollment in question. Total salaries per department were then calculated. In the process of the calculations, the salaries were incremented by whatever percentage increase was chosen to be applied to the period in question. These new average salary values were saved and used as base figures for the next cycle. This process was repeated for as many cycles as desired, each time supplying the program with the Freshmen enrollment and percentage increase in salaries.

All computer programs must be verified as to the correctness of their logic by checking the answers generated with carefully worked out hand calculations. In addition, the development of predictive programs must be validated by running them with historical data and checking the calculated results against the actual figures. As a first step in the validation of the predictive phase of the model, the data for a given year was run against itself. That is, the computer was instructed to bypass the procedure for calculating a new enrollment, and to use the enrollment figures for the year entered. It was then instructed to use the induced course load matrix and to calculate the number of student credit hours that would be generated in each department and the full time equivalent faculty necessary. The results of such a run are shown in Table XIII. This served to check the procedure for making these calculations because the actual values were already on hand as a result of running the descriptive phase of the model. The calculated values of student credit hours showed slight variations from the actual values. This was due to the fact that the calculations involved average students; whereas, the true values used the actual registration figures. There was not enough variation, however, to make any difference in the calculations for full time equivalent faculty.

TABLE XIII

Comparison of actual and computed values of student credit hours and full time equivalent faculty for a given year.

	Student credit hours		Full time equivalent faculty	
Dept.	Actual	Computed	Actual	Computed
BIOL	433	433	2.34	2.34
BUS	2061	2060	7.00	7.00
CHEM	904	903	3.12	3.12
CH E	34	34	1.00	1.00
C E	106	106	1.13	1.13
ENGR	540	540	2.28	2.28
ENG	1129	1129	3.73	3.73
EDUC	461	461	2.01	2.01
E E	403	403	2.82	2.82
LANG	291	290	2.00	2.00
HIST	786	786	3.50	3.50
HUM	2672	2672	8.88	8.88
MATH	1289	1288	4.32	4.32
M E	223	222	2.14	2.14
PHYS	282	282	1.62	1.62
RAC	192	192	1.06	1.06
P E	210	209	1.12	1.12
TOTAL	12016	12010	50.07	50.07

To further validate the predictive phase of the model, a three year cycle was run on past data and the computer values compared with the historical results. The induced course load matrix for the first semester of 1971-72, along with corresponding faculty information, was used as the base. The entering Freshmen enrollments for 1972, 1973 and 1974 were supplied and the computer instructed to perform the calculations for the first term of those three years.

Table XIV shows the comparison between the actual enrollment figures and those predicted by the model. As indicated by the differences between corresponding figures, the survival ratios utilized in calculating predicted enrollment figures were not entirely accurate. This inaccuracy was due to the rather small values available for determining these ratios. In some fields there were not sufficient majors to allow calculation of accurate survival ratios. In addition, during the period under consideration, some new fields had been opened up while others were being phased out. A more stable enrollment would have led to more accurate survival ratios and, therefore, to more accurate predictions of enrollment. It was felt that the ratios used and the results achieved were accurate enough for the purposes of this study.

The results of interest which were generated on each cycle are (1) the number of student credit hours required by

TABLE XIV

Comparison of actual and calculated full time equivalent figures by major field for the first semester of 1972, 1973 and 1974.

Major	1972		1973		1974	
	Actual	Predicted	Actual	Predicted	Actual	Predicted
ACCT	83	84	89	92	87	89
ECON	12	111	8	7	5	6
MKMN	106	107	74	80	67	65
BUS	40	47	53	52	50	50
ENGR	13	12	16	16	22	23
CH E	19	20	18	22	18	17
C E	43	45	28	34	36	33
E E	96	109	92	91	86	78
M E	44	46	40	45	47	48
BIOL	56	54	65	66	69	70
CHEM	7	5	4	6	3	3
MEDT	20	15	27	20	22	19
MEDR	18	17	12	14	5	9
MATH	17	17	9	10	5	10
NSCI	0	0	1	0	6	3
PHYS	16	11	9	6	5	4
ENG	42	43	31	35	28	28
HIST	124	118	100	98	58	68
HUM	34	38	64	62	61	49
MTHA	16	20	15	12	10	8
RAC	16	13	10	8	17	4
ARTS	22	24	25	30	22	31
TOTAL	838	856	790	806	729	715

the calculated enrollment, (2) the full time equivalent faculty required, and (3) the expenditures required for the latter's salaries—the direct costs for classroom instruction.

Table XV shows the comparison between actual and calculated values of student credit hours for each of the three years in question. In the Table XVI a similar comparison for full time equivalent faculty is given. Table XVII shows the comparison for the expenditures required by department. Examination of these tables indicates that while a number of the comparisons are quite reasonable, a number of others are not quite so good. The inaccuracies of the calculated values can be explained largely by the instability of the induced course load matrix over a period of years. In other words, the average or typical student in a given field does not enroll in exactly the same set of courses year after year. While major courses remain fairly stable, various new electives may be taken over a period of years. The predictive phase of the model assumes that the induced course load matrix will be stable and that the same set of values were used during each cycle of the program. With a larger and more stable enrollment than the one used in the illustrative run, this assumption could have more validity.

In addition to the above mentioned reason, a few other changes were taking place during the years represented. A

TABLE XV

Comparison of actual and calculated student credit hours generated by department for the first semester, 1972, 1973, and 1974.

	1972		1973		1974	
Dept.	Actual	Predicted	Actual	Predicted	Actual	Predicted
BIOL	544	480	639	540	433	464
BUS	2238	1874	2187	1903	2061	1851
CHEM	717	699	783	757	904	740
CH E	155	75	128	82	34	47
C E	241	307	191	297	106	166
ENGR	596	690	510	591	540	602
ENG	1447	1316	1323	1225	1129	1030
EDUC	361	356	293	281	461	252
E E	514	596	395	486	403	371
LANG	504	478	471	433	291	343
HIST	1230	1342	1152	1174	786	967
HUM	2234	1008	2175	981	2672	844
MATH	1601	1574	1383	1374	1289	1270
M E	211	339	190	340	223	245
PHYS	290	308	232	218	282	242
RAC	630	558	637	554	192	502
P E	277	171	265	160	210	156
TOTAL	13790	12179	12954	11406	12016	10099

TABLE XVI

Comparison of actual and calculated full time equivalent faculty by department for the first semester of 1972, 1973, and 1974.

	1972		1973		1974	
Dept.	Actual	Calculated	Actual	Calculated	Actual	Calculated
BIOL	2.21	2.25	2.35	2.48	2.34	2.27
BUS	8.25	6.95	7.00	6.66	7.00	6.24
CHEM	3.64	2.64	3.17	2.97	3.12	3.01
CH E	1.31	0.64	1.23	0.67	1.00	0.54
C E	1.99	1.90	1.75	1.41	1.13	0.82
ENGR	3.16	1.92	1.79	1.63	2.28	1.73
ENG	5.61	4.97	4.48	4.67	3.73	3.82
EDUC	1.75	1.29	1.50	1.23	2.01	1.15
E E	2.71	3.09	2.39	2.36	2.82	1.66
LANG	3.05	2.71	2.00	2.41	2.50	1.87
HIST	3.20	3.44	3.25	3.03	3.50	2.40
HUM	7.01	7.11	6.08	7.26	8.88	6.41
MATH	5.45	4.58	4.01	3.94	4.32	3.73
M E	2.76	2.32	2.17	2.24	2.14	1.63
PHYS	1.73	1.83	1.53	1.21	1.62	1.39
RAC	2.25	2.09	2.33	1.97	1.06	1.70
P E	1.04	0.98	1.04	0.95	1.12	0.85
TOTAL	57.12	50.71	48.07	47.09	50.07	41.22

TABLE XVII

Comparison of actual and calculated expenditures for instructional salaries by department for the first semester of 1972, 1973, and 1974.

	1972		1973		1974	
Dept.	Actual	Calculated	Actual	Calculated	Actual	Calculated
BIOL	17957.44	27682.73	16256.16	32720.61	16021.00	29542.89
BUS	42410.10	33435.36	39125.42	35594.90	44888.58	36457.93
CHEM	29475.87	20440.65	22840.11	23291.18	25456.64	24036.09
CH E	10350.90	3482.27	9658.88	3943.12	7645.24	2411.45
C E	14775.71	14549.50	10680.72	14836.20	7921.38	8736.92
ENGR	24996.24	14718.68	14897.10	13299.94	16556.40	14369.25
ENG	24092.55	25634.17	24091.83	25100.39	20299.42	22185.54
EDUC	6674.89	5532.58	5476.17	4600.50	8394.81	4325.98
E E	25458.42	18336.73	18134.45	15770.81	21540.35	12736.06
LANG	10236.24	12220.70	7460.64	11650.21	10013.31	9697.93
HIST	18523.80	21088.02	18190.08	19397.20	16144.44	16827.37
HUM	34381.26	15173.77	29928.00	15553.28	41870.24	14118.50
MATH	34613.62	32995.75	25945.08	30406.89	28886.49	29656.02
M E	20781.39	16200.04	18089.90	17119.52	16644.72	13017.69
PHYS	10445.80	10600.14	11792.56	7892.19	12664.62	9221.63
RAC	11793.60	11870.91	12198.55	12383.65	4283.52	11834.03
P E	622.96	3363.20	5411.30	3644.96	6495.30	3729.43
TOTAL	343194.79	287625.19	290176.96	287205.54	305726.46	262904.70

large number of courses were opened in the department of Humanities (HUM) beginning in 1972. Such changes were accounted for in the induced course load matrix prepared from 1971 registration data. Also, beginning in 1973, the department of Religion and Culture (RAC) began to be phased out, with many of its courses being placed in the department of Humanities. This explained the small number of actual student credit hours taken in the department of Religion and Culture compared to the large number predicted to be taken in that department.

Another fact that had to be taken into consideration in the interpretation of the predicted values related to departments with a small output in terms of student credit hours. A typical case in point was Chemical Engineering (CH E). With only a few majors requiring a small number of student credit hours, a very small faculty was predicted. However, those student credit hours were produced in a number of courses of small enrollment, rather than in the one or two indicated by the total number of student credit hours. For this reason, the actual number of faculty was quite a bit larger than that which was predicted. The use of part time instructors in some departments also caused some inaccuracies in faculty salaries.

The usefulness of the prediction phase of the model was, of course, limited by these various sources of

inaccurate predictions. However, if these considerations were kept in mind, it was felt that there were sufficient uses for the predictive phase. These included a study of the effects of increasing incoming Freshmen enrollment by various amounts and studies of the effects over time of closing out certain majors. When the results were interpreted in light of the assumptions made in constructing the model, those results were found to be sufficiently valid.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to develop a computerized model of a college that could be used by administrators as a tool in analyzing the expenditures for classroom instruction. In addition to supplying a method for studying these expenditures for a given term, the programs developed were to be able to predict possible future values based on assumptions supplied to the model. The programs to be developed were to be capable of running on the on-campus computer in order to make the model more accessible to the administrators as well as to avoid the expense of renting computer time from a service bureau.

The model was deliberately limited to the budgetary line item for classroom instruction. This line item comprised approximately fifty percent of the total budget. The objective of developing this particular model was to be able to study, in as much detail as possible, how this expenditure was spread out among the various instructional departments and major fields so that the college administrators would have a clearer understanding of just where the money was spent.

The mathematical model along with the computer programs and illustrative output presented in the previous chapters indicate that this was a feasible undertaking. The descriptive phase of the model was operated using data for several past years, and the output examined to determine its correctness. Using historical data, the predictive phase of the model was tested. In addition, certain predictions involving future needs or plans were obtained. As a result of the work involved in developing the model and of the examination of the various results, certain conclusions and recommendations for further work will be listed below.

I. CONCLUSIONS

The following conclusions are given as a result of the development and running of the models:

1. The output of the descriptive phase of the model was judged to be more useful than that of the predictive phase. The description of expenditures for student credit hours by instructional department and major field was found very helpful to the college administrators and heads of departments. Comparisons of results for several years lead to the discovery of trends which were then utilized in making plans for the future.

2. The predictive phase of the model did not turn out results as accurately as had been foreseen when the study

was undertaken. There were several reasons for this. For one, the enrollment in many fields was small and varying. This made it difficult to prepare accurate forecasts. Secondly, the induced course load matrix was not as stable as desirable in making accurate predictions. Finally, faculty productivity was assumed constant over the period of years, and this turned out not to be correct in several departments.

In addition to these conclusions, the following cautions with regard to using such data will be reiterated.

1. While there are many valid reasons for examining college expenditures in the amount of detail illustrated in this study, administrators who make use of such figures must keep in mind the assumptions and processes used to obtain these figures. Student credit hours are easy to obtain and are one of the most readily quantifiable of college outputs. They should not, however, be considered as the only or the most important output of a college. Those who make use of such figures as those developed in the various phases of the model must be careful to put them in their proper perspective.

2. Even when the figures produced are accurate, it may not always be expedient to use them at their face value. The most efficient departments in terms of student credit hours are not necessarily the most effective in terms of the

education of the students. Consequently, administrators should not close out departments based on these numerical results alone.

II. RECOMMENDATIONS FOR FURTHER STUDY

1. In preparing the induced course load matrix, the identity of the various classes is lost. A study should be made to determine the feasibility of collecting and utilizing registration data at the level of the course section rather than at the departmental level as was done in this study.

2. Average faculty salaries as used in the study were not found to be extremely accurate. Large models incorporate salaries according to rank and department. However, departments in small colleges are too small to utilize this method. A study should be made to determine if there is some better method of moving salaries from one prediction period to the next.

3. Since the induced course load matrix was found to be somewhat unstable, a study should be made to determine a method of forming a generalized matrix that would have stable characteristics. Another possibility would be to examine methods for adjusting the induced course load matrix as it is moved through various periods.

4. The use of faculty productivity in determining the number of faculty needed did not take into account the number or size of course sections. A study should be made to determine the feasibility of incorporating these variables into the model.

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VITA

Jerome David Wegener was born in St. Louis, Missouri, on January 22, 1929. He attended elementary school in University City, a suburb of St. Louis. He received his high school diploma in 1946 from La Salle Institute, Glencoe, Missouri. On graduation from high school, he joined the teaching order of the Brothers of the Christian Schools. The Christian Brothers are a Roman Catholic order with some 20,000 members worldwide.

He received a B. S. degree in Physical Science from St. Mary's College, Winona, Minnesota, in 1950. He taught for a number of years in high schools in Chicago and other midwestern cities. During the summers, he attended graduate school and received a Master of Arts for Teachers degree from St. Mary's College in 1958. At that time, he joined the staff of Christian Brothers College, Memphis, Tennessee.

While teaching at Christian Brothers College, he attended National Science Foundation Summer Institutes at St. Louis University, Louisiana State University, Columbia University, Manhattan College, and Fordham University. In 1966, he entered the University of Tennessee-Memphis State Center for Advanced Graduate Studies in Education. He attended classes at the Knoxville campus in 1970-71 which

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His publications include three articles published in Theoretica chimica Acta for which he was a coauthor, and several papers presented at meeting of COMMON, a computer users' organization. He is a member of the honor society of Phi Kappa Phi, and of the following professional organizations: American Association of Physics Teachers, American Association for Higher Education, American Association of Collegiate Registrars and Admissions Officers, and the Association for Institutional Research.