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The basic prototype model presented in this report simulates the impact of federal, state, and private funding programs by using differential dynamic programming to construct a 5-year operating plan for several classes of institutions. The institutional supply of spaces for students is identified by these operating plans for each of the classes of institutions; and the interaction of the institutional supply with the student demand (generated in a stochastic choice section of the model) produces calculations of students enrolled, empty spaces, unsatisfied demand, financial conditions, and faculty levels of each group of institutions. This report concludes with a discussion of the research necessary to transform the prototype model into a fully developed analytic tool for federal educational policy analysis. (Author)

A DESIGN FOR A FEDERAL PLANNING MODEL FOR ANALYSIS OF ACCESSIBILITY TO HIGHER EDUCATION

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1973

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ABSTRACT

This report presents the results of an initial research effort in the development of a comprehensive national planning model for higher education. The design of the prototype model discussed in this report is based on existing or derivable institutional and student data and is designed to permit prototype planning studies to examine the impact of alternative federal programs on accessibility and, to a lesser extent, on institutional viability. The model also will assist in identifying high-payoff areas of future research necessary for the development of a comprehensive planning model and the additional data requirements of such a model.

The basic prototype model simulates the impact of federal, state, and private funding programs by using differential dynamic programming to construct a five-year operating plan for several classes of institutions. The institutional supply of spaces for students is identified by these operating plans for each of the classes of institutions; and the interaction of the institutional supply with the student demand (generated in a stochastic choice section of the model) produces calculations of students enrolled, empty spaces, unsatisfied demand, financial conditions, and faculty levels of each group of institutions. This report concludes with a discussion of the research necessary to transform

the prototype model into a fully developed analytic tool for federal educational policy analysis.

PREFACE

This report was developed by Vaughn Huckfeldt and Dr. Wayne Kirschling of the NCHEMS research and development staff and Dr. George Weathersby, formerly of the Office of Analytic Studies at the University of California, as a result of research efforts funded by the U.S. Office of Education. Comments on the prototype federal model for analysis of accessibility to higher education were received from the National Planning Committee of the NCHEMS Technical Council.

This report is released in order to provide a comprehensive review of the design of the prototype model, including its assumptions, mathematical formulations, suggested data sources, and summary output report. The model in the current state of development will permit prototype planning studies, do research on the model capabilities, and assist in the identification of high-payoff areas of research necessary for the further development of a more comprehensive planning model. The model is designed for use by the Office of Program Planning and Evaluation in the U.S. Office of Education, research agencies interested in national policy studies, and research agencies interested in planning models for higher education.

The model should not be used without due consideration given to design assumptions, limitations on data reliability, and the fact that the model has not been pilot-tested. Consideration should also be given to the fact that the prototype model is not a comprehensive national planning model, since it provides only for analysis of accessibility to higher education. This report and the prototype model software are being released as Type II NCHEMS software (not supported or guaranteed) and, depending on additional funding, may be replaced within one year by an improved prototype that has been fully pilot-tested, includes a complete user's manual, and has improved data. The model data should be updated at least yearly. The model describes terms necessary for national planning but does not attempt to set national standards on these terms.

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CHAPTER I

INTRODUCTION

Comprehensive federal planning in higher education is a relatively recent development in the United States, dating from the increased commitment and involvement of the federal government to financing higher education through the 1963 Higher Education Facilities Act, the 1965 Omnibus Higher Education Act, and the recent 1972 Higher Education Act. Although state and private sources contribute the vast majority of the resources used in higher education, the federal role has become quite significant in the areas of student finance, facilities funding, developing institutions, and programmatic research.

In this paper a conceptual framework is presented that will be useful in analyzing and evaluating federal programs in higher education, in particular the extent to which alternative federal financing plans accomplish national objectives such as increased student accessibility to higher education. Furthermore, the design of a prototype model that represents the complex interaction of institutional decision making, student decision making, and governmental programs is presented, which ultimately will enable federal planners to examine the effectiveness and efficiency of alternative federal programs in higher education. The immediate products of this investigation are specification of data that need to be collected, the identification of basic research that needs to be conducted before all of the necessary relationships will be identified, and a prototype planning model that illustrates the feasibility of analytic investigations of alternative federal programs.

Relevant Literature

The formulation and testing of national educational planning models in other countries has preceded developments in the United States. Although none of these models is directly applicable to federal educational planning in this country, they do provide valuable insight and experience. Tinbergen and Bos (1964) developed a planning model for the educational requirements of economic development that set the pattern for many subsequent model developments. Their objective was to derive manpower requirements for balanced economic growth over an extended time period. Their model was very macro, with seven variables in its simplest form. Tinbergen and Bos assumed that a federal government could decide upon and enforce secondary and postsecondary enrollments to achieve the appropriate skill-level mix in the labor force with the necessary time lags. They included no differentiation of students by any socioeconomic characteristics and assumed that all institutions were equivalent at each level.

Correa (1969) was involved with Tinbergen and Bos in their efforts and amplified their approach into a comprehensive view of educational planning for economic growth. Correa's models are much more complex and sophisticated than the earlier work, but they still make the same assumptions: economic growth is the major objective of education, and the federal government controls all educational institutions and students sufficiently to specify enrollments by level. Correa also includes extensive calculations for the supply and demand for teachers as an integral part of educational planning. The feedback role for teachers is included in most recent macro educational planning models.

Nordell (1967) developed an input-output formulation of the California educational system, including teacher feedback. Bolt, Koltun, and Levine (1965) modeled doctoral feedback into higher education through the solution of simultaneous difference equations. Reisman (1966) extended the Bolt, Koltun, and Levine model by taking into account the different levels of the educational system. Reisman and Taft (1969) extended Reisman's model by incorporating flows to and from foreign countries and socioeconomic costs.

Although Tinbergen, Bos, and Correa dealt primarily with developing nations, there are some examples of similar efforts applied to more developed countries. Armitage and Smith (1967) described what was essentially a student flow model of the British educational system. The purpose of their model was to forecast student enrollments to meet manpower targets. The points of policy intervention were ceilings placed on university enrollments and targets specified for manpower needs. Once again, they assumed perfect governmental control over enrollments.

Returning to developing countries, Bowles (1969) developed a dynamic linear programming model to maximize economic growth as measured by discounted incremental lifetime earnings by specifying optimal enrollments from primary to postsecondary levels. He applied his model to the Nigerian and Greek educational systems. Golladay (1968) constructed an input-output model for the educational system in Morocco. Kleindorfer and Roy (1969) applied a Markovian flow model to enrollment planning in Pakistan. The Swedish Central Bureau of Statistics (1967) and UNESCO (1970) have developed linear resource projection models oriented towards student flows and manpower requirements. Optimizing models have been proposed for France by Bernard (1967) and for Germany by von Weizsaecker (1967). Several manpower planning models that are specifically directed to obtaining optimum analytic solutions have been developed by Balinsky (1970).

However, none of these efforts really addresses the issues central to this study. American higher education is much more complex, the power to decide and authority are more diffuse, institutions and students are more diverse than ever conceptualized in these earlier models. The federal government has multiple objectives and, with some exception (in graduate and professional schools), manpower "requirements" are rarely a dominant objective. Academic and socioeconomic characteristics of students and student bodies are a vital concern of federal policy makers. Government sets incentives and not enrollments; it enables and supports rather than controls institutions. The next section describes and documents the concerns of members of Congress and educational administrators relative to national-level planning for higher education.

Higher Education Priorities

The Higher Education Research and Development (HERD) group (Berkeley) presented a joint report to the National Institute for Education specifying fifteen research priorities for higher education as of April 1972. The issue of central concern to this NCHEMS study was listed by the HERD group as one of the priority research items:

> Student Access and Distribution is concerned with the problems of the access of various potential student populations to the diversity of postsecondary institutions and agencies of education. The dimensions of the problem for students include their decision processes and information sources for selecting postsecondary opportunities and the societal forces that lead to or away from particular types of opportunities. Student populations of particular concern are low income students, moderate and low ability groups, women, and minorities. Problems for policy planning at institutions at state and national levels relate to making access available, creating information systems, encouraging rational student choices, stimulating the development of new and appropriate programs for particular student populations. . . . Little research is being done on policy planning on the whole subject of access and implementation and evaluation programs.

The statement that student access is currently a major goal at the federal level is documented in the mandate by Congress to the National Commission on the Financing of Postseconday Education in Public Law 92-318, Section 140:

> Sec. 140(a)(1). It is the purpose of this section to authorize a study of the impact of past, present, and anticipated private, local, State and Federal support for postsecondary education. . . . Such study shall include at least (A) an analysis of the existing programs of aid to institutions of higher education, various alternative proposals presented to the Congress to provide assistance to institutions of higher education, as well as other viable alternatives which, in the judgment of the Commission, merit inclusion in such a study; (B) the costs, advantages and disadvantages, and the extent to which each would advance the national goal of making postsecondary education accessible to all individuals. . . . The Commission shall make a final report to the President and Congress on the results of the investigation and study authorized by this section, together with such findings and recommendations, including recommendations for legislation.

Student access is certainly not the only major educational goal at the federal level. For example, the National Finance Commission has specified the major federal educational goals as accessibility, quality, and diversity.

A comprehensive National Planning Model would provide a simultaneous analysis in all of these areas, but the available project funding and limitations on modeling techniques and the availability of data for all of these areas have necessarily limited the scope of the present study. Student access to higher education was selected as the initial area to be studied. Accessibility for students has different meanings for different people. For example, accessibility can mean access to admission, access to continued participation and success in higher education, or access to a degree or certification. None of the previous models addresses any of these three types of accessibility. The prototype design developed here considers only the initial question of accessibility to admission to higher education. This initial effort is therefore only one step in the direction of a comprehensive National Planning Model for higher education.

CHAPTER II

MODEL CONCEPTS AND DESIGN

Background

The federal government has identified a number of important objectives for postsecondary education in the United States and attempts to allocate its available resources in a manner which best achieves these objectives. The purpose of the federal role in education is divided into the broad categories of increasing equality of access, improving the quality of education, or enhancing the diversity of higher education opportunities. While these phrases are emotionally and politically appealing, a major analytical development will be required before they become operational. The purpose of this section is to present one way this analysis might proceed with respect to one of the major federal objectives: improved equality of access.

Unlike other national educational planning models, the proposed model does not assume that the federal govenment allocates students or faculty to institutions. In the United States the role of the federal government is indirect, working through various general and categorical aid programs for institutions and many forms of student aid. Nor does the federal government fiscally dominate American postsecondary education; it provides only about 10 percent of the total resources devoted to institutions and students. However, the federal role is significant because it is the largest single financial supporter of postsecondary education and the only public agent with national responsibilities. The individual states collectively bear the major costs and make the majority of public decisions, but they, too, work through institutional governing boards and through individual students.

The global interaction of the federal and state governments, institutions, and individuals is seen as a complex pattern of very complicated microdecisions which can be abstracted in the following manner (see Figure 1). Congress establishes and federal agencies administer various institutional aid programs that provide financial incentives to groups of institutions through such legislation as the Developing Institutions Act, Educational Professional Development Act, and Higher Education Facilities Act. State governments also establish institutional support programs, many on a per student basis.* In response

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*See Kirschling and Postweiler (1971) for a discussion of alternative federal funding schemes and the interaction of federal and state support decisions. In this model, we do not consider the impact of federal support decisions on state support decisions.

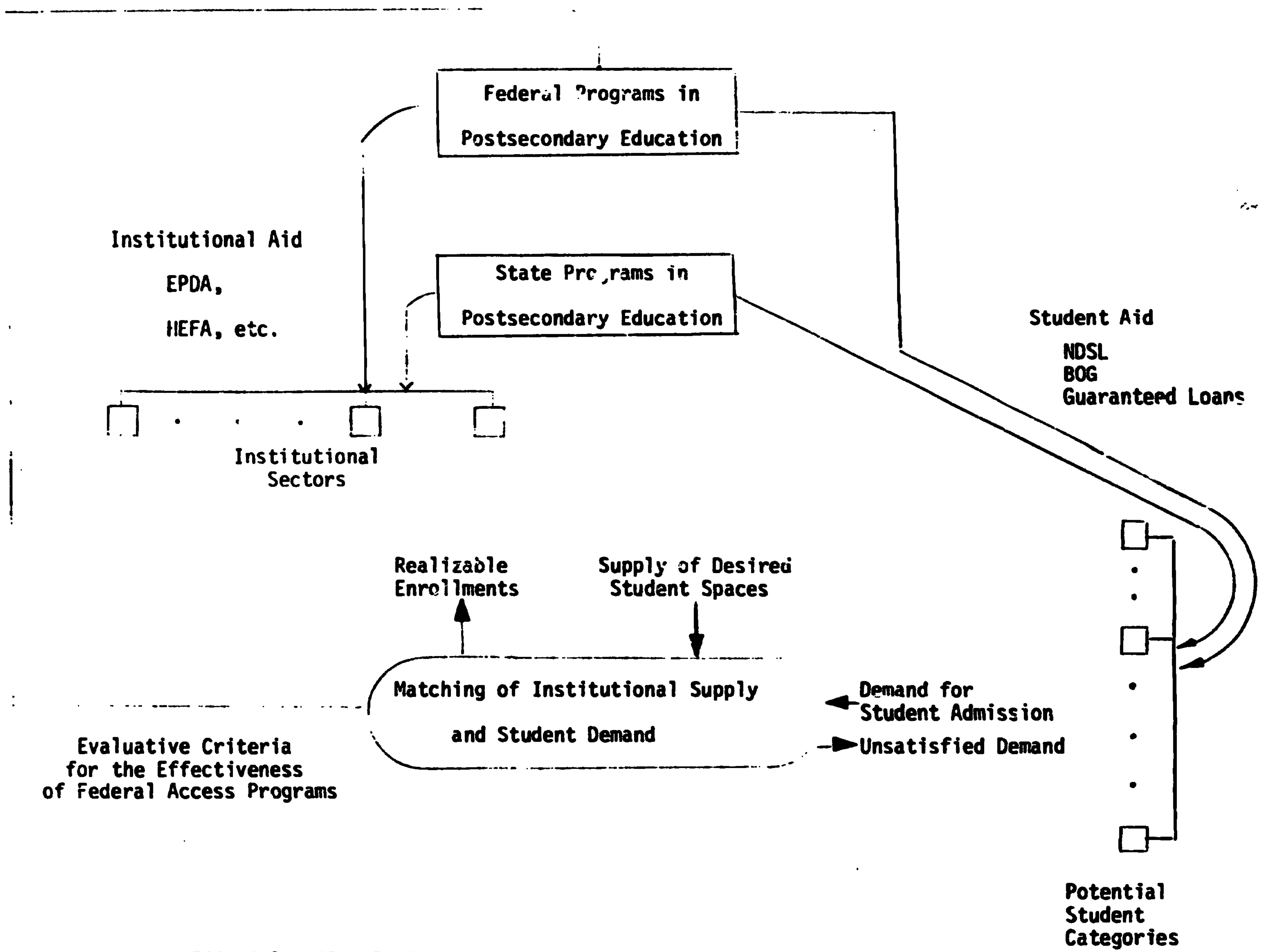

FIGURE 1. Global View of Postsecondary Decision Making in the U.S. and the Federal Role in Affecting Student Access

to these external incentives and consistent with their internal goals and objectives, institutions allocate resources by hiring new faculty members, providing academic support, admitting and providing financial aid to students, constructing new facilities, and undertaking various projects of research and public service. One consequence of these decisions is that institutions desire to admit a mix of students by ability, income, and other student characteristics.

Meanwhile, federal and state governments offer financial incentives for individuals to attend postsecondary education. In particular, the federal government provides veterans' benefits, social security survivors' benefits, National Defense Student Loans, guaranteed student loans, Basic Opportunity Grants, numerous categorical fellowships, and other student aid funds. In response to governmental and institutional financial support and various social characteristics of educational institutions, and cognizant of alternative options in employment, the military, and elsewhere, various types of individuals actively seek admission to different institutions.

The matching of institutional desires for students, i.e., the supply of student places, with individual demands for admission as students is a very complicated market which operates on far more than purely economic information. However, the effect of this matching process is to determine (1) realizable enrollments for the different institutional sectors, (2) a measure of unsatisfied admissions demand by categories of individuals, and (3) some evaluative measures of the effectiveness of federal programs to improve access to postsecondary education. These evaluative measures then feed back into the federal decision process for the selection of programs to support in the next year. This entire process can be repeated for several forecasted years into the future.

With over 2,500 institutions, nearly nine million students, and approximately 306,000 faculty, postsecondary education is much more complex than suggested by Figure 1. There are many forces, from students, faculty, alumni, politicians, donors, and critics, that tug at an institution's fabric, and many of the organizational and governance questions raised by these forces have been addressed in the literature of postsecondary education. Although these organizational and psychological factors are recognized, the model design assumes they remain constant and does not include them, because the focus of this analysis is the federal role in influencing institutions and students in such a way that, when both act in their own best interests, the consequences are those desired by federal policy planners. Therefore, the model design attempts to include only those variables which are (1) affected by government policy instruments, or (2) direct measures of equality of student access. The choice of this formulation has led to a number of design considerations, which are described in the next section.

Design Considerations

A number of studies attempting large-scale model development have failed to produce lasting results because they sought only the optimum model without sufficient consideration of data availability and the current research state of the art. A statement of the problem-solving philosophy which has influenced the development process of this model would be different: <u>It is better to begin with a rough approximation of a solution to an important policy problem and seek to improve it than to search for the optimum solution before beginning</u>. While data requirements have been restricted to those elements that are currently feasible if not readily available, the model includes a sufficient level of detail to incorporate the next generation of data collection. At the present time, the many operational assumptions made are described as they occur in the text to provide a working prototype model that can be refined and improved both analytically and empirically over the coming years.

Student access is the major federal objective under investigation. However, the prototype model formulation also gives attention to institutional financial viability (that is, the ability of the institution to survive with a given level of federal aid), faculty staffing needs, construction needs, and the effectiveness of alternative institutional support programs. The concept of "needs" employed in the model is the economic demand function incorporating prices, preferences, and fiscal constraints.

Institutions can be meaningfully grouped as shown in Table 1. The bases of this grouping are: (1) those institutions which follow similar objectives, e.g., doctoral research universities or highly selective liberal arts schools, and (2) those schools which use similar instructional resources in similar patterns (production functions). Essentially, these sectors are the Carnegie categories with some very small categories eliminated and three developing institution categories added. In the past these categories have been established largely by arbitrary judgment, but sufficient evidence is becoming available to shed some light on both criteria. The ETS Institutional Goals Survey described by Uhl (1971) and similar instruments can give a profile of institutional objectives which could be matched for similar institutions. Recent work by Carlson (1972) on the estimation of institutional production functions lends

TABLE 1

LIST OF INSTITUTIONAL GROUPS
USED IN THE PROTOTYPE MODEL DESIGN

1. Developing Two-Year Public Institutions
2. Public Two-Year Institutions
3. Private Two-Year Institutions
4. Developing Public Universities or Colleges
5. Developing Private Universities or Colleges
6. Public Liberal Arts Institutions
7. Private Liberal Arts Institutions
8. Highly Selective Private Liberal Arts Institutions
9. Public Comprehensive Colleges
10. Private Comprehensive Colleges
11. Public Doctoral Research Universities
12. Private Doctoral Research Universities

some evidence to the appropriateness of the Carnegie categories. More research certainly needs to be done, but at the current time this design assumption seems quite supportable.

Individuals who are potential students may be grouped as shown in Table 2. Many attributes other than those of Table 2 are of interest to federal policy makers, e. ., age, sex, race, state of origin and attendance, full-time or part-time, and possibly highest previous deg'ee, but data on all of these variables are very difficult to obtain in sufficient detail to be meaningful for policy analysis. The needed student demand and progression parameters are available for the categories shown in Table 2, and income, ability, and level seem to characterize the macroview of equality of student access reasonably well.

TABLE 2

LIST OF CATEGORIES FOR POTENTIAL STUDENTS
USED IN THE PROTOTYPE MODEL DESIGN

Student Level :	Lower Division, Upper Division, Graduate
Family Income :	Relative Quartiles
Student Ability:	Relative Quartiles of Verbal SAT Scores

Federal financing programs can be grouped into a set of generic types of federal aid programs. To build in all of the specific requirements of each and every possible program for aiding students or institutions would only provide a model that would require modification as new programs are considered. Assigning specific programs such as Basic Opportunity Grants to a generic type of aid (federal grants per student) permits the generalized model structure the flexibility of considering many types of aid programs without repetitive modifications to the model. Federal aid to institutions is included in the model by establishing the following generic types of institutional aid: federal construction aid for assignable square feet (ASF) built, federal construction aid per student, federal general aid per student, and federal general aid. In the prototype model, the financial incentives for students from the federal government are grouped into the following generic types: federal grants to students and federal loans to students.

The role of the state governments can be aggregated to represent all states as one state component in the model. This design consideration is enforced because of the limitations of data availability by specific region of the country if groups of states are used in the model, and because of the infeasibly large dimensions required of a model that might consider all states separately. The aggregation of the states is included in the model with generic types of state programs that parallel the federal programs. State aid to institutions is categorized by state construction aid per ASF built, construction aid per student, state general aid per student, and state general aid. State aid to students is categorized by grants to students and loans to students.

Specific disciplines are not included in the current prototype model design. Thus no provision is made for federal programs related to a specific discipline. The National Science Foundation, National Institute of Health, National Foundation on the Arts and Humanities, and National Aeronautics and Space Administration are some of the federal agencies that contribute to specific discipline funding for higher education. In the current prototype design, such programs must be included in one of the generic types of federal aid.

Instruction is the primary institutional component to be included in the prototype model design. The research and public service components of the institution are not to be disregarded; but the accessibility issue at the undergraduate level is tied for the most part to the instruction function of the institution. Although the other components do have a certain impact on accessibility, the current design focuses only on instruction.

The planning horizon for the model should be five years for the institutional component and three years for the federal component. This design concept is specified due to the instability of institutional data beyond a five-year time period. For the federal planning period, several considerations have influenced the selection of a three-year planning period. The time needed for current legislative changes to take effect will always require multiperiod federal-level planning. The political realities of policy changes would seem to negate moving beyond three years. Calculation costs do grow at a nonlinear rate for additional planning years added to both the institutional and federal planning horizons.

Logic Flow of the Model

From the description of the general design and from Figure 1, it is clear that this is a very large model with up to a dozen institutional sectors, thirty-three student categories, and over one hundred generic federal aid categories all acting and interacting at the intersection of student, institutional, and federal decision making. However, not all of these decision makers are equal in authority; some are "more equal" than others, with the state and federal government sectors structuring the environment for institutions, which make decisions that in turn contribute to the environment in which students make decisions that affect the attainment of institutional and governmental objectives. In other words, this interaction is viewed as hierarchical and coupled, although by no means a "system" in the global point of view. Furthermore, the various decision makers have different time horizons over which they are considering their alternatives. Consequently, the federal policy and resource allocation problem implicit in Figure 1 is actually a hierarchical, coupled, multistage, dynamic decision problem which can conceptually be solved in toto, as described in Weathersby (1969).

However, the practical solution of such a large problem is not currently feasible because of data considerations, dimensions of the problem, solution techniques readily available, and the limitation of funds in solving these other problems. The approach used in this analysis is several steps short of the full optimization problem. Essentially, it is a simulation of the effects of alternative federal institutional and student aid policies on the measures of equality of student access in an environment in which institutions allocate their resources in an optimal pattern given their own objectives, which includes students' manifest choices among alternative institutional sectors (and the option of no attendance). The full formulation of Figure 1 would require optimal decision problems for four sectors: (1) federal government, (2) state governments, (3) institutions, and (4) students. In the design of the prototype version of the model reported in this paper, only one optimal decision formulation is included, and that is in the institutional sector. The federal optimization problem has been replaced by a simulation formulation. The state optimization problem has been ignored altogether, because higher education is but one part of state decision problems that also include welfare, health, highways, etc. The state government sector of the model is incl ' in the form of exogenous state dollars flowing into generic types of institutional and student programs. The student optimal choice problem has been reduced to the student's attendance decisi,n function (demand function), relating the student's utility-maximizing choice to personal, institutional, governmental, and environmental variables as described in research by Miller (1971). The result of these decisions is shown in Figure 2.

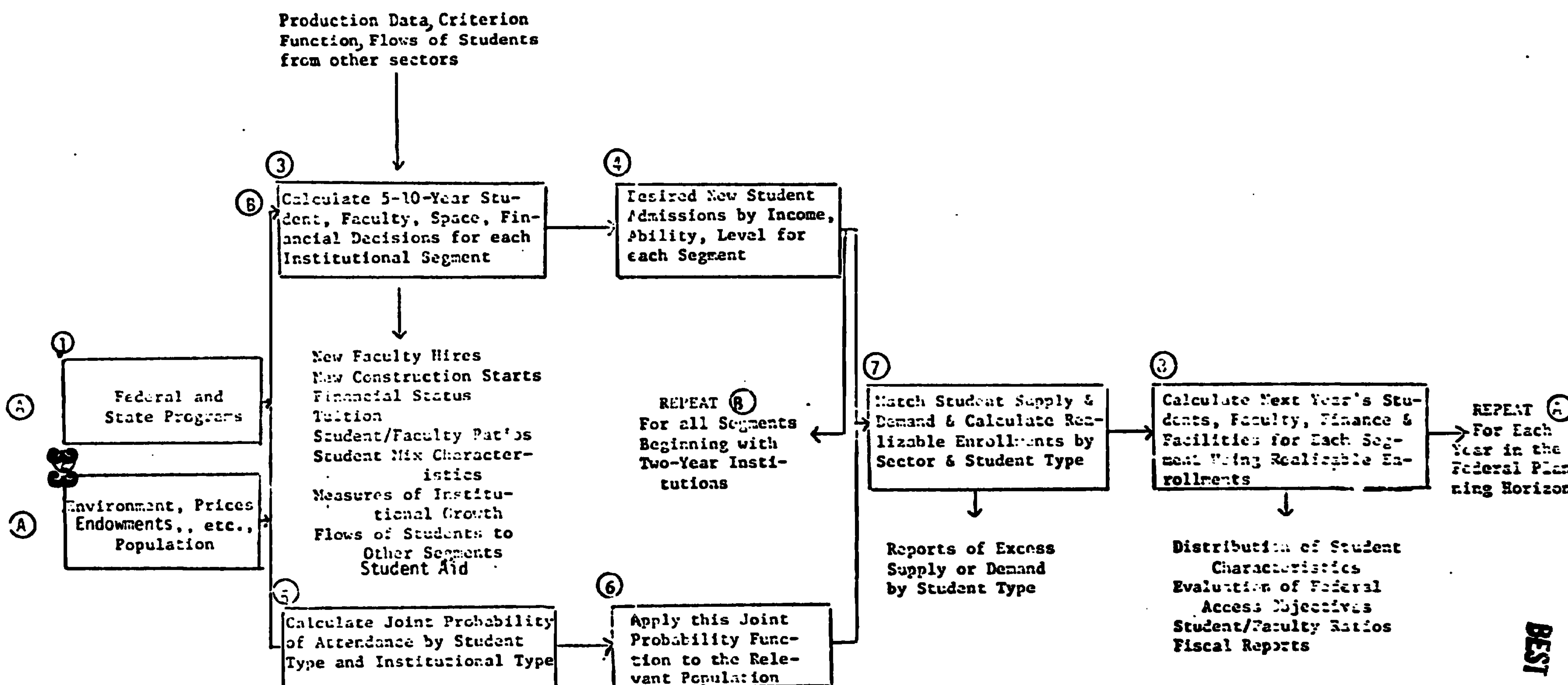

FIGURE 2. The Logic Flow of the Calculations in the Prototype Model

In Figure 2 the boxes represent either policy specification or calculations. External inputs are shown coming into the calculations from above; externally useful outputs are shown coming out below the calculations. The boxes are numbered in the order of the calculations.

For each year in the federal planning horizon, the user specifies the federal policies for support of higher education to be evaluated and specifies the environmental context of state programs, prices, population, endowments, and so forth that will be held constant while varying federal policies (boxes 1 and 2). This enables the prototype model to separate the marginal effects on federal student access objectives induced by changes in federal programs from those induced by state programs or environmental factors, such as the population.

The institutional sectors are represented by boxes 3 and 4 in Figure 2. Box 3 represents the planning and decision making of each sector over a five-year horizon to determine the desired student admissions, faculty recruitment, new construction, tuition, and other measures of the socioeconomic, academic, and financial status of the sector. To make these decisions, institutions in each sector need information on their production relationships, their operational criteria, and the exogenous forces impinging upon them. As explained in detail in a subsequent section, this decision-making process is formulated as a multiperiod optimal dynamic control problem and is solved for each institutional segment over a five-year planning horizon. Box 4 represents one of the outputs of this decision process, the supply of student spaces, indicating the desired new student admissions by income and ability quartiles and by level of student. It is this supply of student spaces that will later be matched with the calculated student demand to determine realizable enrollments. Meanwhile, the calculation in box 3 is repeated for each institutional segment, beginning with two-year institutions because the intersegmental flows of students are assumed to be primarily between two-year and four-year institutions and the four-year institutions must plan on having to accommodate a significant number of upper-division transfers.

Student demand for college attendance is represented by boxes 5 and 6. In box 5 the model calculates the joint probability density of attending each of the institutional types and an alternative of nonattendance for each individual income and ability group based on some of the institutional outputs from box 3, namely, total cost to the student and average enrolled student ability measures. This density function is then applied in box 6 to the population to estimate the potential student demand for admission by sector and by student type.

Potential student demand for admission and institutional supply of student spaces are "matched" in box 7 to determine realizable enrollments for each institutional sector by each student type. This matching process is a key factor in the model.

When demand by student type equals or exceeds the supply of spaces for an institutional sector, all institutionally desired admissions of students of this type are realizable for that type of institution. The difference is recorded as unsatisfied demand for higher education. When demand by student type is less than the supply of spaces for some institutional sectors, the difference is recorded as unsatisfied supply or empty spaces. The mechanics of this process are quite straightforward, requiring no optimization algorithms, and they are described in detail in a subsequent section.

Also contained in the matching process are two additional assumptions: (1) undergraduate admission to a sector occurs at lower-division only except for two-year transfer students, who enter exogenously, noting that all interinstitutional transfers within a sector net out; and (2) graduate admissions are not constrained by demand. This latter assumption is questionable in some academic disciplines, but in the aggregate it appears that graduate enrollments are expanding much more slowly than undergraduate enrollments, and the conscious efforts of many institutions to limit graduate enrollments in response to manpower considerations presages supply-constrained graduate enrollments.*

The outputs of the matching process are realizable enrollments by type of student in each institutional sector and measures of excess supply or demand by student types and by institutional sectors. These latter measures are not very informative student access indices, but they do indicate unfulfilled expectations of both students and institutions.

However, the realizable enrollments are very important because, as shown in box 8, they are used to calculate the student body and institutional characteristics that would most likely result under the combined federal, state, and institutional decisions. It is at this point that one can meaningfully evaluate the effectiveness of federal access policies, and these forcasted

*For a discussion of graduate enrollments and academic labor demand see Dean, Reisman, and Rattner (1971) and Balderston and Radner (1972).

student and institutional characteristics are the foundation for the consideration of federal policies in the next planning year. Steps 1 through 8 are repeated for each year in the federal planning horizon.

This concludes the discussion of the logic of the calculations employed in the prototype model. There follows a discussion of the analytical descriptions of the government, institutional, and student components of the model.

CHAPTER III

ANALYTIC DESCRIPTION

Government Sectors

The broad conceptualization shown in Figure 1 identified two autonomous government sectors, federal and state. For the purposes of this prototype model, no attempt has been made to formalize the interaction of federal policies and state policies. Although federal programs often create incentives which affect state decisions, and revenue sharing is only the most obvious direct federal subsidy program, the choice was made to experiment with separate but parallel state and federal policy instruments. This implies perfect substitutability between state and federal support programs, which may not be true if the recipients perceive greater uncertainty about future support levels from one source or the other.

The government policy instruments are primarily resource subsidy programs channeled through various incentive schemes. Table 3 lists the government policy variables included in the institutional and student sectors of the model. Government subsidies on a per student basis, either institutional- or student-based, can be differentiated by level, income, and

TABLE 3

GOVERNMENT POLICY VARIABLES

Component	Policy Variables
Institutional Sectors	Subsidy per student General operating assistance Subsidy per assignable space built General capital assistance
Student Sector	Student aid per student

ability of student, which means that this model can simulate the access effectiveness of subsidy programs in significant detail to identify target populations and to explore realistic program specifications. Similarly, subsidies per new net assignable square feet constructed are by type of space, allowing some programmatic emphasis in capital support programs. Thus, the government sectors of the model contain only the financial aid dollars to the institutions and students, which result from interactions within an extensive bureaucratic system of decision making. This extensive governmental system does contain the flows of information, manpower, facilities, and governmental objectives that influence the decisions on specific financial aid packages, but such components are not included in the current model.

Institutional Sector Models

When considering the variables which characterize the institutional sectors, it is important to distinguish between the policy or control variables available to the institutions on the one hand and the externally and internally determined variables on the other hand. The control variables are those elements of the institutions that a decision maker can literally control or specify. Any operational policies must be expressed in terms of these control variables to be meaningful. In some areas of concern there may be no control variables, or, upon careful quantitative investigation, a decision maker may find that the presumed control variables have little or no effect on the institution. This analysis then provides the foundation for further administrative investigation and possible legislative changes that would enable the decision maker to have greater impact.

It is also important to recognize the externally imposed exogenous variables that affect the operation of the institution and partially influence the achievement of a decision maker's objectives. Market demand for college graduates, resource prices, and family socioeconomic characteristics are all examples of variables that are largely exogenous to higher education. Finally, one should identify the internally determined endogenous or state variables which describe the remaining salient characteristics of the institution. In general, all measures of the stocks of people and facilities and the financial flows of the educational systems are endogenous variables. Figure 3 illustrates some of the variables used in the institutional sectors of the prototype model. The next four subsections describe in detail the faculty, facilities, students, and finances in institutional sectors of the model.

Institutional State Variables Next Period	Current Institutional Variables			Federal Control Variables
	State	Control	Exogenous	
$X_i(t+1)$ $i=1,---,4$ # of faculty by rank.	$X_i(t)$	$U_j(t)$ $j=1,---,4$ # of new hires		
$X_i(t+1)$ $i=5,---,12$ # ASF in physical facility by type.	$X_i(t)$	$U_j(t-3)$ $j=5,6$ ASF new construction started		
$X_i(t+1)$ $i=13,---,45$ # of students by level, income, ability.	$X_i(t)$	$U_j(t)$ $j=7,---,23$ # of new students admitted	$Z_k(t)$ $k=1,---,16$ # of transfer students to upper division	
$X_i(t+1)$ $i=46,---,49$ Net cash balance	$X_i(t)$	$U_j(t)$ $j=24,---,38$ Endowment spent Student aid Tuition		Q_i, $i=1,---,43$ Z_i, $i=17,---,20$ \$/Student Block Grants HEFA Subsidies

FIGURE 3. Example of Variables in Institutional Sector

Faculty in the Institutions

Faculty members are the major resource of most institutions. The direct and indirect costs of the faculty account for over half the total cost of operating most higher education insitutions. Furthermore, faculty hiring decisions have long-run consequences because of tenure and multiyear contracts. Although perhaps the most important classification of faculty for an institution is by academic specialties, we have not included any disciplinary distinctions because: (1) the federal objective addressed is access and not manpower; (2) to be truly informative, the disciplinary classification would have to be far more extensive than the 33 frequently used HEGIS categories and the dimensionality of the model would become infeasibly large; and (3) consequently, we have assumed that the cost-related differences, e.g., science vs. nonscience, will remain in the current proportion during the federal and institutional planning periods.

With these caveats, the faculty retention and promotion relationship is written as:*

*See Rowe, Wagner, and Weathersby (1970) for a full discussion and analysis of this formulation and for references to the literature.

$$X_i(t+1) = F_{i,j}X_i(t) + G_{i,j}U_i(t \quad \begin{matrix} i=1,---,4; \; t = 0, 1, 2, \ldots, n \\ j=1,---,4 \end{matrix}$$

where

$X_i(t)$	=	the state vector of faculty in an institutional sector continuing at time t categorized by rank i: instructor, assistant professor, associate professor, and full professor (or equivalent ranks)
$U_i(t)$	=	the control vector of newly hired faculty in an institutional sector at time t who are also categorized by rank i
$F_{i,j}$	=	the retention and promotion probability matrix from rank j to rank i for faculty in an institutional sector where the probability matrix is assumed constant for all relevant periods
$G_{i,j}$	=	the retention and promotion matrix of probabilities from rank j to rank i for a faculty member hired at time t
n	=	the number of future periods in the institutional sector's planning horizon where t=0 is the current period

This is a very simple semi-Markov flow equation that has been used extensively in other institutional models.* The coefficients of $F_{i,j}$ can be estimated in a variety of ways; there is the assumption but little evidence of the constancy of $F_{i,j}$; and $G_{i,j}$ is usually taken to be an identity matrix except in rapidly growing institutions in tight labor markets--hardly a description of the situation today. The prototype model implicitly assumes that the supply of potential faculty members is always greater than the demand at the current salary rates, i.e., perfectly elastic supply, which seems a very good assumption for the coming years.

Physical Facilities in the Institutions

Institutional physical facilities are very paradoxical resources. Because of their high visibility they often precipitate controversy over location, design, naming, etc., and great anguish over their high costs; yet relative to operating costs, capital is a minor cost. Many people think of physical facilities as primarily classrooms and student laboratories when in fact these rarely comprise more than 15 percent of an institution's space.

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*See Weathersby and Weinstein (1970) and Wagner and Weathersby (1972).

Capital investments are long-run decisions yielding long-run services but are funded on a cash-flow basis. To a layman, physical facilities almost always seem underutilized, but increased space utilization frequently costs far more in increased operating expenditures than it saves in capital requirements, as shown in Smith and Wagner (1972). Space is often viewed as a major constraint, but, especially in the aggregate, it is rarely a binding constraint.

Paradoxically or not, physical facilities occupy a prominent place in planning in postsecondary education and in federal institutional support programs and are, therefore, explicitly included in the prototype model. The prototype model distinguishes between instructional and support space and between space currently available for use and that under construction. An average construction time of four years from initial planning to final occupancy is assumed. Thus, the intertemporal relationship for physical facilities can be written as:

$$X_i(t+1) = F_{i,j}X_i(t) + G_{i,j}U_i(t) \quad \begin{matrix} i=5,---,12; \; t = 0, 1, 2, \ldots, n \\ j=5,---,12 \end{matrix}$$

where

$X_i(t)$ = the state vector of assignable square feet both available and under construction in an institutional sector at time t, including both instructional and support space

$U_i(t)$ = the control vector of assignable square feet for which construction begins in sector i in year t with the space available for use in year t+4, by type of space

$F_{i,j}$ = the aging matrix for space, which accounts for both work-in-process and depreciation

$G_{i,j}$ = the control impact matrix, which channels the new construction into the appropriate work-in-process variable and which is the same for all sectors

Students in the Institutions

For each year in the institutional sector's planning horizon, the student vector describes the number of continuing students classified by level, income, and ability. This component of the state variable vector takes up 33 elements because, as shown in Table 2, there are three student levels, four income quartiles, and four ability quartiles (graduate students are not categorized by income and ability). After admission, students can change their level by progressing through the various curricular requirements, but it is assumed that they do not change their income or ability status. Student aid plans reduce the cost of attendance rather than increase family income, and verbal ability is measured most commonly prior to entrance. One desirable expansion of the design would be to extend the student description to separate full-time and part-time students, and at that time transitions will be possible between these categories. This expansion would depend primarily on data availability by these categories.

Thus, the student persistence and promotion relationship is expressed as:*

$$X_i(t+1) = F_{i,j}X_i(t) + G_{i,j}U_i(t) + H_{i,m}Z_k(t) \qquad \begin{array}{l} t = 0, 1, 2, \ldots, n \\ i = 13, ---, 45 \\ j = 13, ---, 45 \\ k = 1, ---, 16 \\ m = 24, ---, 44 \end{array}$$

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*For a recent discussion of student flow models see Lovell (1971).

where

$X_i(t)$ = the state vector of students in an institutional sector at time t characterized by level, income, and ability, where

i = 13, ---, 28 = lower division

= 29, ---, 44 = upper division

= 45 = graduate students

$U_i(t)$ = the control vector of new admissions in an institutional sector at time t who are categorized by level, income, and ability:

i = 7, ---, 22 = lower division admitted

= 23 = graduate students admitted

$Z_k(t)$ = the exogenous vector of transfer students into a four-year institutional sector, the mandatory acceptance of which enables them to enroll at time t; and these students are also classified by level, income, and ability

$F_{i,j}$ = the persistence and promotion (from level j to level i) probability matrix for students in an institutional sector which is assumed constant for all relevant periods

$G_{i,j}$ = the "show-up" persistence and promotion matrix of probabilities that affects the flow of a student of each type admitted to a sector at time t

$H_{i,m}$ = the corresponding show-up matrix for transfer students

As a first approximation $G_{i,j}$ and $H_{i,m}$ can be taken to be identity matrices until some historical sectorial experience is available. The coefficients of the $F_{i,j}$ matrix can be calculated directly from data from two successive terms or years or averaged over several terms and years. Alternatively, if enough years of data are available, a constrained regression problem can be formulated and coefficients estimated by quadratic programming, as shown by Rowe, Wagner, and Weathersby (1970). Finally, average coefficient estimates can be made from longitudinal cohort studies like projects TALENT or SCOPE. The forecasting experience with the USOE enrollment model suggests that, at least in aggregate, the $F_{i,j}$ matrix is reasonably constant.*

The vector of transfer students could be formulated as a matrix of flows from sector i to sector j. However, at this time adequate national data is not available to estimate the coefficients of such a matrix, and therefore only the net flow (in or out)

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*See Pfeferman (1970).

independent of source is included, assuming that the major net flow is from two-year institutions to four-year institutions.

This relatively large degree of detail in the student sector has been included because federal objectives for student access are the major focus of this analysis. The other institutional variables have been included in the prototype model in a more abbreviated form.

Finances

All institutional allocation decisions in the model have associated costs which must be included in determining the annual net cash balance. In addition, most state and federal institutional support policies operate through financial incentives, which appear in the annual net cash balance equation. Consequently, the nexus of institutional planning and federal policies is the net financial condition of each institutional sector. For macroplanning purposes, generic federal policy has been used rather than the plethora of different specialized programs, and consequently subsequent conclusions will apply to the type of federal policy and not its specific administrative arrangements. Finally, the restricted endowment funds, unrestricted endowment funds, capital funds, and operating net cash balance funds are separated because of different private, state, and federal funding programs, but they are recombined in the institutional objective function.

With this introduction the net cash balance equation for each of the accounting funds can be written by showing the term components of each accounting fund. The $F_{i,j}$, $G_{i,j}$, and H_i are control matrix values that channel expenses and revenues into the proper fund, contain the actual cost of a state variable (e.g., $F_{49,1}$ is the average salary of full professors), or the rate of return (h_1 is the rate of return on unrestricted gifts).

Accounting Fund	Terms Used In This Fund	Explanation of Terms
$x_{46}(t+1) =$		Current restricted endowment
	$+ f_{46,46} \cdot x_{46}(t)$	Carryover
	$+ z_{17}(t)$	Restricted gifts
$x_{47}(t+1) =$		Current unrestricted endowment
	$+ f_{47,47} \cdot x_{47}(t)$	Carryover
	$+ h_1 \cdot z_{18}(t)$	Unrestricted gifts
	$+ g_{47,24} \cdot u_{24}(t)$	Gifts spent on construction
	$+ g_{47,25} \cdot u_{25}(t)$	Gifts spent on operation

Accounting Fund	Terms Used In This Fund	Explanation of Terms
$x_{48}(t+1) =$		Net cash balance construction
	$+ \sum_{5}^{7} f_{48,j} \cdot x_j(t)$	Cost of construction of instructional
	$+ \sum_{9}^{11} f_{48,j} \cdot x_j(t)$	Cost of noninstructional construction in progress
	$+ g_{48,5} \cdot u_5(t)$	Cost for new ASF begun (instructional)
	$+ g_{48,6} \cdot u_6(t)$	Cost for new ASF begun (noninstructional)
	$+ f_{48,48} \cdot x_{48}(t)$	Carryover
	$+ f_{48,46} \cdot x_{46}(t)$	Return on restricted endowment
	$+ g_{48,26} \cdot u_{26}(t)$	Capital financed
	$+ g_{48,24} \cdot u_{24}(t)$	Gifts allocated to construction
	$+ h_2 \cdot z_{17}$	Return on restricted gifts
	$+ z_{19}$	State construction funds (LUIIP)
	$+ z_{20}$	Federal construction funds (LUMP)
	$+ q_1(u_5(t)+u_6(t))$	State construction funds (ASF)

Accounting Fund	Terms Used In This Fund	Explanation of Terms
	$+ q_2 \cdot (\sum_{7}^{22} u_i(t) + \sum_{13}^{28} x_i(t))$	State construction aid (LD students)
	$+ q_3 \cdot (\sum_{29}^{44} x_i(t) + \sum_{1}^{16} z_i(t))$	State construction aid (UD students)
	$+ q_4 \cdot (u_{23}+x_{45}(t))$	State construction aid (Grad students)
	$+ q_5 \cdot (u_5(t)+u_6(t))$	Federal construction aid (ASF)
	$+ q_6 \cdot (\sum_{7}^{22} u_i(t) + \sum_{13}^{28} x_i(t))$	Federal construction aid (LD students)
	$+ q_7 \cdot (\sum_{29}^{44} x_i(t))$	Federal construction aid (UD students)
	$+ q_8 \cdot (u_{23}(t)+x_{45}(t))$	Federal aid (Grad students)
$x_{49}(t+1) =$		Net cash balance operating
	$+ \sum_{1}^{4} g_{49,j} \cdot u_j(t) + \sum_{1}^{4} f_{49,j} \cdot x_j(t)$	Faculty costs

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Accounting Fund	Terms Used In This Fund	Explanation of Terms
	$+ f_{49,8} \cdot x_8(t)$	Noninstructional space costs
	$+ q_{10} \cdot (\sum_{7}^{23} u_j(t) + \sum_{13}^{45} x_j(t) + \sum_{1}^{16} z_j(t))$	Other administrative costs
	$+ z_{21}(t)$	State operating funds (LUMP)
	$+ z_{22}(t)$	Federal operating funds (LUMP)
	$+ q_9 \cdot (\sum_{7}^{23} u_j + \sum_{13}^{45} x_j + \sum_{1}^{16} z_j(t))$	State operating funds (per student)
	$+ \sum_{11}^{43} q_i \cdot x_{i+2}(t) + \sum_{7}^{22} q_{i+4} u_i(t) + q_{43} \cdot u_{23}(t) + \sum_{11}^{26} q_i \cdot z_{i-10}(t)$	Federal operating aid to institutions (i,a,l)
	$+ q_{49,25} \cdot u_{25}(t)$	Gifts spent on operations

Accounting Fund	Terms Used In This Fund	Explanation of Terms
	$+ u_{38} \cdot (\sum_{13}^{45} x_j(t) +$	Tuition revenue
	$\sum_{7}^{23} u_j(t) + \sum_{1}^{16} z_j(t))$	
	$+ \sum_{i,a,l} x_{i,a,l}(t) \cdot$	Student aid costs
	$(u_i + u_a + u_l)$	

where i,a,l refer to the income, ability, and level of students.

Notice that certain terms (tuition, revenue, and student aid) in the operating net cash balance fund are products of state and control variables. This means that the dynamic flow constraint is nonlinear and will require several iterations of the optimizing algorithm to arrive at an acceptable stopping point.

Objective Functions in the Institutions

As discussed earlier, institutional objective functions are not easily observed or measured, and the state of the art of institutional goal assessment, while improving, is still very primitive. Some exploratory work has been done on direct assessment techniques by Geoffrion et al. (1971) and on single institution paradigms of the current multisector model by Wagner and Weathersby (1971). One purpose of the research described in this report is to explore the usefulness of explicit objectives and to identify the information needed to employ objectives in their most useful form.

There is obviously a large number of criteria that an institution might use to measure its performance. No claim is made that the sample criterion function developed in the prototype model is "best" or "adequate" for all institutions or for all problems facing a single institutional sector. It is primarily intended to serve as an example of the kind of function which makes the problem both relevant for policy analysis and tractable mathematically.

It is assumed that institutional decision makers are concerned with proxy measures of academic quality, quantity, and fiscal solvency. In particular, quality will be represented by (1) the student-faculty ratio, (2) the faculty mix ratio, (3) the adequacy of physical space, and (4) the relative mix of students by level. Quantity is measured by the total number of students and faculty in a sector. Solvency is measured by the level of the total net cash balance at the start of each period. One other criterion the institutional decision makers may want to control is tuition, by holding tuition close to a desired level and admitting students at a rate equal to some forecast of actual attendance. Consider first the quality components of the objective function:

(1) If TS_t = the total number of students in a sector at time t

TF_t = the total number of faculty at time t

R_1 = the desired ratio of students to faculty

then the objective is to minimize $\left(\frac{TS_t}{TF_t} - R_1\right)^2$

(2) If F_1 = total full professors at time t

F_2 = total associate professors at time t

F_3 = total assistant professors at time t

F_4 = total instructors at time t

then the objective is to minimize $\left(\frac{F_{i_t}}{TF_i} - R_i\right)^2$ $i = 1,---,4$

(3) Assuming that space requirements in each sector are a linear function of students and faculty with some fixed investment required, the objective is to minimize $[C_1 + C_2(TS_t) + C_3(TF_t) - X_j(t)]^2$, $j = 8,12$.

(4) The mix of students by level may be approximated by the ratios of lower-division students (LD) and upper-division students (UD), to total students. If R_{12} is targeted ratio LD/TS and R_{13} is the targeted ratio UD/TS, then an institution would want to minimize

$$\left(\frac{LD_t}{TS_t} - R_{12}\right)^2 \quad , \quad \left(\frac{UD_t}{TS_t} - R_{13}\right)^2$$

Now consider the quantity and solvency components of the objective function. In the past decade it was a safe assumption that most institutions desired increasing numbers of students and faculty, partly because more students meant more resources, usually funded at the average cost which, when it exceeded the marginal cost of expansion, enabled institutions to free some "additional" resources. Now that the link of additional students to additional faculty has been broken in many states, some institutions are showing considerably less enthusiasm for additional students.

Depending upon one's perception of the future, institutional objectives (1) achieve and maintain some target number of students (R_i) and faculty (R_j), with the targets possibly growing over time, e.g., minimize $[TS_t - R_i(t)]^2$ and $[TF_t - R_j(t)]^2$; (2) achieve and maintain some target rate of growth in students (R_i) and faculty (R_j), e.g., minimize $\left[\frac{TS_{t+1} - TS_t}{TS_t} - R_i\right]^2$ and $\left[\frac{TF_{t+1} - TF_t}{TF_t} - R_j\right]^2$ or (3) desire continuing growth but recognize a diminishing marginal utility, e.g., minimize $\exp\left[-aTS_t\right]$. For purposes of illustration, the target is taken to be a forecasted number of students that will attend if accepted, and the criterion term is specified for each type of lower-division student admitted:

$$\sum_{i=14}^{29} (U_{i-6} - \text{Forecast}_i)^2$$

A similar analysis can be done for institutional preferences for money: everybody wants more of it and the problem is the lack of enough of it. Assuming that endowments are handled separately, institutions should either consume or invest their net cash balance as long as there is any positive opportunity cost to holding cash. Therefore, the formulation of the solvency objective is to minimize $(NCB - R_{10})^2$, where R_{10} is taken as a desired level of net cash to retain at the year's end and $(x_{47} - R_9)^2$ is the current level of unrestricted endowment.

This leaves the additional criterion of holding tuition near a targeted value, $(U_{38}(t) - R_8)^2$; and of holding student aid near a targeted value, $(U_i - R_j)^2$, where i = 27,---, 37, the components of student aid for each income, ability, and level, and j = 31,---, 63. Then adding weights w_i, the final form of the objective function summed over n planning years is:

$$V = \min \sum_{t=1}^{n}$$

student/faculty ratio		$w_1\left(\frac{TS}{TF} - r_1\right)^2$
full prof/ faculty	+	$w_2\left(\frac{F1}{TF} - r_2\right)^2$
assoc. prof/faculty	+	$w_3\left(\frac{F2}{TF} - r_3\right)^2$
ass't prof/faculty	+	$w_4\left(\frac{F3}{TF} - r_4\right)^2$

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instr. space/total space	$+ \; w_5 \left(\frac{x_8(t)}{TSP} - r_5\right)^2$
instructional space	$+ \; w_6 \, (c_1 + c_2 * TS$
	$+ \, c_3 * TF - x_8(t))^2$
noninstructional space	$+ \; w_7 \, (c_4 + c_5 * TS$
	$+ \, c_6 * TF - x_{12}(t))^2$
tuition	$+ \; w_8 \, (u_{38}(t) - r_8)^2$
unrestricted endowment	$+ \; w_9 \, (x_{47} - r_9)^2$
NCB	$+ \; w_{10} \, (NCB - r_{10})^2$
lower div. stu./total stu.	$+ \; w_{12} \left(\frac{LD}{TS} - r_{12}\right)^2$
upper div. stu./total stu.	$+ \; w_{13} \left(\frac{UD}{TS} - r_{13}\right)^2$
institutional aid	$+ \; \sum_{31}^{63} w_i (u_i{}^{(t)} + u_a{}^{(t)}$
	$+ \, u_e{}^{(t)} - r_i)^2$
proximity to forecast	$+ \; \sum_{14}^{29} w_i (u_{i-6} - FE_i)^2$

instructional space begun	$+ \quad w_{64} \left(\frac{u_5}{x_8} - r_{64}\right)^2$
noninstructional space begun	$+ \quad w_{65} \left(\frac{u_6}{x_{12}} - r_{65}\right)^2$
gifts spent on construction	$+ \quad w_{66} \left(u_{24}\right)^2$
gifts spent on operations	$+ \quad w_{67} \left(u_{25}\right)^2$
capital financed	$+ \quad w_{68} \left(u_{26}\right)^2$

This still leaves the important task of choosing the relative weights, k, and the targets, R. As usual, there are several alternative approaches to each task. To choose the weights one could: (1) convene a panel of experts and ask each to assess the relative losses of each variable, perhaps using a Delphi technique; (2) use relative intensity and a goal survey instrument as a measure of relative value and scale the k proportionately; or (3) attempt to construct a "neutral" set of weights such that a 1 percent deviation from average values of each variable or numerator would yield the same loss. Similarly, for the choice of targets one could: (1) question a panel of experts again, especially since the targets are all familiar notions; (2) examine institutional or state master plans because some of these targets are frequently used in institutional planning; or (3) conservatively assume status quo objectives. In the prototype model, alternative (3) was selected for determining the initial weights and targets.

At this stage the purpose is not to find the "true" objectives of institutional sectors but to explore the sensitivity of control variables to specification of objectives, test alternative forms of objective functions for feasibility, and gain enough experience to recommend meaningful data collection on institutional objectives. It is believed that a formulation similar to the objective function equation presented will serve these purposes well.

The current version of the prototype model has two capabilities with regard to the above institutional sector formulation. The first is to simulate the results of the system flow equations, starting with the current state of the system x(t) and advancing over the institutional planning horizon by using last year's control decisions U(t-1) for each year. This option has the advantage of permitting a look at a status quo set of institutional decisions and measurement of the impact of federal alternative funding plans. This option would be used to evaluate slight changes in the federal planning policies only. But, since institutions will react to the incentives in federal and state funding programs, it is also important to know the types of decisions institutions might make to satisfy their objectives on the basis of a dramatic shift in funding. It is for such a case that the second capability for optimizing the institutional sector was included in the prototype model. The following summarizes the institutional sector of the model and gives a summary of the optimization component of the model.

The institutional component of the model is formulated as a dynamic programming problem with linear and nonlinear flow constraints, extending the institutional work of Wagner and Weathersby (1971). This formulation assumes institutions will respond to federal, state, and private dollar incentives by making operating decisions that will attempt to satisfy specific institutional objectives. The institutional objectives are stated as a summation of quadratic loss functions over a five-year planning horizon. The linear and nonlinear flow constraints make up the semi-Markov institutional components for:

Student flow
Faculty flow
Space flow
Dollar flow

This formulation, with 49 state variables and 38 control variables, is optimized using differential dynamic programming (Jacobson and Mayne [1970]). The procedure starts at a nominal control sequence and applies Bellman's principle of optimality in reverse time through the inversion of a series of 38-by-38 matrices (which are components of a second-order Taylor series expansion of the objective function) to achieve a new, improved control sequence. This control sequence is applied to the institutional system flow equations, producing a new state sequence that defines the institutional desires (for example, students to admit, tuition to charge) relative to the potential new student population. This dynamic programming formulation is repeated for each of the types of institutions in the model, where there may be up to twelve different types of institutions (for example, the Carnegie categories).

Student Sector

In thinking about individual participation in higher education, currently enrolled students can be separated from individuals who might enroll as students and who are the target audience to whom federal access programs are directed. The continuing participation of currently enrolled students is included in the institutional sector description and will not be discussed further in this section. On the other hand, the choices of individuals who are potential students will be the focus of this discussion.

A logical starting point for the analysis of student choice of attendance in postsecondary education would be a multistage utility maximization formulation of all possible consumption and investment decisions. The expected utility derived from attending different types of institutions would be compared to the expected utility of working, traveling, marriage, and all combinations of other alternatives. This is clearly a difficult task and requires much more information than is actually needed for educational planning. Under the basic assumption of separability, changes in the prices and availability of education do not affect the prices, availability, and utility of other options; a demand function describing an individual's willingness to attend postsecondary education is sufficient to estimate changes in demand for admission as a function of prices, availability, institutional characteristics and individual characteristics.*

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*For a discussion of techniques for estimating national admissions demand and a review of the recent literature on student demand analysis see Jewett (1971).

Among the various student demand studies, the formulation of Miller[*] using Project SCOPE data comes closest to the perspective of the prototype planning model and provides the basis for the current estimation of potential student demand. Miller classifies institutions by, among other attributes, cost to the student and average verbal ability of enrolled students, while the model classifies institutions by type and control, as shown in Table 1. This doesn't affect the verbal ability measure, but it does affect the student cost measure. The combination of tuition and student aid from all sources determines the net institutional cost to the student, but extra living and transportation costs for a particular individual would vary greatly among the institutions in a single sector. The model does not deal with the geographical dispersion of institutions and students, both because of the tremendous increase in dimensionality that would be required and because data are currently not available to support such a description. Consequently, the assumption is made that differences in extra living and transportation costs for various individuals attending different institutions in the same sector essentially net out, i.e., do not differ significantly from the mean, and differences between sectors can thus be approximated by the difference of the mean

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*As reported in Miller (1971).

extra living and transportation costs of the sectors. In addition, Miller considers the individual attributes of family income and verbal SAT scores, which are the same categories used in the model.

In essence, Miller's results are used to estimate the joint probability of attendance at all institutional types and non-attendance as a function of the four factors: student verbal ability, average verbal ability of the institutional sector, family income, and institutional (and extra personal) cost to the individual. The actual parameter estimates and functional form used in the model are as follows:

$A_{i,a}$	=	average SAT ability for student group i,a
$Y_{i,a}$	=	average family income for student group i,a
S_j	=	average SAT ability for students in sector j
$C_{i,j}$	=	the net cost of student i going to sector j
$P_{i,a,j}$	=	probability of students with background i,a selecting sector j

$$P_{i,a,j}, = \frac{e\left(\beta^1 \frac{C_{ij}}{Y_i} + \beta^2 \frac{A_{ia}S_j}{1000}\right)}{\sum_{j=1}^{13} e\left(\beta^1 \frac{C_{ij}}{Y_{ia}} + \beta^2 \frac{A_{ia}S_j}{1000}\right)}$$

and

$$\therefore \sum_{j} P_{i,a,j} = 1$$

Then, given a population of potential students (number of high school graduates, NHG) by income and ability quartiles the student demand is given by

$$\text{Demand}_{i,a,j} = NHG_{i,a} \times P_{i,a,j} \qquad \begin{array}{l} i = 1,---, 4 \\ a = 1,---, 4 \\ j = 1,---, 5 \\ \text{for S sectors} \end{array}$$

Supply and Demand Interaction

The process by which the supply and demand interaction takes place is quite straightforward. Given the supply of spaces by income and ability from the institutional sector

Supply (I, A, J) for sector J

and the demand for spaces by income and ability from the student sector

Demand (I, A, J) for sector J

the interaction produces an enrollment:

Enrollment (I, A, J) = Minimum [Demand (I, A, J), Supply (I, A, J)] for sector J.

The interaction also provides for calculation of excess student demand

Excess Demand (I, A, J) = [Demand (I, A, J) > Supply (I, A, J)]

and for excess supply of empty spaces

Excess Supply (I, A, J) = [Demand (I, A, J) < Supply (I, A, J)]

Evaluation of Accessibility

The next difficult task is identifying effectiveness criteria for student access. Until this point "access" has been treated for simplicity's sake as if it were a precise notion, but this is of course not the case. Intuitively, "access" refers in some sense to the possibility for students with various socio-economic characteristics to attend educational institutions with various other characteristics. Therefore, one obvious starting point is to identify the student characteristics relevant to access from the federal point of view. For example, these characteristics might include their racial or ethnic background, sex, age, experience, academic ability, parental income, or intended field of study, some of which are explicit variables in the prototype model. In general, there may be many more factors influencing an individual's choice to attend college than the set of characteristics which federal policy makers feel to be the basis of either discriminatory admission or inherently unequal opportunity. Surely an individual's personal motivation could influence the likelihood of attending college and presumably few would argue that, all other things being equal, the federal government should insure that non-college-motivated individuals attend college with the same frequency and success as highly motivated college-oriented individuals.

The general description of equal access may be written more precisely by defining the notation of n policy-relevant attributes included within the total number of m behaviorally relevant attributes that determine college attendance choices.* Therefore, the model writes as m-vectors the student populations (s) and the general population (p). If a policy-relevant attribute set is written as pa_i (e.g., Caucasian, male, 19 years old, no college or work experience, high ability, annual family income $10-12 thousand, desiring to be a philosophy major), then the strictest measure of equality of access in each period is

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*Miller (1971) presents many of these noneconomic behavioral attributes which significantly influenced college attendance in the TALENT sample.

$$\frac{s(pa)_i}{p(pa)_i} = \frac{s(pa_j)}{p(pa_j)} \quad \text{for all attribute sets } i \text{ and } j$$

In other words, at the finest level of detail that may be considered, the proportion of individuals with each possible set of attributes that actually enroll is identical for all possible sets of attributes.

However, there are m - n behavioral attributes which can lead to differential enrollments for precisely the same value of the n policy attributes. If we choose a single set of these behavioral attributes as a reference, say $\overline{ba}$, then an alternative measure of equality of access in each period is

$$\frac{s(pa_i \mid ba)}{p(pa_i \mid \overline{ba})} = \frac{s(pa_j \mid \overline{ba})}{p(pa_j \mid \overline{ba})} \quad \text{for all } i \text{ and } j$$

A simple (and admittedly simplistic) example can illustrate this point. Suppose that an individual's probability of attending a particular type of college is a function only of his or her race and family income. If we measure race by a dichotomous variable which equals zero for nonwhites and one for whites, and if we measure income in deciles, then a hypothetical relationship describing a person's probability of attendance (% Attend.) is

$$\% \text{ Attend.} = 0.25 \text{ (Race)} + 0.06 \text{ (Income)}$$

In this case, a white in the sixth income decile and a nonwhite in the tenth decile would have virtually the same probability of attending college; for Race = 1, Income = 6, probability of attendance = .25 + .36 = .61; for Race = 0, Income = 10, probability of attendance = 0 + .60 = .60. However, is this a case of equal access?

There is no general answer to this question, but suppose for the purpose of this example that access differentials attributable to race are deemed to be socially unacceptable, while income-produced access differentials are socially acceptable. Then for equivalent incomes we would observe that nonwhites have 25 percentage points less chance of attending college and, by our second definition, access is not equal. One would then seek a public policy instrument, such as financial aid, that could be used to exert a countervailing force improving the access of nonwhites.

The purpose of this discussion is to suggest that federal objectives can be expressed in terms of variables describing the student (or clientele) population and institutional characteristics (such as enrollment). Simplest access evaluative criteria would be unadjusted participation rates by income and ability groups in each sector. Without the relationships which describe the conditioning effects of behavioral attributes, the more appropriate measure is not feasible.

Federal policy makers may also be concerned about the rate of change of student access. One possible measure here is the proportion of new admissions, na, with policy-relevant attribute set, pa_i, in each period:

$$\frac{na(pa_i)}{p(pa_i)} = \frac{na(pa_j)}{p(pa_j)} \qquad \text{for all } i \text{ and } j$$

If the federal criterion were achieved every period, the total student body would move toward criterion $\frac{s(pa_i)}{p(pa_i)}$ as long as retention rates were equalized by financial aid and counseling.

The problems of effectiveness criteria extend beyond the choice of a measure. To derive an operational effectiveness summary measure one must also resolve comparisons among individuals with different policy-relevant attribute sets and comparisons between different time periods. This is the problem of assessing utilities for multiattributed consequences, which is in general a very difficult task. However, Geoffrion et al. (1971) have shown how educational administrators can effectively deal with a multidimensional choice problem, and their approach provides some basis for future exploration in this research.

CHAPTER IV

DATA REQUIREMENTS AND SOURCES

The prototype planning model does require a large amount of data; over 10,000 different values. Yet the data collection task is a feasible task, as demonstrated by the preliminary data collected for initial tests of the prototype model. A very short summary of the topic areas of the required data and sources used for the preliminary data is presented in Table 4. A complete discussion, with examples, of the data requirements is presented in Preliminary Data For A Federal Planning Model For Analysis of Accessibility to Higher Education.

TABLE 4

Data Summary and Sources

Topic Area	Source Used
Population Data	Jewett (1971)
Numbers	
Income Averages	
Average Ability Levels	
Distribution by Income and Ability	
Financing Programs	Bureau of Higher Education
Gifts	Bureau of Higher Education
Transition Rates	Wagner and Weathersby (1971)
Faculty	
Space	
Students	
Finances	
Initial State Values	NCES
Initial Control Values	NCES
Objective Function Targets	Based on State Variables
Objective Function Weights	Based on State Variables

CHAPTER V

SAMPLE PROTOTYPE REPORTS

The vast quantities of information available from the model would include:

1. Federal aid dollars by type of institution, general type of aid, and year in which the aid was used.
2. Institutional data on faculty by level, space by type of space, accounting statements for each type of funds, students for each income/ability quartile and level of student, and the number of empty spaces in the institution for each type of institution.
3. Student data on the number of applicants desiring entry to higher education, the number enrolling for the first time, and the number not entering higher education, all separated into income and ability quartiles.

Obviously, a report containing all of the above information for two alternative financing plans would be too detailed for effective use by a policy analyst. Rather, the first comparison of two plans should be made using summary reports, followed by an examination of more detailed reports as necessary.

One of the summary reports prepared for use with the model is shown in Table 5. It shows a hypothetical analysis of the following two alternative financing plans:

PLAN 1

In addition to the current financing for higher education add a $100 student voucher for every low-income-quartile student attending a higher education institution.

PLAN 2

In addition to the current financing for higher education add $100 of general institutional aid for every low-income-quartile student admitted to a higher education institution.

From Table 5 it is easily seen that Plan 1 results in the admission of more students, while Plan 2 results in a higher net cash balance for the institutions and increased numbers of faculty. While this is necessarily a hypothetical evaluation of two fictional plans, it does illustrate the types of comparisons that could be made with the model.

Table 5

SUMMARY OF INSTITUTIONAL STATISTICS

NOTE

This report is presented as an illustration of the information the model can provide. The data presented in this report is hypothetical data and does not represent actual results of comparisons of the two financing plans.

****PLAN 1 -- SUMMARY OF 1974 INSTITUTIONAL STATISTICS---
(in Thousands)

	Net Cash Balance	Total Faculty	Total ASF Space	Total Students	Federal Dollars	Cost Per Student
PUBLIC UNIV	247,322	103.1	268,224	2,354	1,020,769	2.5
PUBLIC 4-YR	87,071	64.2	152,613	2,178	214,925	1.1
PUBLIC 2-YR	46,710	31.1	96,460	2,503	17,254	1.1
PRIVATE UNIV	84,643	38.2	94,500	706	718,774	4.6
PRIVATE 4-YR	126,164	64.2	123,806	1,339	522,310	1.4
PRIVATE 2-YR	3,779	5.5	11,250	119	4,262	2.4
--TOTAL--	586,689	306.3	746,853	9,199	2,498,294	1.8

****PLAN 2 -- SUMMARY OF 1974 INSTITUTIONAL STATISTICS---
(in Thousands)

	Net Cash Balance	Total Faculty	Total ASF Space	Total Students	Federal Dollars	Cost Per Student
PUBLIC UNIV	273,155	107.4	268,440	2,105	1,025,243	2.7
PUBLIC 4-YR	92,721	66.2	152,658	2,156	216,969	1.2
PUBLIC 2-YR	74,308	35.4	96,510	2,485	23,300	1.1
PRIVATE UNIV	92,175	42.3	94,327	688	721,254	4.7
PRIVATE 4-YR	143,643	71.2	123,744	1,274	520,250	2.4
PRIVATE 2-YR	11,205	5.9	11,113	107	4,341	1.9
--TOTAL--	687,207	328.1	746,842	8,815	2,511,357	2.0

CHAPTER VI

FUTURE RESEARCH NECESSARY

The prototype model in the current state of development will permit procotype planning studies and research on the model capabilities, and it does illustrate the feasibility of developing the model into a useful working tool for policy analysis. At least three phases of research would be necessary before the current prototype higher education model could be considered a fully developed analytic tool to be used in analyzing the extent to which alternative financing plans accomplish all of the national objectives of postsecondary education. The phases of this future research are

1. Modification, data refinement, and testing of the current higher education model to provide a fully operational tool.
2. Designing a postsecondary education model that would consider additional segments of postsecondary education.
3. Complete design and development of a comprehensive National Planning Model for postsecondary education.

First Phase

The research activities connected with the first phase would include:

1. Modification of the Prototype Higher Education Accessibility Model

The prototype higher education model developed by NCHEMS requires several modifications before it can be classified as a fully operational tool for analysis of alternative financing programs. These were identified as the prototype was developed. Some of the modifications were not necessary for prototype development to illustrate the concept and design, but are necessary for a fully operational tool; others involve relationships that were not identified until the final stages of prototype development and that have now been classified as high-payoff modifications that will make the model more useful to federal analysts. Examples of the two types of modifications are

1. The institutional sector of the model evaluates its enrollment policy by comparing the number of students it will admit with the forecasts of the number of students who would actually enroll.

The current forecast of the number of students who would actually enroll is taken to be the number who enrolled in the last year. This forecast does not take into account the impact of changing tuition or changing student aid on the demand for admission to an institution. An improved forecasting capability in the institutional sector of the model would permit the institutional sector to admit students who are likely to enroll based on the institutionally controlled levels of tuition and student aid.

2. The group of potential students seeking admission to higher education institutions in the model should be classified into two groups, those receiving financial aid and those not receiving financial aid. The current version of the prototype applies student aid to all potential students, and the modification would obviously move the model closer toward current student aid policy.

Other modifications necessary to make the prototype model fully operational are:

The capability to place limits on the variables in the model.

The expansion of the types of student aid in the student sector of the model.

The capability to vary institutional planning targets over time.

The equalization of the terms in the mathematical function expressing the institution's objectives by balancing the weights of the objective function.

Inclusion of rates of inflation, price changes, and income changes over time.

The capability to evaluate separately the construction and operating net cash balance in the functional expression of the institution's objectives.

Inclusion of student mix ratios by ability and income levels in the functional expression of the institution's objectives.

Improving the functional expressions of the institution's objectives in the terminal planning periods.

Improving the criteria for analytical termination in the institutional optimization.

Technical improvements in the computer software.

2. Pilot Test of Operational Higher Education Model

A pilot test of the model for analysis of accessibility to higher education will demonstrate the operational capabilities and identify the sensitive features of this planning tool. A pilot test of the model is necessary to (1) validate the model, thus illustrating its ability to simulate the interaction between federal and state finances and institutions and students; (2) ensure the proper performance of the model over a wide range of federal financing plans, institutional data, and student data before using the model for actual analysis of financing plans; (3) gain the experience necessary to develop an effective user's manual (see below) that would include cautions about sensitive operating characteristics of the model.

3. Data Refinement for Operational Higher Education Model

In the last six months, NCHEMS has assembled a prototype data base for the higher education model. This data base lists the current sources of the data, their reliability, and recommended improved sources. A number of improved data sources will be available during 1973 (for example, data collected in the evaluation of federal programs by the Office of Planning, Budgeting, and Evaluation, and data collected by the National Commission on the Financing of Postsecondary Education). The current prototype data available for the model are sufficient to illustrate the current prototype model's capabilities, but some of the prototype data date back to the 1960s and must be replaced with current reliable data before the operational higher education model can be used for actual policy analysis. In this activity a large representative sample data base would be collected, as feasible, for the federal model for analysis of accessibility to higher education. This data collection will (1) refine the current prototype data and (2) establish recommended data collection procedures.

4. User's Manual for the Operational Higher Education Model

This activity will develop a user's manual providing all the necessary technical instructions for use of the operational higher education model. The instructions will document step-by-step procedures for (1) providing input to the model for a financing plan to be analyzed, (2) executing the operational phase of the model to simulate the application of a particular financing plan, and (3) requesting summary output reports comparing the results of alternative financing plans.

Second Phase

The research activities connected with the second phase would include:

5. Design of Prototype Postsecondary Education Model

The current version of the national planning model is not designed to deal with postsecondary education. For example, the federal model for analysis of accessibility is curren designed to deal with only the traditional higher educatior sector of postsecondary education. This activity would conduct basic research to identify a prototype design of the national planning model to include broader aspects of postsecondary education. Examples of possible additional sectors are: (1) proprietary schools, (2) military training schools, (3) corporation training programs, and (4) vocational-technical schools.

6. Experiment with the Prototype Postsecondary Education Model

The prototype postsecondary model will need extensive evaluation and experimentation to determine the validity of the model design. The variety of different structures of postsecondary institutions outside the traditional higher education community will make the validation of the postsecondary model more difficult than validation of the higher education model.

Third Phase

The research activities necessary to complete the third and final phase of continued research on national planning models would include:

7. Federal Funding Classification Structure

The purpose of this activity would be to identify and classify alternative federal financing plans into specific types of funding that are applicable for inclusion in national models. The procedures identified in this activity would determine a standard methodology for assigning federal financing plans to a common structure of financing plans. This methodology will insure that an analysis performed by two different policy analysts would use the same basic assignment of specific financing plans to the same generalized financing structure that would be included in the national planning models.

8. National Models Identification, Testing, Comparison, and Interfacing

This activity would identify, assemble, and describe in one document the structure and data requirements of several existing national educational models. Examples of the types of models that it would be possible to include are the USOE Office of Planning, Budgeting, and Evaluation National Enrollment Model by Pfeferman and Froomkin; Manpower and Planning Models by Reisman, Balinsky, and Michenzi; and a National Enrollment Forecasting Model by the Inner City Fund.

This activity would then consist of bringing the documented national models up on a computer system available to NCHEMS so the models can be used for (1) a discussion of the current state of the art in national models, (2) an evaluation of each model's abilities, and (3) the identification of possible interfaces between the various national models. This activity more specifically would include testing and evaluating each of the models to insure an operational status under a common data base.

This activity would also consist of preliminary analysis of several alternative financing plans to determine the capabilities of each of the national models in evaluating alternative financing plans.

Finally, this activity would modify the models to facilitate the interfacing of data for the models. For example, the OPBE National Enrollment Model does not currently provide data that can be used as input for or compared with output from the NCHEMS federal model for analysis of accessibility.

It may be possible to modify the national models to have a standard interface of data requirements on both model inputs and outputs. The benefits resulting from this activity would be a full coordination of national models that would extend the range of possible policy analysis studies.

9. State-of-the-Art Solution Techniques

A number of national models are using or have developed techniques that are near the state of the art in solution of large planning model problems. Yet expansion of the models through increased dimensions of data requirements or to more comprehensive model interrelationships is not feasible without adopting additional state-of-the-art solution techniques. This activity would identify available state-of-the-art solution techniques that exist in current literature and research the possible combination of existing techniques to develop capabilities for an expanded national planning model.

10. Design of One Comprehensive National Planning Model

This activity would conduct research on the refinement of models to develop one comprehensive national planning model.

Such a comprehensive national planning model would have the capability of analyzing alternative federal financing plans and considering their impact not only on accessibility to higher education and institutional viability but also perhaps on national manpower production, quality of education, institutional diversity, and freedom of choice. This activity would depend upon much of the work performed in developing the preliminary national planning models in the postsecondary education area, the identification and operation of other national models, and the expansion of the state-of-the-art capabilities for data, relationships, and objectives.

This phase would include research on the refinement of the models specifically to expand the dimensions of the data in the model. For example, student data in the federal model for analysis of accessibility are currently defined by student income quartile, student ability quartile, and student level (lower division, upper division, graduate). Expanded data definitions for a national planning model could include student data identified by age, race, sex, period of attendance (full-time, part-time, half-time), and geographic region or origin. Such expansion in the design of an improved national planning model would build upon advanced state-of-the-art techniques adapted from activity 9.

This phase would also include research on the refinement of models to include required relationships among data in the national model. For example, in the federal model for analysis of accessibility, federal dollars and state dollars are assumed to be totally independent. Yet increases in federal dollar allocation in certain areas do result in decreased state funding in the same area. The addition of these refinements would be necessary for a fully comprehensive model.

This activity would also include research on the refinement of models specifically to include goals or objectives as a part of the planning model. This simply means the planning model would have the capability of determining alternative decisions that would come closer to meeting desired objectives. This capability could be of particular value to planning groups analyzing many different joint combinations of alternative funding patterns. Research required in this activity would include the identification of specific national objectives to be included in the national planning model and the adaptation of state-of-the-art solution techniques identified in activity 9. The resulting model would be pilot-tested using refined data and included in the national planning model user's manual.

11. Preliminary Study of Alternative National and Educational Policy

This research activity would consist of the application of the current state of the art embodied in a national planning model to study alternative financing plans in postsecondary education. This activity is intended (1) to illustrate the usefulness of the national planning model in making an analysis of alternative financing plans, and (2) to assist federal agencies in answering questions relative to the impact of alternative financing plans.

12. Preliminary Study of Alternative Futures

This activity would conduct research on the use of the national planning model in analysis of alternative futures for postsecondary education. For example, it is feasible to consider the use of the national planning model for analyzing the impact of several alternative scenarios of the postsecondary education future as described by the Syracuse Policy Research Center. Some of the alternative futures that could be examined might include: (1) the extended campus system (an extension of the present system by 20 percent), (2) the extended credit system (an expanded credit by examination system), (3) the diminished campus (a 20-percent reduction of the current system), (4) the empty campus (a complete replacement of the current higher education system).

CHAPTER VII

DESCRIPTION OF OTHER RELATED REPORTS

Additional information related to the results of this research effort can be obtained from other National Planning Model - Phase II project reports. A listing of all of the project reports would include:

1. A Federal Planning Model for Analysis of Accessibility to Higher Education: An Overview. A summary document that presents a discussion of the prototype model in nontechnical terms such that the basic concepts can be understood by the higher education community. This includes a set of example calculations to illustrate the computations in the model.
2. A Design for a Federal Planning Model for Analysis of Accessibility to Higher Education. A documentation of the assumptions, design considerations, detailed prototype model relationships, and possible future research. This includes the most detailed explanation currently available for the prototype model.
3. Prototype Software for a Federal Planning Model for Analysis of Accessibility to Higher Education. A complete listing of the prototype software for:

a. MODIFY -- a routine that creates or updates the data base for the prototype model.

b. NPM 2.4 -- the current version of the prototype model.

c. VIEW -- output report routine that displays several summary reports from runs of the model comparing two alternative financing plans.

4. Preliminary Operating Instructions for a Federal Planning Model for Analysis of Accessibility to Higher Education. A report that presents very preliminary instructions for using the current prototype model software. This report is not a general user's manual as it does require extensive knowledge of the model and the software. It does, however, provide an initial set of instructions that can be used with the prototype and a basis for an improved user's manual in the future.

5. Preliminary Data for a Federal Planning Model for Analysis of Accessibility to Higher Education. A preliminary report to illustrate the types of data used in preliminary tests of the prototype model. This report contains all of the prototype data values, description of each variable, and the current source of the data.

6. Preliminary Test Reports from a Federal Planning Model for Analysis of Accessibility to Higher Education. A complete set of the current output reports illustrating the current

operational status of the prototype model. Included are the summary output reports comparing two alternative financing plans and a complete step-by-step report of the status of the model at a number of intermediate checkpoints in the model operation. The step-by-step report includes both a simulation run of the institutional sector of the model and a segment of an optimization run illustrating improvements in objective function values.

All of the above reports should be considered preliminary reports on the National Planning Models effort by NCHEMS. These reports should and will be updated and revised extensively as and if NCHEMS is able to further develop the model.

CHAPTER VIII

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