DOCUMENT RESUME

ED 062 946 HE 003 085

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TITLE	Student Flow Models: A Review and Conceptualization.
INSTITUTION	Western Interstate Commission for Higher Education, Boulder, Colo. National Center for Higher Education Management Systems.
SPONS AGENCY	National Center for Educational Research and Development (DHEW/OE), Washington, D.C.
REPORT NO	TR-25
PUB DATE	Aug 71
CONTRACT	OEC-0-8-980708-4533(010)
NOTE	96p.
EDRS PRICE	MF-$0.65 HC-$3.29
DESCRIPTORS	College Students; *Educational Planning; *Educational Research; *Enrollment Projections; Enrollment Trends; *Higher Education; *Institutional Research

ABSTRACT

The manner in which students move through the system of higher education--changing majors, leaving the system for undetermined periods and then returning, failing and repeating courses, continuing on for advanced and professional degrees--can have a significant effect on the planning and managing of institutions. The purpose of this paper is to review the accomplishments to date in the area of student flow modeling and, against this setting, propose an initial and straightforward model for projecting student enrollments at the institutional level. The model provides . . projections of applicants, admissions, enrollments, and departures. It may be used to address questions associated with changes in the status quo through the process of data modification and segmented multiple projection. However, the validity of projections of this type lies primarily with the reliability of the information used to make modifications and the extent to which interactions associated with the changes have been accounted for. (Author/HS)

STUDENT FLOW MODELS
A REVIEW AND CONCEPTUALIZATION

PRELIMINARY DRAFT
for review purposes only.

Preliminary Field Review Edition
Technical Report 25

National Center for Higher Education Management Systems at WICHE

National Center for Higher Education Management Systems at WICHE

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NATIONAL CENTER FOR HIGHER EDUCATION MANAGEMENT SYSTEMS AT WICHE

STUDENT FLOW MODELS
A REVIEW AND CONCEPTUALIZATION

(Preliminary Edition)

by

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NCHEMS Development & Applications Program

NCHEMS is supported by the U. S. Office of Education, National Center for Education Research and Development, Division of Research and Development Resources.

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August 1971

ACKNOWLEDGMENT

This edition of the Student Flow Model document is the product of the efforts of many individuals and institutions. In particular, the combined competencies and dedication of the members of the task force in providing guidance to the NCHEMS staff have been of exceptional value.

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Also contributing to the development of this version of the Student Flow Model were members of the Development and Applications Program of the

National Center for Higher Education Management Systems: Dr. Warren Gulko, Mr. Dennis Jones, Mr. James Martin, Mr. Leonard Romney, Mr. Gordon Ziemer, and Dr. James Topping. Mr. Laci Pook, a graduate assistant at NCHEMS, has been instrumental in programming the model. Dr. Wayne Kirschling of the NCHEMS Ford Research Unit has been particularly helpful in providing special insights to the problems being addressed. Finally, the patient efforts and the editorial assistance of the secretarial staff of Mrs. Virginia Patterson have been invaluable.

PREFACE

The National Center for Higher Education Management Systems is dedicated to the task of assisting colleges and universities to maximize the benefits received from the expenditure of the resources. The benefits of primary concern are those which accrue to the student. Increasingly, a major portion of an institutions' capital and operating budget is devoted to improving the institutions' educational impact upon its students. Therefore, it is essential that institutions know as much as possible about the individual student: who he is, how he moves through the system, and in what ways he is affected by the institution.

The following pages present a preliminary description of the Center's work on student flow models. The initial design is a straightforward strategy for predicting student enrollments at the institutional level. It is intended that this be but the first in a series of documents which will assist higher education in analyzing student flows in an effort to improve institutional management.

This paper is published by NCHEMS and distributed to our participants in order to invite comments and criticisms regarding the approach and techniques presented in the following pages. In order for the Student Flow Model to be a viable asset to the higher education community, it must reflect the needs and objectives of your institution or agency. We therefore welcome any suggestions for improvement which you may have.

Ben Lawrence, Director
National Center for Higher Education
Management Systems at WICHE

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INTRODUCTION

The manner in which students move through the system of higher education -- changing majors, leaving the system for undetermined periods and then returning, failing and repeating courses, continuing on for advanced and professional degrees -- can have a significant effect on the planning and managing of institutions. Whether an institution is growing and thus planning for increases in various department enrollments and the possibilities for new departments, or whether it has a fixed enrollment ceiling and thus must control admissions to stay within bounds, the process of student flows in and among our institutions should be an important consideration at all levels of planning. The purpose of this paper will be to review the accomplishments to date in the area of student flow modeling and, against this setting, propose an initial and straightforward model for projecting student enrollments at the institutional level. A second paper is also proposed which will deal with the more substantive problems in student flow, including the effects of student characteristics, on student flow processes as well as alternative methods for using and expanding this initial model to study and analyze other aspects of student flows.

Over the past few years, considerable effort has been expended on the development of student flow models for a variety of purposes. Among these efforts have been studies of student transitions, the effect of program changes, projective planning, etc. The majority of work, however, has been in the context of larger models (e.g., models of an entire institution of higher education, or as an integral part of a costing and resource allocation model). In addition, a large proportion of these models have been strictly conceptual or ad hoc studies without a focus on continued use in higher education planning. Virtually, no existing model has been developed in conjunction with ongoing systems or packages of related models.

Because of the complexity of the problems and interrelationships between the various segments of management and planning in higher education, it has been the Center's philosophy to develop analytical planning models as independent modules within a framework of related higher education management packages. The student enrollment model proposed in this paper has been designed within this context. The model outputs are explicitly designed to be compatible with and used directly as inputs to the WICHE Resource Requirements Prediction Model.[12] All student-related data elements associated with this proposed model agree in definition with those in the Data Element Dictionary: Student published by the National Center for Higher Education Management Systems at WICHE.

In review of past efforts, alternative methodologies for student flow modeling will be presented for the purpose of providing definitions and the appropriate setting against which existing models can be discussed. Following a general descriptive review of previous modeling efforts, a discussion of the more popular techniques used in these efforts with respect to strengths and weaknesses is provided. The underlying approach taken for the proposed NCHEM model and its relevance to the problem is then presented.

As a part of the introduction, it should be pointed out that the model design presented in the second section of this document is the result of the combined efforts of the NCHEMS Student Flow Model Task Force. The proposed design has evolved through an interactive process within this group over time. It represents the combined judgments of the participants with respect to a variety of considerations. Most important among these considerations is the intent that this model be acceptable to the majority of institutions of higher education with respect to its usefulness, straightforward simplicity, and overall utility payoff. The proposed model design is presented in the second section of this report. A general overview of the admissions and enrollment process as a system is presented, and then, the model design is discussed in relation to this system. Data requirements, estimation techniques, and alternative uses of the model are also discussed in light of institutional planning needs.

SECTION I: STUDENT FLOW MODELS: A REVIEW

METHODOLOGIES IN STUDENT FLOW MODELING

An understanding of the processes of student flow in institutions of higher education is a critical component of any planning effort, and should be a significant part of any study concerned with the products of institutions of higher education. A variety of methodologies exist to assist planners and analysts in acquiring a better understanding of these processes. A number of these methodologies have been used for modeling and some have not. This section will provide a brief discussion of some of these techniques.

Ratio Techniques

Among the more common methodologies currently in use are those which have adopted elementary ratio techniques. These ratios serve as estimates of the probabilities of passing (or failing to pass) from one state* to another, and these states are usually segmented or conditioned on various student characteristics. The most common and popular of this class is referred to as the Cohort Survival Technique, which is a method of tracking of a selected group (cohort) as it progresses through the various states. The basic assumption in using this approach to make projections is that if the cohort is properly selected, the resulting ratios will be relatively constant from one

*The term "state" in the context of student flows usually refers to a catagorical of classification variable such as student level (freshman), major (physics) or status (departed or graduated).

time period to the next. This technique makes no other formal assumptions concerning the process. A variation of the ratio method is the Class-Rate Progression Technique. This method uses the ratio of the number of individuals in one state to the number in the state immediately prior in the progression sequence. This method is mathematically more complex, but simpler to use than the cohort technique and has been found to be surprisingly accurate for short range projections in the absence of extreme external effects. (For a further discussion of cohort survival and class rate progression techniques see Lins, Reference 19.)

Markov Methods

A formal mathematical structure similar to those employing ratio techniques is the Markov Process. The name derives from the works of Markov (circa 1912), whose basic assumption, underlying the structures of these techniques, is that transitions from one state to another during an increment of time depend only on the present state and are independent of the past. Most of these techniques fall under one of two larger mathematical theories -- the Theory of Multi-dimensional Random Walks with Absorption Barriers[16] or the Theory of Birth and Death Processes.[17] The more common and elementary of these theories make certain assumptions concerning stationarity,* as well as independence of past history (Markovian assumption). While nonstationarity* is dealt with briefly in the literature on student flow modeling, semi-Markov

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*A process is said to be stationary if the statistical expectation (average) is independent of time (a constant with respect to time).

and non-Markovian walks have not been applied to the student flow problem. It is likely in the latter case that this is because the technical literature is sparce.

Basically, a Markov model is a discrete time system characterized by a collection of probabilities, one for each of the transitions from the present state to a possible state at the next point in time. The stationarity assumption assures that this collection of probabilities remains constant over time. Under the assumptions for this type of process, one can determine the number of students presently in a given state who will be in another state at the next point in time by multiplying that number of students by the associated transition probability. Those familiar with matrix algebra will note that the entire set of transitions between all possible combinations can be obtained by multiplying the square matrix of the transition probabilities by the vector of groups presently in the respective states.

If the assumptions for a Markov process hold for higher education (i.e., if the probabilities of changing majors and the probabilities of changing level are constant over time and independent of anything except that a student is in a given major and level at the present time), then student flows can be simulated by repeated application of the matrix of transition probabilities to a vector containing the number of students in each state. Obviously, these assumptions are very restrictive. However, similar systems can be postulated in which the transition probabilities vary over time and the "present" state is defined in terms of the combination of present and recent past. For example, if we only have two majors, math and physics, then the transition from math to physics would be replaced by two transitions: one from math to physics (given that the individual was a math major the previous year) and one from math to physics (given that the major was physics the previous year). However, this process of conditioning increases the number of transitions as the square of the number of states. Thus, it becomes impractical to extend this process very far into the past.

Monte Carlo and Other Alternatives

Another method not yet attempted in the study of student flows is the class of Monte Carlo techniques.[14] The basic characteristic that distinguishes Monte Carlo from other methods is that a "random" choice process is included. The method derives its name from the famous gambling house at Monte Carlo and shares with gambling the common element of "chance." The simplest Monte Carlo Model could be envisioned as a situation where members of a group are asked to move "A" or "B" in a game with no other choices available. If the choice of "A" or "B" by an individual player is a strictly random choice with equal chance (half on the average make move "A" and half move "B"), then the game can be simulated by making player choices on the basis of the outcomes of flipping a coin. The reason that these methods have not been more widely used in the study of student flows is likely due to the significant computer requirements associated with Monte Carlo analyses.

The Monte Carlo concept is extendable to a more complex structure using distributions of outcomes and further, by conditioning these outcomes on various characteristics of the "players." Special purpose computer languages designed explicitly to deal with Monte Carlo simulations have been developed. A beginner's treatise on Monte Carlo simulations can be found in the four articles in Reference 13 dealing with the uses of these languages.

Other possible variations of the Markov type process not previously considered for student flow models are the classes of branching[13] and percolation processes.[5] Both of these deal with path-dependent random walks. Another related possibility is the Theory of Flows in Networks.[10] Both stochastic and deterministic applications of this theory could prove promising. Linear, nonlinear, and dynamic programming techniques[22] have been applied to student flow problems but not extensively.

REVIEW OF EXISTING MODELS

Since *ad hoc* studies of student flow generally assume some basic underlying model of the process, we will include in our discussion both studies and theoretically conceptualized models, pointing out in the discussion the underlying model structure inherent in the studies. However, we will not attempt to categorize models or studies by the more commonly accepted sets of criteria such as underlying methodology, level of detail, econometric versus socioeconomic, etc. Rather, we will attempt to group them by purpose or intended use. We will discuss each model in light of its advantages and disadvantages, giving primary emphasis to those models which are more developed and having greatest utility.

System Models*

One of the most recent pieces of work done in student flow modeling is that sponsored by the Office of Program Planning and Fiscal Management in the state of Washington.[25] The Higher Education Enrollment Projection Model (HEEP) resulting from this effort is basically a Markovian model concerned primarily with undergraduates. The HEEP model is an inter- as well as an intra-institutional model. It is iterative in nature, and information for a given year is projected and then adjusted linearly to results from previous years' analyses. The entire model has a strong emphasis toward the pragmatic. This pragmatism is due, in part, to the fact that it is being sponsored by an operational agency with responsibility for planning in higher education for the state of Washington. The most significant point concerning this model may be that it was undertaken with a long-range planning program on a continuing basis as its primary objective.

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*For a comprehensive comparison of existing models and their characteristics, see Weathersby, Reference 40.

For the purposes of the Student Flow Project, probably the most imporant single aspect of the HEEP model will be the extensive feedback obtained from various users. This user analysis and criticism should be invaluable in the process of designing and developing an improved student flow model. The HEEP Design Group is currently incorporating these criticisms into their development of a second generation model for the state of Washington. Since the results of the HEEP model are analyzed by smoothing with respect to past outcomes, some of the primary problems at this time seem to be associated with the lack of sufficient information on student characteristics and student level, and the inability to deal with year-to-year extreme variations on a short-term scale.

Wayne Smith of the Office of Advanced Planning at UCLA has been using a multiplicity of projection techniques, relying, in part, on regression methods to develop estimates of numbers of students -- new, continuing, and returning; by level, department, and major -- and then projecting enrollment demands using ratio techniques.[33] The most significant point in Smith's work seems to be the uncovering of differences in student enrollment patterns as a function of a number of variables. Of significant interest is the effect of exogenous events (such as changes in the local unemployment rate) on returning student rates. In addition, Smith has found that no single projection technique seems to be applicable to every department or major, but rather that each set of circumstances dictates its own peculiar estimation technique. Again, the greatest significance of this work for our purposes seems to be the experience gained and pitfalls uncovered in the area of student flow behavior. The primary objectives of Smith's work were to develop entering student enrollment controls under the constraint of a fixed total enrollment. This work differs from the state of Washington work in that Washington was concerned with inter- as well as intra-institutional flow. However, both studies are primarily directed toward data analyses rather than theoretical conceptualizations of student flow.

A study has been conducted by Trautman at the State University of New York at Stony Brook that is similar in nature to the work of Smith at UCLA. The technique used at Stony Brook has been primarily cohort survival. This work began subsequent to the UCLA effort and does not appear to have come quite as far. However, as with the UCLA work, it has been conducted with the purpose of projecting usable data for planning purposes into the immediate future. Because of the necessity to produce usable results in a short period of time, little or no effort has been made to date to verify results or to study the validity of the techniques involved. Such a program is underway now. Trautman's objectives have been to develop enrollment criteria for maintaining the current ratio of Ph.D. to Master's candidates. Again, the most significant aspect of this work is its pragmatic framework. Hopefully, a great deal can be learned from the errors and pitfalls in methodology exposed in this effort.

The Rensselaer Model,[30] developed by the Rensselaer Research Corporation uses basically a Markovian process for projections. However, the Markovian transition matrices are developed using regression methods on previous years' data to estimate the individual probabilities. This process has the effect of creating a nonstationary Markovian model. While the reliability of the enrollment projections from the Rensselaer model was stated to be directly dependent upon the reliability, accuracy, and availability of input information, Smith's results suggest that strictly weighted regression techniques for developing probabilities for transitions may not be valid in all cases. While the Rensselaer model has been converted to computer form, there is little evidence that it has been used for projecting enrollments for student flow in an institution of higher education. Probably the most interesting aspect of the Rensselaer model is the mixture of techniques used in its design.

Models within Larger Models

Two examples of Student Flow Models which are contained within larger planning models for higher education are the CAMPUS Model[15] developed by the Systems Research Group and the University of Toronto, and the Michigan State University Model[18] developed by Koenig et al. Both models use multiple regression as the primary technique for projecting student enrollments by level and department or academic classification. Neither of these models deals with student flow as a primary objective of analysis, but rather, they deal with student flow information as input into a larger resource allocation and costing model. Both models have extremely rigid data requirements at a highly disaggregate level, and in both cases the student flow portion of the models is relatively elementary in comparison with previously discussed models. Koenig's work is primarily a research effort and is not intended for large scale implementation. On the other hand, efforts are under way to implement the CAMPUS Model at the University of Illinois and elsewhere. Results from this implementation, particularly in the area of accuracy and reliability of student flow projections, should prove very valuable to higher education.

Another university planning model which has a student flow submodel using regression analysis techniques for projection is the Tulane University Model.[9] This model is essentially a resource cost model designed specifically for a nine-year planning period. Data for five years in the past are used to make projections for the next four years. Experience with the model and the reliability estimates are approximately at the same point as other models discussed. A similar model is the one proposed by Dan Bailey[4] to comprehensively simulate the operations of the University of Colorado (CUSIM) including student flow. A part of the simulation system would be a predictive model -- a computerized technique to predict course load requirements based on smoothed historical ratios. This model would amount to a mixture of cohort survival techniques with regression smoothing.

Another model has been proposed by the School of Business Administration at the University of Texas. This system, the Generalized University Model (GUM), contains a further proposal for a computerized version, entitled the Generalized University Simulation Model (GUS).[31] The proposal delineates a number of shortcomings present in other models that will not be present, according to the proposal, in the GUS program. However, it does not make explicit the methodology which will be used to eliminate these shortcomings.

National Models

A great deal of work in the area of modeling student flow has been done abroad. Significant among these is the work of Thonstad,[36] who has developed a Markovian model of the Norwegian education system. He uses Markov theory to gain insights into the long-run implications of present student flows. An important aspect of Thonstad's work is that he tested predictions against actual data with remarkably good results. At the level of aggregation of systems elements used by Thonstad, grades by type of institution and transition rates within a structure such as the university may confound each other. Thus, the true viability of the model for disaggregate data on a level useful for university application has not been demonstrated.

The work of Thonstad has been shown to be quite accurate and reliable for making projections of the Norwegian system. This would suggest that the Markovian assumption is not a significant limitation in analysis of systems at that level of aggregation. However, the Norwegian system is tightly controlled by government policy, and educational achievement is rewarded as a national policy so that it is not difficult to believe that transition to the next state in the progression would depend primarily on the fact that the present state has been achieved. This point -- that the Markovian assumption is acceptable in tightly controlled progression schemes -- is further supported by Mohrenweiser, who used a Markov chain analysis to study student flows in elementary and secondary education in the United States.[23]

Two German models by Deitze[7] and Caspar[6], respectively, use Markov theory in combining student transition matrices with course participation matrices to predict course demands in future years. Both efforts were handicapped, however, since the data required by the models were only available on a limited basis from the German Universities. Gani,[11] after whose work the efforts of Marshall <u>et al</u>.[20] seem to have been patterned, did a similar Markovian study for projection enrollments and degrees in the systems of higher education in Australia. Another Markovian model was the work of Turksen.[37] The Turksen model is similar to the Deitze and Caspar models in purpose and degree of detail. However, it is distinguished by more sophisticated analysis of uncertainties and its allowance for course pre-requisites and eligibility of enrollment by course and program.

Another example of the Markovian type model is the Student Teacher Population Growth Model (Dynamond II),[41] developed by the National Center for Educational Statistics of the Office of Education. It is a mathematical model of the formal American educational system. It differs from most of the models discussed in the previous paragraphs in that it is a model of inter-institutional flow. Apparently, use of this model has been simulated for the purpose of making predictions of elementary, secondary, and college level flows of students and teachers through the education system using limited data from the 1960 census. It is intended to be used by educational officials, planners, and analysts in examining the impact of policy alternatives on the educational population.

Pfefferman in the United States Office of Education has developed a model for making projections of student enrollment on a national basis.[38] This model was designed to provide input to a student financial aid model and uses data taken from the National Center for Educational Statistics, Project Talent, and the Bureau of the Census. Fundamentally, it uses high school graduate projections, allocates them to sixteen combinations of ability and socioeconomic classifications, applies probability estimates of entry into higher education to each classification group, and then applies estimated survival rates to the enrollees. Statistical smoothing was used on the ratio data taken as estimates of probabilities. This straightforward method appears to provide reasonably good estimates when applied to historical data at this level of aggregation.

Small Colleges

In addition to models of university systems and of the national system of higher education, Peat, Marwick, Mitchell, and Company has developed a model for small colleges.[28] This model, the CAP:SC Model, is a long-range planning model and includes student flow analyses as a byproduct. This model includes both linear and nonlinear least squares curve fitting for the estimation of course demand patterns. These estimates of student flow are then used for planning projections.

Projective Studies

Among the *ad hoc* studies and resulting model proposals reviewed, the work of Perl and Katzman at the University of California[29] is significant with respect to the effect of student characteristic measures. This study relied primarily upon a cohort survival technique, and it produced interesting and insightful results with respect to the flow of students within the state of California and between the state of California and the rest of the country. In particular, the study reveals the significance of socioeconomic background and the importance of returning student rates. Perl and Katzman then proposed to model a statewide flow of students in California with a system of production equations. The coefficients for these equations would be estimated by the traditional least squares methods. Variables representing student, parent, and economic data were to be included.

A more recent modeling attempt by Marshall, Oliver, and Suslow[20] at the University of California, Berkeley, used highly aggregated data within a Markovian framework to predict student flows at that university. The levels of classification were attending, vacationing, and absorbing (never returning). This model was used further to predict distributions of these states. Their conclusion was that the method was quite accurate for this level of aggregation. Further, Robert Oliver,[11] working under Ford Foundation sponsorship at the University of California, has developed a series of research models dealing with student flow and attendance. These models were intended to aid university decision-makers in analyzing the effects of policies on admissions and attrition. The models of Oliver;[11] Oliver and Marshall;[27] and Marshall, Oliver, and Suslow[20] represent a series of increasingly sophisticated Markovian models. However, there is no specific methodology presented for the estimation of transition probabilities. Although analysis of the error propagation is included in earlier works of Oliver, it is not applied to the latter, more complex models. In the absence of such consideration, doubt concerning the validity of the Markovian assumption continues to remain. Marshall[20] has pointed out that cyclical time dependencies do appear to exist, particularly among returning students.

Finally, the works of Robert Thompson[34] at the University of Washington, Robert Smith[32] at the University of California, Oliver, Hopkins, and Armacost[26] also of California, and Roland Thompson[35] of AACRAO deserve mention. Robert Thompson's model is highly aggregated and is primarily a costing model. However, it explicitly recognizes the effects of time lags, which appear to be an important consideration. Smith's work is conceptual and deals primarily with a course-scheduling algorithm, according to student demand. The model to be proposed in this paper will not be concerned with this level of detail initially; however, this work is mentioned for reference should it become desirable to consider individual course demands. Oliver, Hopkins, and Armacost propose a network flow model of student-faculty interface, but provide no suggested methods for estimating flow parameters. This model is of interest primarily because it represents the only known attempt to apply network theory to problems of higher education. Ronald Thompson of AACRAO made projections of enrollments in both public and private institutions for the period 1970 - 1978. The projections in this study were obtained using trend data based on the number of births 18 and 20 years prior to a given year in ratio to the number of students enrolled that year. These projections could prove useful in providing expected input numbers of new enrollees for a model of the type being proposed here.

Before proceeding to a discussion of methodological and other shortcomings of previous work, it should be pointed out that a considerable amount of literature related to student behavior and student activities associated with the student flow problem exist. Significant among these are the works of A. W. Astin, [1, 2] Astin and Panos,[3] Oliver and Marshall,[27] Medsker and Trent,[21] and numerous others,* as well as various <u>ad hoc</u>

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*For a more complete list of related research, see the selected list of references on page 89.

thesis projects including the work of Morris[24] at the University of Colorado. Such works are mentioned here because they bear very heavily on the question of design alternatives for student flow models. This point will be discussed more extensively later in this paper. However, as an example, the work of Morris reveals a strong interaction between student residency status and sex in terms of returning student rates. Such interaction should be taken into consideration in projecting student enrollments, particularly in projecting student transition probabilities.

CRITIQUE OF THE METHODS UDED IN EXISTING MODELS

Popularity of the Markov Model

As should be apparent from the review thus far, certain methodological techniques appear to be extremely popular. One might surmise as a result that these techniques sufficiently deal with the problem. However, the extreme popularity of Markovian assumptions tends to be counter-intuitive, at least for some levels of aggregation, since the basic Markovian assumption is that transitions from the present state to a future state are dependent on only the present state and no other past history. Additionally, the assumption of stationarity in Markovian models appears quite popular. Again this seems quite counter-intuitive. If the educational process is, in fact, stationary over a long time frame, no one would be studying aeronautical engineering today since it didn't exist prior to 1920. A more recent example is provided by the significant shifts in student majors during the immediate post-sputnik era. Similar examples exist at present with an increasing demand for study in the social and biological sciences and the apparent decrease in societal demand for chemists and physicists.

Therefore, after taking a second look, it appears that the popularity in methodological technique may in fact be more associated with ease of application and availability of established technique than with a valid representation of the structure of the problem being approached. The Markov process is relatively uncomplicated and easy to deal with, while regression techniques are probably the most developed and easily available of all statistical techniques for projection. It is possible that the mathematical methodology is not yet sufficiently developed for dealing adequately with the problem of student flows in their full range of complexities. On the other hand, approximations at certain levels of aggregation may be obtainable with an adequate degree of accuracy for some purposes using existing techniques.

Basic Shortcomings of Models

In reviewing considerations of student flow models and studies to date, there appears to be four basic weaknesses in most past efforts. These concerns are:

1. Underlying assumptions. For example, there is the question: Is the system actually Markovian? This assumption, as has been pointed out already, is invalid in a number of cases, while in others it may be quite valid. Additionally there are two assumptions underlying multiple regression. First, it is assumed that there is independence in the sample taken for the variables, and secondly, that the underlying data can, in fact, be represented by trends. The latter assumption can be affected significantly by variations associated with exogenous events. (This will be dealt with in point four.)

2. Model Validity. The primary underlying question is just how close a given model estimates reality. This question relates both to the methodology and its assumptions as presented in Point One and, additionally, the very significant aspect of the variability of the underlying data. Given that the assumption in Point One and the resulting methodology are correct, one still must deal with the variability in the estimates that are used for projection purposes. To date, the question has been grossly ignored in most studies of student flow processes in higher education. The

question of variability inevitably leads to Point Three.

3. Data. The question of data is all too frequently ignored during the development of simulation models. It is often argued that one's thinking is restricted, and thus, the model development is restricted if data availability is taken into consideration during the design. However, in reviewing the past efforts, it should be apparent that too many models have problems associated with the unavailability of data. Thus, it is wise to consider data and data systems from the outset if the model being developed is going to have a good chance to be useful. The best model with no data to drive it is useless. On the other hand, it is easy to say that all necessary data exist. However, a key point to be made here is that they do not necessarily exist in usable form -- that is, it may be too expensive to convert existing data to a form usable with respect to a model's design. Further, the data may not exist in fact -- that is, they may not have been collected or they may not be retrievable. Thus, it could be four to five years in the future before appropriate data in sufficient quantities are available for making projections. This understanding leads to Point Four.

4. Completeness of variable definition. Most would argue that not every student is alike, and that one student's probability of success is not based on the same variables as every other student. In fact, a student graduating from the middle of his class from a school with an extremely high rating and whose parents' socioeconomic status is in the top ten percent of the nation may have a much higher probability of graduating than a student who graduated from high school in the top five percent of his class in one of the economically depressed ghetto regions. This implies a definition of certain variables which condition the probability of success. Additionally, variables not directly related to the student may have an extremely significant effect on the ultimate student flow. For example, the recent work of Smith at UCLA has shown both a high increase in returning student rate and a significant decrease in dropout rate in the past year. This is apparently due in part to a national economic situation and, in particular, to the economic situation in the city of Los Angeles.

These four points, with few exceptions, apply universally to all models developed or proposed. This evaluation is not intended to be a condemnation of these models, but rather an indication of the degree of difficulty these problems present.

Data Aggregation in Model Design

An additional decision problem in the conceptualization of student flow models is the question of the appropriate level of data aggregation. Although it is an oversimplification, a pragmatic view of one of the differences between micro-and macroanalysis is in the probability of making errors. In the case of microanalysis, the fundamental error source is suboptimization -- that is, solving a small problem very well, while failing to assess properly its contribution to the larger problem. On the other hand, in macroanalysis a primary problem lies in aggregating at such a level as to confound highly significant interactions between variables at the more detailed levels, thus failing to consider an apparently insignificant variable that might, in fact, have a highly significant effect on the overall picture.

Theoretically, the answer to this problem is to break the total system down into modular subprograms, analyzing each subprogram at the micro level and recomposing the results into a macroanalysis. In practice, however, this generally introduces second order problems. In particular, there is the possibility of interaction between modules which were assumed in the initial breakdown to be independent, but which, in fact, are not. Secondly, the costs and complexity of recomposing a sequence of microanalyses are primarily a function of the loss of validity associated with aggregating across the more detailed components. This latter point leads us to an interesting observation of existing models and studies.

It might be said in general, with the exception perhaps of the State of Washington Model, that we either have models awaiting validation with perhaps the hope of iterating into a more appropriate form or that we have studies and analyses hopefully evolving into models. In short, we don't seem to know what is truly significant and what is not. Those who are working from conjecture are forced to test their model hypotheses and correct for errors where possible, while those who are studying the process in detail are evolving models representative of their findings. We cannot afford the errors of the former nor the luxury of the latter. It would, therefore, seem incumbent upon us to approach assumptions with great flexibility while also maintaining the capability for in-depth analyses. This view has been a major factor in determining the approach being taken in development of a NCHEMS student flow projection model.

The NCHEMS Model

The initial model to be developed will be a relatively simple, straightforward enrollment prediction model to assist planners and analysis in estimating enrollments at a reasonable level of aggregation. The model design will attempt to address the most pressing problems in higher education enrollment for the largest proportion of the institutions. It has been proposed that concomitantly with the pilot test of this model a set of analytical tools and procedures be developed for the analysis of student characteristics and economic factors that can influence or condition the probability of a student making a decision to move from one point in the system of higher education to another. This set of tools and procedures will be presented separately from the model in a case study framework. This approach allows model testing to be conducted in conjunction with related studies and analysis, hopefully eliminating the majority of pitfalls associated with doing either independently. The choice of a relatively simplistic initial approach to the model design is being taken for two reasons. First, it should provide a structured approach for assisting a large number of institutions in making enrollment and other basic student related projections for planning. Second, it provides a relatively unencumbered framework for expansion to more sophisticated or specialized models developed on the basis of results of the analysis effort.

The design being chosen is referred to as a linear probability model. That is, the operations performed by the model will have additive and distributive mathematical properties. The word probability in the name refers to the fact that ratios will be used to represent the expected percent of students who move from one state to another during a given time interval. The term linear probability model includes the class of Markov models and, in fact, this model will resemble a Markov model. However, two major differences exist between this design and a classical Markov design. In this model, as with the Rensselaer model, the transitional probabilities may be altered to reflect time related or episodic changes. Thus, the model will not necessarily represent a stationary process.

The second distinction from the classical Markov model is slightly more subtle. In the Markov model, states of the system are defined as being independent of time. Thus, if the major fields of study were considered, the relevant state distinctions, time and student level, would both be dealt with through repeated applications of the transition probabilities. However, the NCHEMS model will consider combinations of student level and major fields of study as states, as well as considering certain additional factors such as entering status (e.g., new freshman, transfer student, etc.). The use of student level as part of the defining characteristics of a state partially condition the model on time in the system and more specifically the amount of time spent in a major field. Thus, the transitional probabilities defined for this model will not be, in fact, classical Markov probabilities. Investigations will be made during both the pilot test of the model and the case studies to assess the effect of this conditioning and the need for further refinement in terms of the classical time independent model.

SECTION II: CONCEPTUALIZATION OF A STUDENT ENROLLMENT PROJECTION MODEL

ENROLLMENT PROJECTIONS FOR PLANNING

The basic purpose of the NCHEMS Enrollment Prediction Model will be to assist in long-range planning for higher education. Student enrollment predictions have implications for a number of decision-makers in higher education management. Among these are admissions officers, business officers, and academic facility planners. Although a level of detail sufficient to handle individual course requirements is not presently envisioned, the model should be adaptable for use by academic planners if it is determined desirable through the use of an induced course load matrix similar to that included in the NCHEMS Resource Requirements Prediction Model (RRPM).[12]

Scope of the Problem

Institutional planning is done against a myriad of objectives. No one model will ever be a panacea for the planner, and one that attempts to solve all problems will probably solve fewer, if any at all, than a model well targeted on a selected set of problems.

At the present time the single most important planning problem at the institutional level is that of resource allocation. It follows, then, that enrollment projection for resource planning purposes is one of the important needs of planners. For this type of planning, information on expected numbers of students by level and major field of study is needed.

Other kinds of information of considerable importance to institutional planners are those associated with providing educational opportunities to their constituencies and with planning to meet manpower needs of society. The first of these two may be viewed as planning to meet input demands, while the second suggests planning to meet output requirements. In both of these cases some behavioral information on students is necessary to determine with reasonable accuracy the effect of institutional decisions designed to assist in meeting planning objectives. For example, if one objective of the institution is to produce a certain number of qualified physicists per year, then it is important to know what student characteristics are associated with the highest persistency among physics majors and what institutional incentives have the most payoff in terms of choice of major and tendency to persist. Similarly, if, for instance, the institution undertakes to change the make-up of its student body to reflect a higher percentage of a particular minority group, then it is important for the planner to know what differences in persistency may exist within this target group and what differences in reaction to institutional aid and incentive programs may be reflected in this change.

While it is true that changes in the constituency may occur without any specific effort being made by the institution, and while demands for particular fields of study may change as a result of factors external to the institution, in most cases these events are episodic and the effects are transient. When such situations do occur. the prediction of the resulting effects on resource demands are likely to be dependent on the analysis of factors that are not normally relevant to similar predictions under steadystate conditions or on factors for which no historical data exists.

For the purposes of this discussion, the aggregate flow of students into the institution, through fields of study and by level, and out of the institution will be called the enrollment process; a model of this process will be referred to as an enrollment model. A student flow model will be one which considers economic and socioeconomic factors that affect or condition the process. Thus, this paper is primarily concerned with the specifications of an enrollment model to assist in resource planning.

ENROLLMENT FLOWS

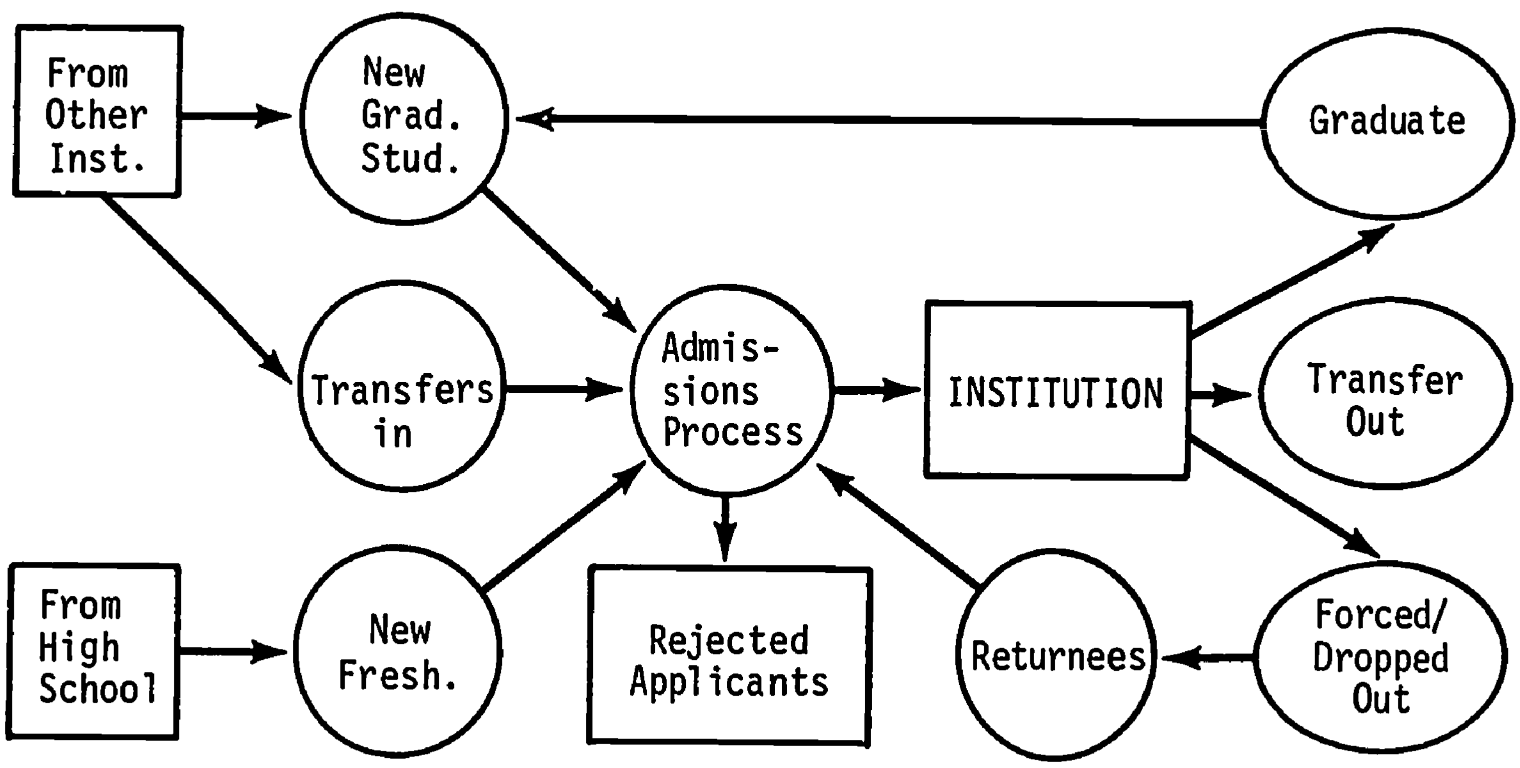
The enrollment process can be considered to have two major components. These are the input-output processes and the system process. The input-output processes as the name implies are the processes by which students enter and leave the institution while the system process is the process by which students move between major fields-of-study and progress through the various levels.

The Input-Output Processes

The schematic in Figure 1 represents the flow of students into and out of the institution.

Figure 1

INPUT/OUTPUT FLOW



New students arrive from both high school and other institutions either with or without a delay during which they are part of the general population. Former students may return as previous degree winners. All of these groups proceed through some form of admissions process while returning nondegree winners may or may not go through this process.

Because of the varying admissions policies among institutions, it is important to distinguish between the various conditions under which a student can enter or re-enter an institution, and similarly, it is important to distinguish between the various ways in which students leave an institution. Table 1 presents a list of student status for entering and departing the system. For many institutions, it may be desirable to further divide the categories under Entering Status into in-state and out-of-state.

Table 1

ENTERING/DEPARTING STATUS

Entering Student Status	Departing Student Status
1. New Admissions	1. Program Completion
a. New Freshmen	a. Transferring to other institution
b. Transfers	b. Dropped out
c. New Graduate Students	c. Forced out
2. Previously Enrolled	(1) academic
a. Departed in good standing	(2) other
b. Other	

While it is obvious that additional distinctions are possible, this list was chosen as representing those aspects of the basic input and output sets which may be of most interest for planning purposes to the majority of institutions. An obvious question that arises is how to classify students who transfer out and later transfer back, since these students meet the criteria of both previously enrolled and transfer. The choice is generally based on whether or not the student must reapply for admission and the manner in which he applies. The primary consideration in distinguishing between entering categories is type of admissions decisions that are involved.

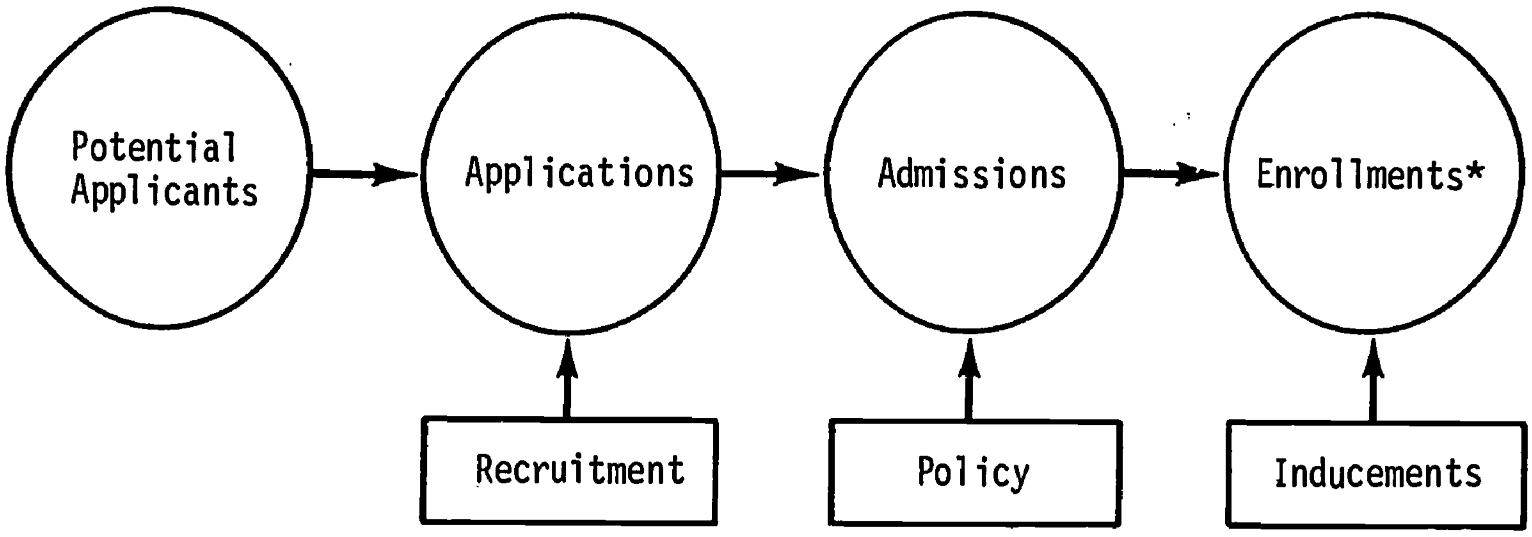
In making distinctions between the various departing states, again the primary consideration is the kind of data necessary for planning decisions. For a number of institutions it may be sufficient to simply distinguish between degree completers and all others leaving. Since dropouts and force-outs are different kinds of potential returnees, it may be desirable that an attempt be made to make that distinction. However, many institutions may not be able to distinguish in their data between dropouts, force-outs, and transfer-out students, and thus, it will be necessary to treat them as the same.

The Admissions Process

Within the input-output processes there is a subprocess associated with admissions. This is a linear process in which the number of students, in general, decreased from one state to the next. Figure 2 represents the admissions flow.

Figure 2

ADMISSIONS FLOW



An institution may influence the process in any of three ways. One is the extent to which it engages in recruitment for applicants from the potential pool, second is the admissions decision it makes with respect to the applications it receives, and third is the extent to which it offers inducements to admitted applicants.

The System Process

Within the present framework of resource planning there are two dimensions to student enrollment or an institution that are as essential as input to the planning process. These are the student's field of study and student level.

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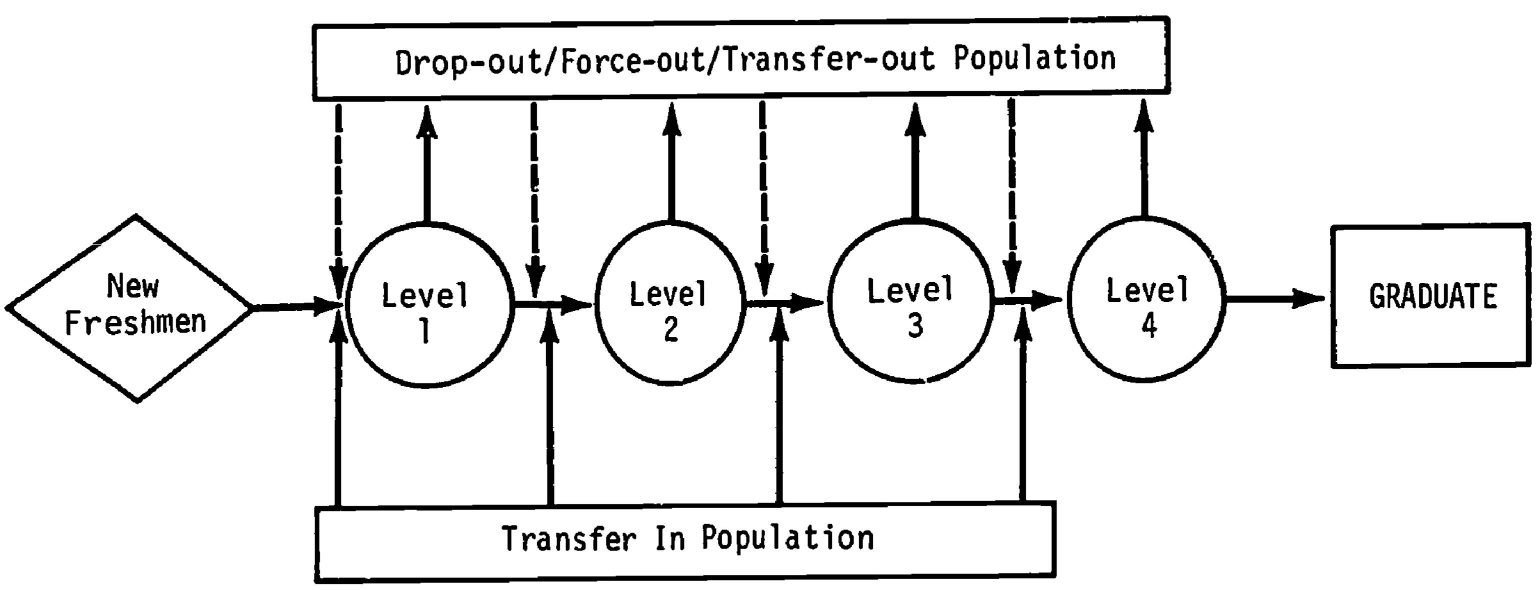
*Enrollment here refers to the act of enrolling as opposed to the state of being enrolled as referred to in the systems process.

The system process includes the movement of the enrollment population between the various combinations of these two dimensions and from the input to the output states. Figure 3 is an elementary schematic of the relation between input-output and movement between levels for an undergraduate institution.

Figure 3

STUDENT MOVEMENT BETWEEN LEVELS



The arrows indicate the progression of movement, and the dotted arrows indicate that some portion of the drop-out/force-out/transfer-out population returns to the system. The entering arrows between levels are meant to imply that entries take place before terms begin while departures may occur at any time.

The movement between fields of study is somewhat more complex than those already discussed. Two primary problems contribute to this complexity. First, transfers between any two majors are conceivably possible, although not necessarily probable. Second, a large portion of first and even second year students either may not declare a major, or, if they do declare, the choice is subject to considerable change. However, the problem becomes less complex for upper division students. At that level the rational alternatives are fewer, and, while seemingly irrational changes are still possible, their actual occurrence may be rare enough to justify ignoring them in aggregate projections.

It is possible that changes in major field of study between the bachelor's degree and graduate school are, in general, more constrained than are changes within lower division, but less so, in general, than changes within upper division. On the other hand, once the graduate major field is chosen, a change in major prior to completion of a degree is probably less frequent than at any other level.

Thus, in general, there appears to be a decreasing propensity to change fields of study as the level of the student increases, with the majority of changes occurring between lower and upper division and again between upper division and graduate or professional schools. For these reasons it appears appropriate for projection purposes, at least in the case of baccalaureate grating institutions, to consider lower division students by aggregated fields of study and upper division and graduate students by disaggregated fields of study. Aggregation among lower division students to the school level appears appropriate for resource planning purposes for these institutions since a large proportion of their students may not declare majors in the freshman year, and, further, the presence of lower division students in a given school tends to induce a reasonably homogeneous course load. Two-year Colleges, on the other hand, will probably want to make projections based on major field of study, since movement patterns for the lower division student in their case are probably more complex.

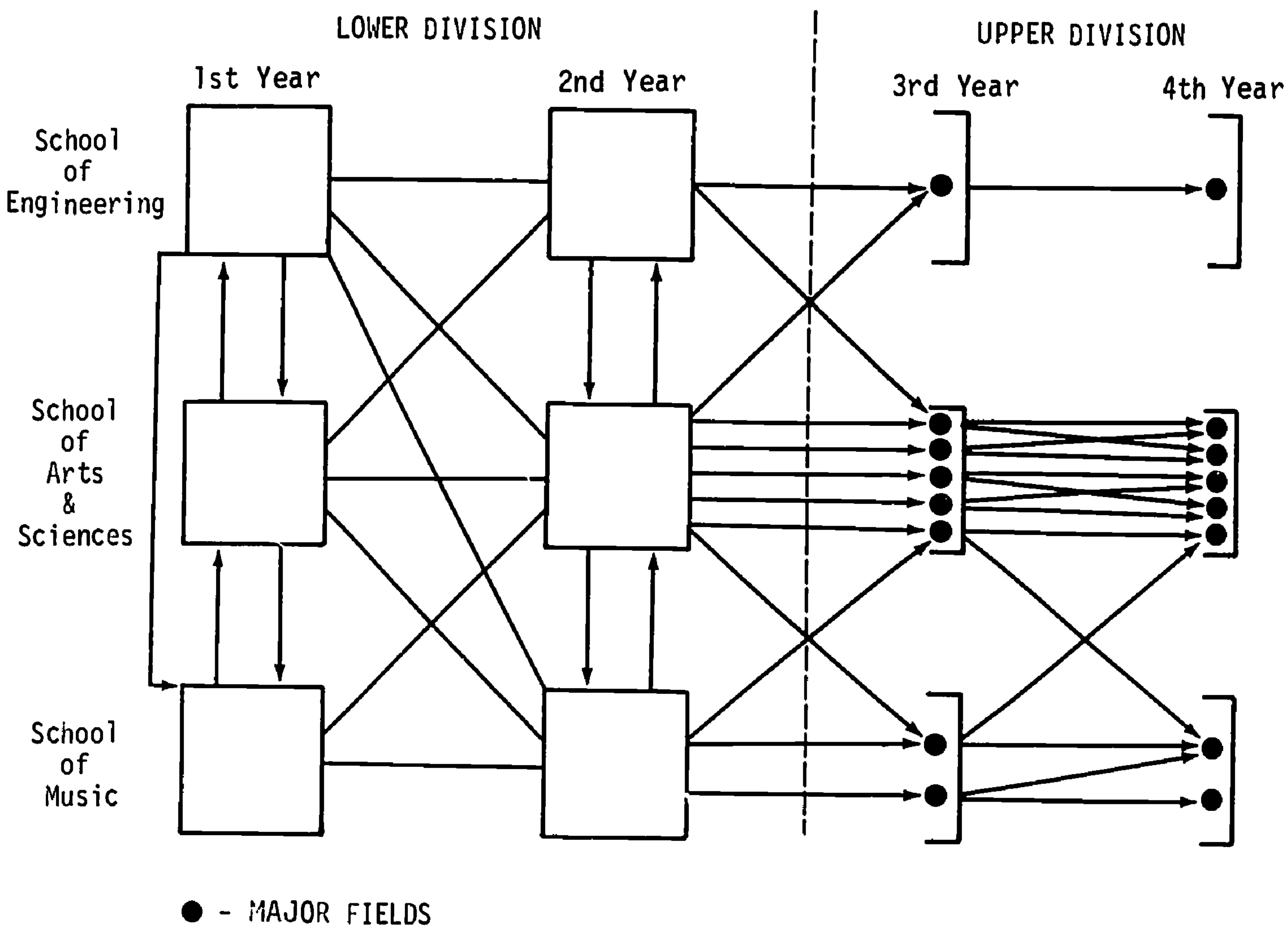
The schematic in Figure 4 represents a hypothetical network of one set of possible movements between three schools and related fields of study across the four undergraduate levels. This schematic would have to be modified for two-year and specialized institutions.

The input and output component is not included in the diagram because of the obvious complexity.

The composite of the various component flow processes described thus far represent the enrollment flow in an institution of higher education.

Figure 4

MOVEMENT BETWEEN MAJORS AND SCHOOLS OVER TIME



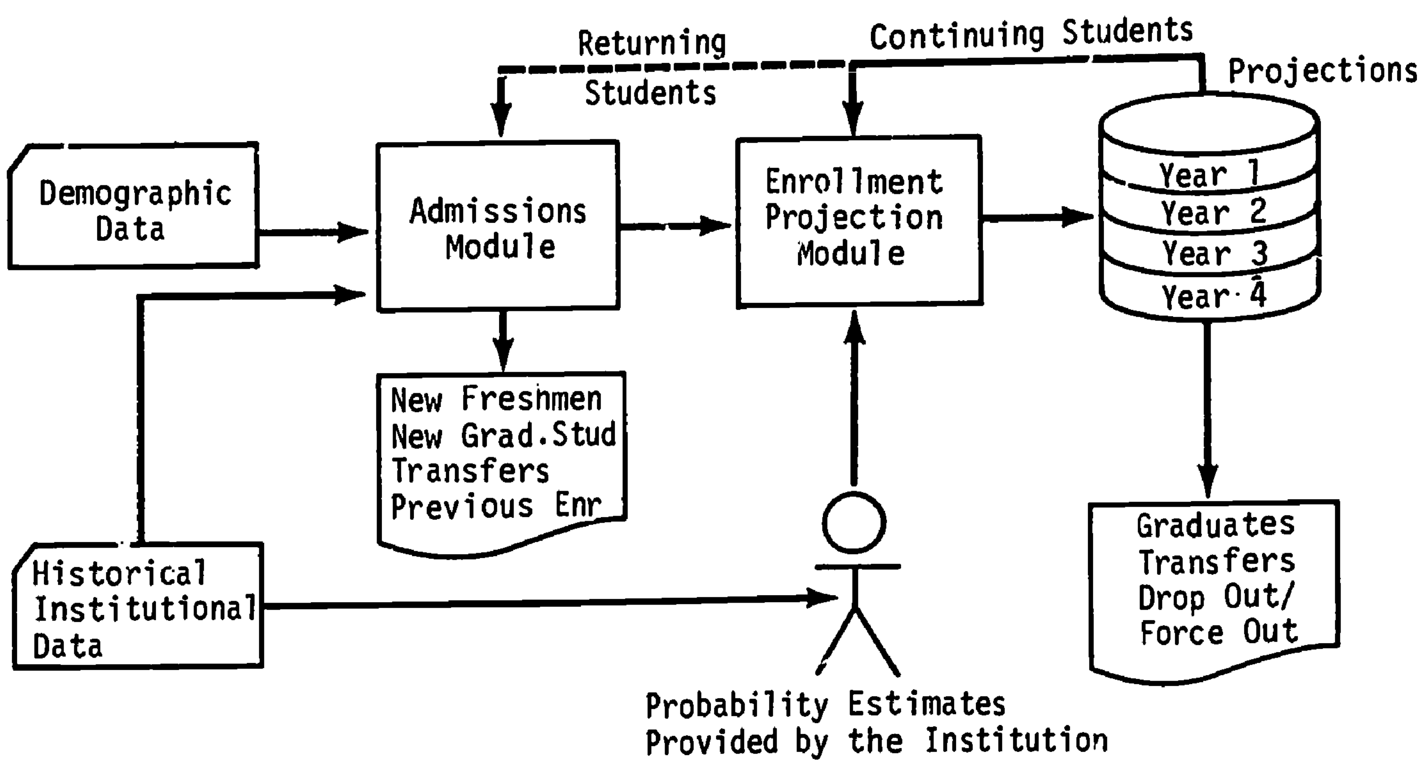
THE MODEL DESIGN

The NCHEMS Enrollment Projection Model will be comprised of a series of three interrelated modules. The first of these will deal with the admissions process and produce, from demographic and historical institutional data, estimates of the applicants for admission and the number of admitted students who enroll. The second module is the enrollment module which will use the new enrollment provided by the admissions module and the previous enrollment to project the next enrollment set by major and level. The third module is to be provided by the user to develop estimates of the probabilities of making the various transitions required by the other two modules.

The interrelation between the three modules is depicted in Figure 5.

Figure 5

INTERRELATIONSHIPS OF MODEL MODULES



The dotted line in Figure 5 indicates that projected numbers of graduate and other departures may be used to estimate readmissions in lieu of historical data. The user may choose to by-pass either the admissions module or the probability estimation module in making projections and use his own estimates of new enrollments or probabilities as input. This option will be discussed further in the section dealing with those modules.

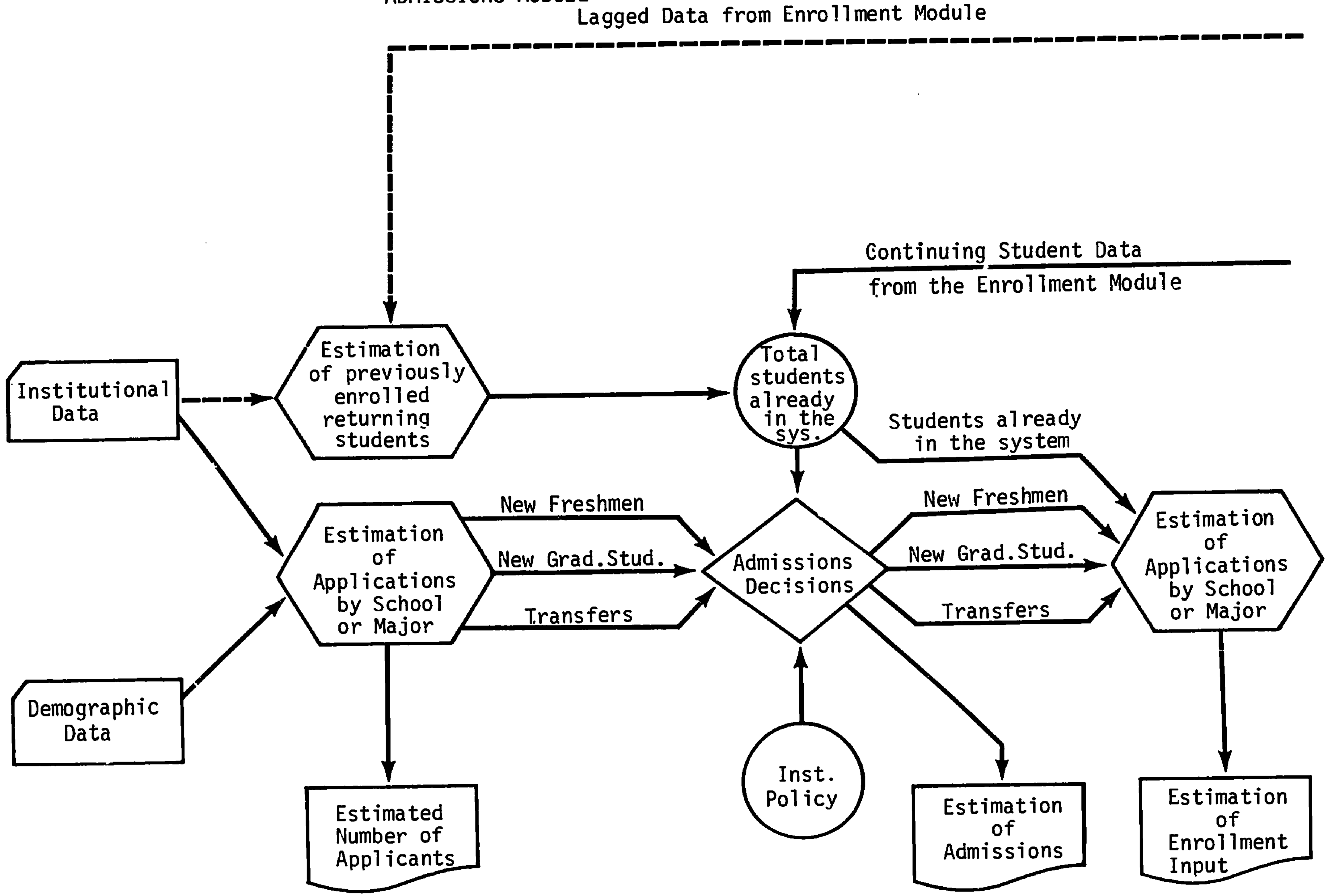
The Admissions Module

The purpose of the admissions module is to provide estimates of the number of incoming students each year for input to the enrollment module. Estimates of the number of applicants for admission will also be produced by this module at the option of the user. Figure 6 is a schematic of the admissions module.

For the purposes of the following discussion, it should be understood that the admissions process is viewed differently by the student and the institution. That is, the student sees the process in relation to time or the sequence of events he goes through. Thus, the admission process from his point of view flows logically from application to acceptance to enrollment. On the other hand, from the point of view of decision making, the process is not so directly time/event oriented. For example, the decision on the number of applicants to admit follows the decision on how many new students the institution wants or can handle. Between these two decisions it is generally necessary to estimate the expected number of admitted students who will actually enroll. Therefore, the institutional decision process, and, as a result, a substantial portion of a model of the system works in reverse of the student's view of the process. While the discussion of the admission module will follow the normal time/event sequence, it will be necessary to relate institutional decisions and their model counterparts to previous paragraphs in order to make the relevant connections in the process.

Figure 6

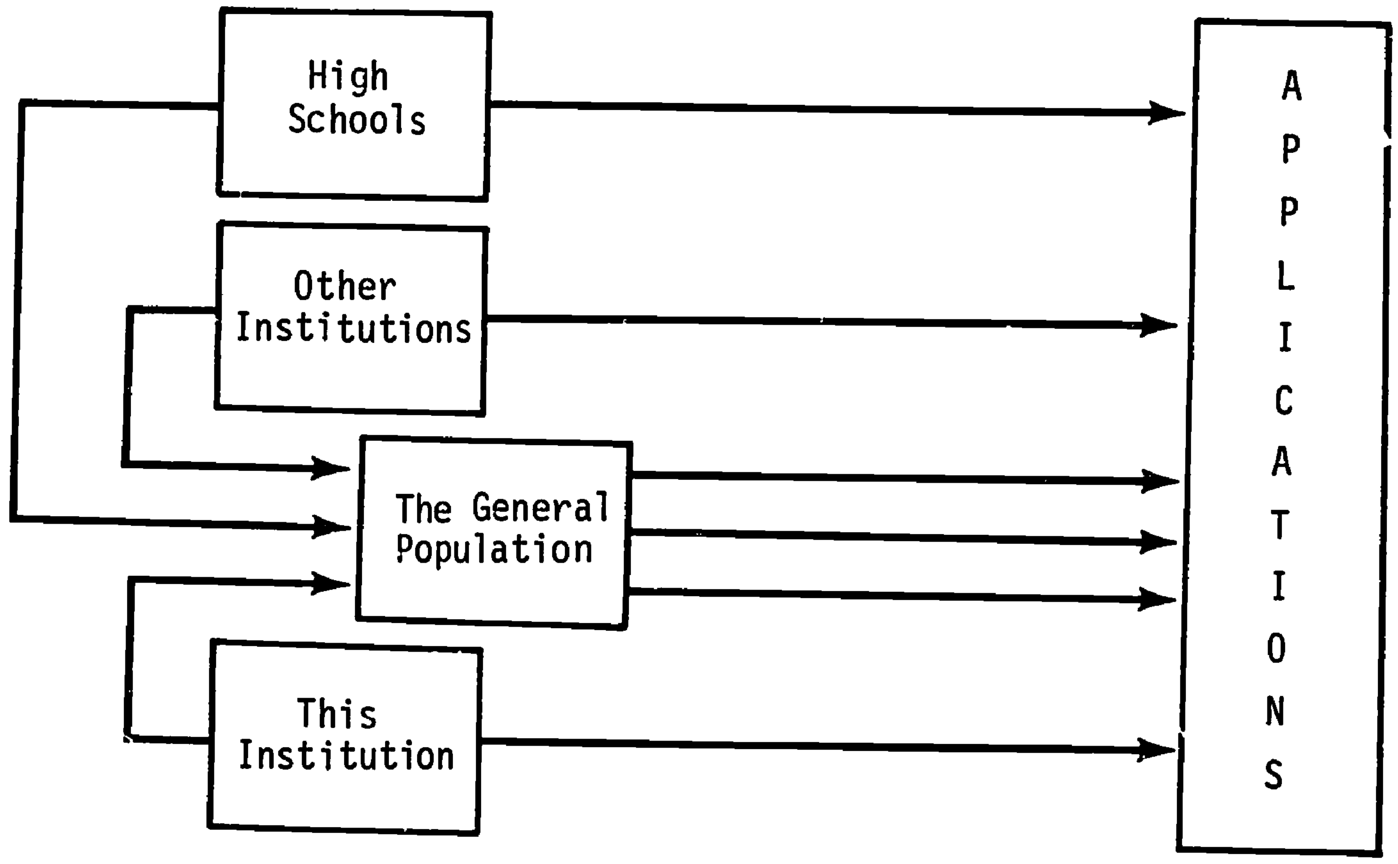
ADMISSIONS MODULE



Applicants come from four sources -- high schools, other institutions, the population at large, or from the same institution, e.g., new graduate students. Those coming from the population at large actually come from one of the other three sources, but have not been attending for some period. The schematic in Figure 7 shows this relationship between sources.

Figure 7

SOURCE OF APPLICANTS TO AN INSTITUTION



Associated with the different sources of students are basically two types of data available for making forecasts. First, there may be data available on the population of potential applicants, and second, there are data on past action. For example, data on the number of high school graduates over time in a particular locale may provide information on that potential applicant source while both percent of high school graduates who attend and the number that apply provide information on the past action of that potential source. The latter two differ in that the probability is of little value if the number of graduates is not known, while the number of applicants provides directly usable information. These two indicators will be referred to as relative measure and direct measure respectively.

Table 2 provides a list of the kinds of information relevant to the various sources of applicants. Clearly, not all of this information is readily obtainable. As a result the same technique for forecasting applicants is not equally applicable for all cases.

Various forecasting techniques are available for estimating the number of applicants from the various sources. One such technique is linear and nonlinear least squares regression. This technique is intended to be used for cases in which direct measures are the best information reasonably available for making projections. For example, probably the best information available on applicants from the general population who previously attended other institutions is the number who have applied over past years. A

TABLE 2

SOURCES	POTENTIAL POPULATION	RELATIVE MEASURE	DIRECT MEASURE
DIRECT			
High School	Number graduating each year	Percentage who apply	Number who apply
Other Institution	Number graduating and number departing for other reasons each year	Percentage who come to this graduate school Percentage who transfer to this institution	Number of graduate students applying from other institutions Number of trans.
This Institution	Number graduating	Percentage who attend this graduate school	Number who continue in graduate school
THE GENERAL POPULATION			
High School Graduates	Number graduating and not attending in the past	Percentage of some previous year's number that attended this year	Number applying each year
Attended Other Institution	Graduated or departed some time past	Percentage of previous grads. (departures) who apply to this institution	Number who apply each year
Attend This Institution	Drop-outs and force-outs in the past	Percentage of previous departures that reapply	Number who reapply per year

least squares prediction for future years based on that information could be attempted using regression techniques.

Another alternative technique for projecting applicants is a combination of estimating the propensity to apply (percentage of the given population that apply) and estimating the population. These two numbers are then multiplied to obtain the estimate of the number that will apply. The estimates of the percentage value and the size of the population are obtained using regression. This approach produces essentially the same estimate of applications as would be obtained using a single multiple regression prediction with time and population size as independent variables. However, the necessity of estimating future values for population size would still remain. The primary advantage in estimating the percentage separately is that the user can observe and, if it is desired to reflect some expected phenomenon not represented in the historical data, change the percentage of the population that applies. Suppose, for example, if it is discovered that on the average ten percent of the past five years' total drop outs and force outs return for readmission each year, then ten percent of the smoothed estimate of that number who will have dropped out over the next five years can be used as the expected number of readmissions for that year. If, however, in making similar projections for next year it is known that the unemployment rate has doubled it would probably be desirable to alter the ten percent figure upward to obtain some measure of the impact of the increased number of returning students that can be expected.

A third alternative technique is a lagged correlation estimation (or cross correlation) technique. This technique is most appropriate for situations in which a lag exists between two actions such as between leaving one institution of formal education and entering another. A coefficient of correlation is computed between the two variables (such as number leaving and number re-entering) as a function of the number of years between values (lag). The purpose of a lag technique is to determine what number of years between departure and return is best to use for estimation purposes. If, for example, the number of students returning for readmission in a given year is most highly correlated with the number of students that left the institution three years before, then departures in a given year can be used as a predictor of returnees three years later.

It may be reasonable in many cases to estimate the number of applications from more than one potential source in an aggregate manner. This will be true if the situation is relatively stable over time or if the best predictor of applicants is the same for more than one source. Some institutions will find it appropriate to aggregate applicants from the general population or at least the high school graduates and transfers and perhaps also the direct transfers. For many institutions, admissions policies and data on applicants will be sufficiently different for in-state and out-of-state students that a distinction is necessary in making projections. In such cases, it will probably be more convenient to project them separately, then aggregate by status after the projection is made. Further, different techniques may be implied by the difference in source. For example, it may be best to project in-state new freshmen on the basis of high school graduates and out-of-state freshmen using simple least squares regression against time.

Model Admissions Controls

Admission decisions are made on the basis of two factors. These are the qualifications of the applicants and the maximum number of vacancies available for additional students. This maximum is an enrollment ceiling, self-imposed or established by law. This number may change from year to year and may be a function of the previous year's enrollment. In the case of institutions required by law to accept all qualified applicants, the enrollment ceiling must be considered for all intents and purposes to be infinite. In the case of institutions that are operating below their maximum capacity, there may, in fact, be such a maximum number. However, it has no practical value and thus may be any arbitrary large value with respect to present enrollment.

The number of qualified applicants is provided to the admissions decisions routine either by the projection process already described or directly by the user. The number of maximum enrollments allowable can be determined in either of two ways. In one case a predetermined number or series of numbers is provided to the routine. This will represent the enrollment ceiling which may be specified separately for graduate and undergraduate enrollments. For some institutions this ceiling is constant, for others it may represent a planned growth, and for others it may be infinite. In the second case a percentage growth rate is provided. This represents the maximum growth from year to year that the institution can accept. It will be applied to the previous year's enrollment to determine the maximum allowable enrollment for the subsequent year. This rate can also be negative.

In the model, applicants are admitted by one of two methods. The user specifies either a priority ranking for admission such as freshman first, graduate students second, transfers third, or a percentage of the enrollment by type of admission. A combination of these two can be used. For example, a user can specify that ten percent of the admissions should be graduate students and other students should be admitted in some order of priority. If there is not a sufficient number of applicants in a category to make up the percentage specified, the user may at his option have the difference made up from the other categories on the priority basis specified.

If the user does not wish to specify either a priority ranking or a percentage, the admissions will be distributed in proportion to the numbers of students previously enrolled. For example, if ten percent of the previous year's students were in graduate school, twenty percent freshmen and seventy percent other, admissions would be made in the same proportions.

The number of admissions are converted to numbers of enrollees by use of a percentage adjustment based on smoothed historical ratios of the number that enroll to the number that are admitted. This number is actually used twice in the model. First, this proportion is applied inversely to the vacancies to meet the requirement for over-admission so that a sufficient number will actually enroll to fill the vacancies. The ratio is subsequently applied directly to the admissions to project the number of enrollments. A different ratio may be used for each type of entering status and may be varied with time.

The final component of the admissions process that must be dealt with is a consideration of students who return to the institution after an absence without having to meet a requirement to reapply for admission. The numbers of these students can be estimated in the same manner as applicants who previously attended. If the estimates are made with a regression equation, the numbers are entered directly into the admission module. If, instead, a lag equation is used that requires the numbers of departures in a previous year, these are obtained from earlier projections made by the enrollment module. In any case, these numbers are combined with the numbers of students in the system. This is accomplished before the continuing student enrollment is subtracted from the allowable total enrollment to obtain the number of vacancies for admissions purposes.

Admission Data and Output

The specific data necessary as input to the admissions module has been implied through the discussion of the operation of the module. Available output projections have also been implied. Table 3 summarizes the minimum data necessary to make admissions projections, the data required for making projections in the suggested* manner, and the outputs that are available from the module.

The Enrollment Module

The purposes of the enrollment module is to project the total postregistration enrollment and the end-term status of the enrolled group. The module consists of three major components. The first is a transformation routine that distributes the new enrollees into major fields of study by level and projects the changes in levels and majors for students continuing from the previous year. The second routine aggregates the new and continuing students producing the total postregistration enrollment. The third routine projects the end-term status such as forced-out, graduated, etc., by major and level. This information is used for output purposes and as input to the admissions module for subsequent year's projections. Figure 8 is a schematic of the enrollment module.

The transformation routine makes projections to new majors and levels using estimates of the percentages of students that historically have

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*Suggested here refers to the data which is assumed to provide the most stable and accurate projections. The question of what data are most appropriate for the projections will be addressed in considerable detail during pilot testing of the model.

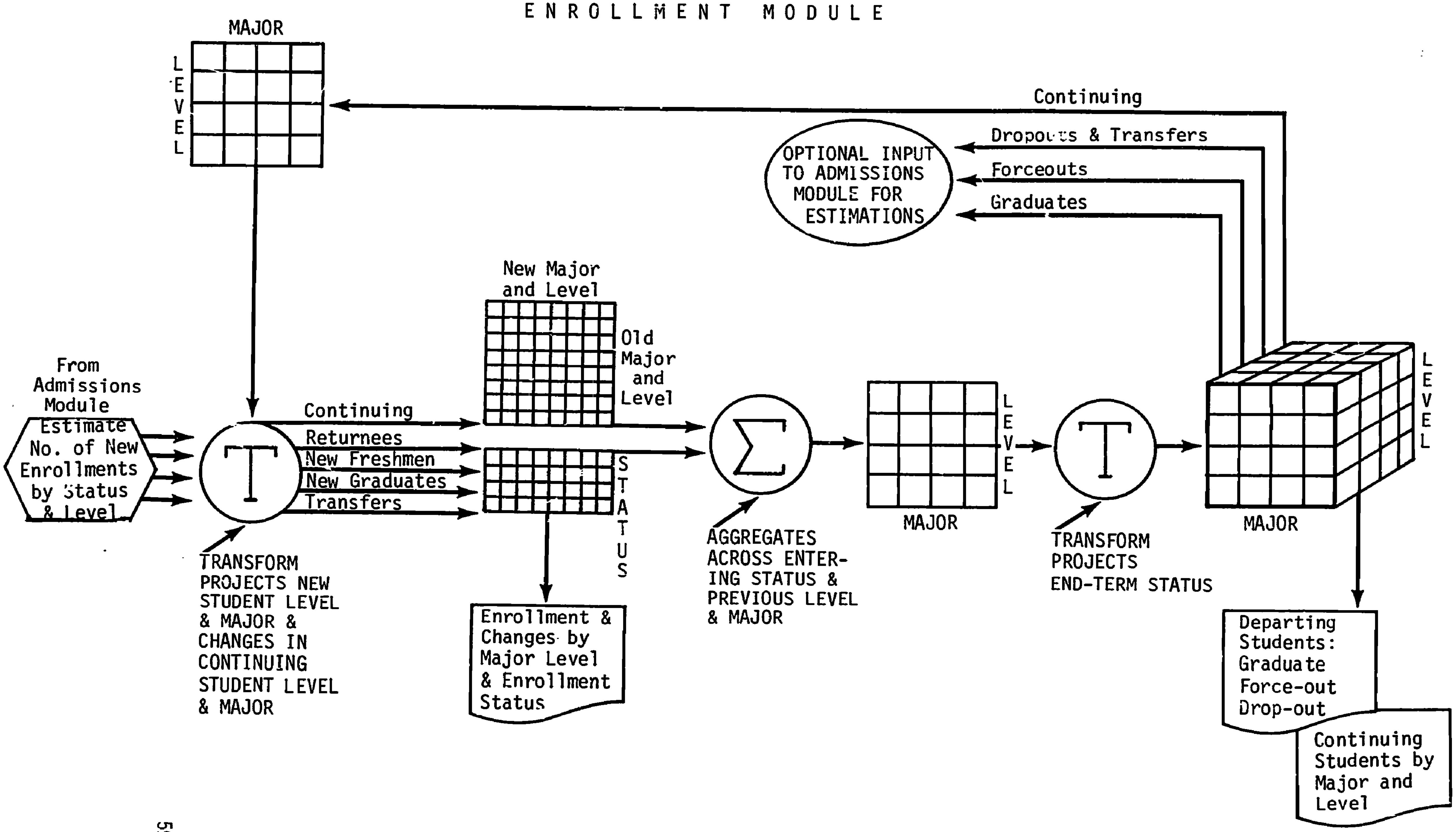
TABLE 3

ADMISSIONS MODULE DATA

Minimal Input	Preferred Input	Output
Number of new freshmen	Number of new freshmen by year (Direct/Indirect)	Number of applicants*
Number of returning students by year	Number of returning students by year	Number of admissions*
Number of new freshmen by year	Number of graduates	Number of enrollees*
Number of new graduate students by year	Number of students who continue on to this graduate school	Number of returning students
Number of transfers by year	Number of new graduate students (Direct/Indirect) from other institutions	
Percentage of applicants who enroll	Number of transfers (Direct/Indirect)	
Demographic Data		
	Number of high school graduates by constituency locale	
Institutional Decision Data		
Enrollment limits by number or growth rate Distribution of admission by percent or priority	Enrollment limits by number or growth rate Distribution of admissions by percent or priority	
Other Data That May Be Useful		
	Number of high school graduates not attending any institution initially by constituency locale Number of drop-outs/force-outs by year	*Each by new Freshman, transfer, and new graduate students

Figure 8

ENROLLMENT MODULE



made the same changes. These estimates are obtained from historical institutional data through the use of the estimation module. Two sets of transformation operations are performed. The first establishes majors by level for the new students. As an example, assume that the institution has four graduate level majors and that the historical pattern exhibited by new graduate students entering the institution is given by the numbers in parentheses in Table 4. Then if there were 76 new graduate students they would be distributed as:

Table 4

HYPOTHETICAL DISTRIBUTION OF NEW GRADUATE STUDENTS

	Beginning Graduate	Advanced Graduate	TOTAL
Program 1	23 (.30)	4 (.05)	27 (.35)
Program 2	15 (.20)	2 (.025)	17 (.225)
Program 3	11 (.15)	8 (.10)	19 (.25)
Program 4	11 (.15)	2 (.025)	13 (.175)
TOTAL	60 (.80)	16 (.20)	76 (1.0)

Two points should be noted. First, the probabilities associated with distributing any specific input group must sum to one in order to guarantee that the distributed sets match the input set. Second, in the diagram of Figure 8 the incoming students are projected into an array with major and level as designators for both the rows and columns. This array is read as students coming from a row designation and going to a column designation. For example, a student previously in major 1, level 2, projected into major 1, level 3, would appear in the second row, third column. Since new students do not have a previous major and level, they are arrayed in rows by their entering status and in columns by their new major and level.

The transformation required to project the students continuing from the previous year is, in general, a square array of ratios representing the proportion of students moving from each combination of major and level to each other combination. Thus, in general, the number of entries across the top or along the side of the array is equal to the number of levels times the number of major fields of study. However, as discussed earlier, the number of reasonably possible transitions is something less. In particular, backward movements in student level are rare and for some institutions are not possible by definition.

By way of example, assume we have an institution with four student levels and two majors. The array in Table 5 represents a set of hypothetical transition probabilities between combinations of level and major.

Table 5

HYPOTHETICAL TRANSITION MATRIX

New Status (going to)

Old Status (coming from)	LEVEL	Major 1: 1	Major 1: 2	Major 1: 3	Major 1: 4	Major 2: 1	Major 2: 2	Major 2: 3	Major 2: 4
Major 1	Level 1	.08	.83	.02	0	.02	.05	0	0
	2	0	.05	.85	.02	0	.02	.06	0
	3	0	0	.02	.93	0	0	.02	.03
	4	0	0	0	.95	0	0	0	.05
Major 2	1	.01	.04	0	0	.04	.90	.01	0
	2	0	.01	.03	0	0	.03	.91	.02
	3	0	0	.01	.02	0	0	.02	.95
	4	0	0	0	.03	0	0	0	.97

In this array, each of the rows adds to one. The probability of students moving from level 4 to level 4 is equal to one since the only level four students in the data set are by definition continuing students and the only alternative to remaining at level four is graduating.

If the enrollment set:

	Major 1				Major 2				TOTAL
LEVEL	1	2	3	4	1	2	3	4	----
NUMBER	500	400	300	30	300	250	200	20	2000

is premultiplied by the matrix array of probabilities, the component result would represent the students projected from each major and level combination to each other. This result is presented in Table 6.*

Table 6

PROJECTED NUMBERS OF STUDENTS BY LEVEL AND MAJOR

NUMBER COMING FROM:		TOTALS COMING FROM	NUMBER GOING TO: MAJOR 1 LEVEL 1	MAJOR 1 LEVEL 2	MAJOR 1 LEVEL 3	MAJOR 1 LEVEL 4	MAJOR 2 LEVEL 1	MAJOR 2 LEVEL 2	MAJOR 2 LEVEL 3	MAJOR 2 LEVEL 4
MAJOR 1	LEVEL 1	500	40	415	10	0	10	25	0	0
	2	400	0	20	340	8	0	8	24	0
	3	300	0	0	6	279	0	0	6	9
	4	30**	0	0	0	29	0	0	0	2
MAJOR 2	LEVEL 1	300	3	12	0	0	12	270	3	0
	2	250**	0	3	8	0	0	8	228	5
	3	200	0	0	2	4	0	0	4	190
	4	20	0	0	0	1	0	0	0	19
	TOTAL	2000	43	450	366	321	22	311	265	225

---

* Each column of this array is obtained by multiplying the entries in the corresponding column of the array of probabilities by the matching level and major number in the enrollment set.

** Totals are not equal to the row sum due to round-off error.

The user may choose to treat every major within each level with the model. However, unless so specified, the model is designed to treat lower division students by school and upper divisions and graduate students by major. One way this may be done is through the use of a matrix of the type depicted in Table 7. The X entries in the matrix of Table 7 designate cells that most likely have nonzero entries.

Table 7

EXAMPLE OF A MIXED TRANSITION MATRIX

	Going to:	School 1		School 2		Major 1		Major 2		Major 3	
Coming From:	Level	1	2	1	2	3	4	3	4	3	4
School 1	1	x	x	x	x						
	2		x		x	x		x		x	
School 2	1	x	x	x	x						
	2		x		x	x		x		x	
Major 1	3					x	x	x	x	x	x
	4						x		x		x
Major 2	3					x	x	x	x	x	x
	4						x		x		x
Major 3	3					x	x	x	x	x	x
	4						x		x		x

Also, unless specified differently by the user, the model will treat seven student levels.* Table 8 designates the number of levels and fields that are standard in the design with optional numbers in parentheses.

*Chosen to agree with the specifications of the NCHEMS Resource Requirements Prediction Model (RRPM).

Table 8

NUMBER OF MAJORS AND LEVELS AVAILABLE IN THE MODEL

	Number of Levels	Number of Schools of Major Fields of Study
LOWER DIVISION	2 (1)	5 schools (up to 80 major fields)
UPPER DIVISION	2 (1)	33* Major Fields (up to 80)
GRADUATE	2 (1)	33* Major Fields (up to 80)
OTHER	1	33* Major Fields (up to 80)

After the projections of new levels and majors for continuing students have been made and the output displays developed, the model will aggregate the numbers across previous majors and levels to obtain total counts within majors and levels postregistration ("total going to" numbers in Table 8) and also across status such as new student and continuing student to obtain the total postregistration enrollment.

The final routine in the enrollment module will project the end-term status by level and major. This will be accomplished in essentially the same manner as the other projections. An array of probabilities is obtained using historical institutional data, and the enrollment set is applied to these probabilities. The basic status variables are program completion (graduation), force out, drop-out, transfer, or continuing next year. The force out and drop-out or transfer can be treated as a single variable -- departed, incomplete -- if desired.

Table 9 presents a hypothetical array for projecting end-term status for one major and four levels.

Table 9

END-TERM STATUS RATIOS FOR ONE MAJOR

Status / Level	GRADUATING	DROPOUT	FORCE OUT	CONTINUING
1	0	.19	.10	.71
2	0	.10	.07	.83
3	.03*	.02	.02	.93
4	.86	.02	.02	.10

Assuming that after the new students and the continuing students have been aggregated, the enrollment within the major of this example is:

Level	1	2	3	4
Number	100	80	60	45

*These numbers represent the fact that some students can, in fact, accumulate enough hours to graduate in three years.

then the projected end-term status would be:

Level \ Status	GRADUATING	DROPOUT	FORCEOUT	CONTINUING
1	0	19	10	71
2	0	8	6	66
3	2*	1	1	56
4**	39	1	1	5

This projected array is obtained through simple matrix multiplication of the vector of students by level and the matrix of probabilities.

Performing this operation for each major yields the projected number of graduates, other departures, and continuing students. The latter of these is used as direct input to the next set of projections while the other two may be used as inputs to the estimation of new graduate students and with appropriate lag as input to the estimation of returning students.

Table 10 provides a summary of the inputs required by the enrollment module and the outputs produced by it.

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* These numbers represent the fact that some students can, in fact, accumulate enough hours to graduate in three years.

** Row does not sum to the input number due to round-off error.

Table 10

ENROLLMENT MODULE INPUT AND OUTPUT DATA

INPUTS	OUTPUTS
New student input from Admissions Module	New student majors by level
Continuing student input from previous projection	Numbers of continuing students moving from any level and major to any other
Probability estimates for new student major and level	
Transition probabilities for continuing student changes in level and major	Summary enrollment
Probability estimates of end-term status by level and major	Drop-outs, Force-outs, and degrees earned by major and level

Probability Estimation

The purpose of this section is to discuss some methods and techniques that the institution may want to use to develop estimates from historical data of the probabilities used in the various modules. There are a number of alternative methods for estimating the appropriate values to place in a transition matrix for a particular year. The following five techniques for estimating are relatively common:

Least Squares*

Exponential Smoothing*

Mean over N Years

Last Year's Ratio

Conjecture

The relative value of an estimation technique appears to depend, in part, on how far in the future projections are to be made. Near-time estimates can generally be done with reasonable accuracy on a three-year sample, using means of the data or exponential smoothing. For long-range projections, a technique that accounts for trends or cyclic behavior is usually desirable. However, caution should be taken to prevent over-sophistication in making these estimates in order to prevent the estimation problem from dominating the projection problem.

Standard techniques for estimation are linear and nonlinear least squares and exponential smoothing of the data. In the cases where the least squares estimate is not statistically different from the sample mean, the mean should be taken as the estimate. When the estimates do appear to be time dependent, a sequence of estimates for the projection period may be developed for the other modules.

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*For a complete discussion of these methods see, for example, R. G. Brown, Smoothing Forecasting and Prediction of Discrete Time Series, Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1962.

Because of the differing variability of data sets and because the reliability of time dependent estimates tends to decrease as a function of time which estimate is to be used, estimates should be developed individually by the user when appropriate. The user has the facility to input alterations to estimates from the estimation module at any point.

DATA STRUCTURE AND ANCILLARY SYSTEMS

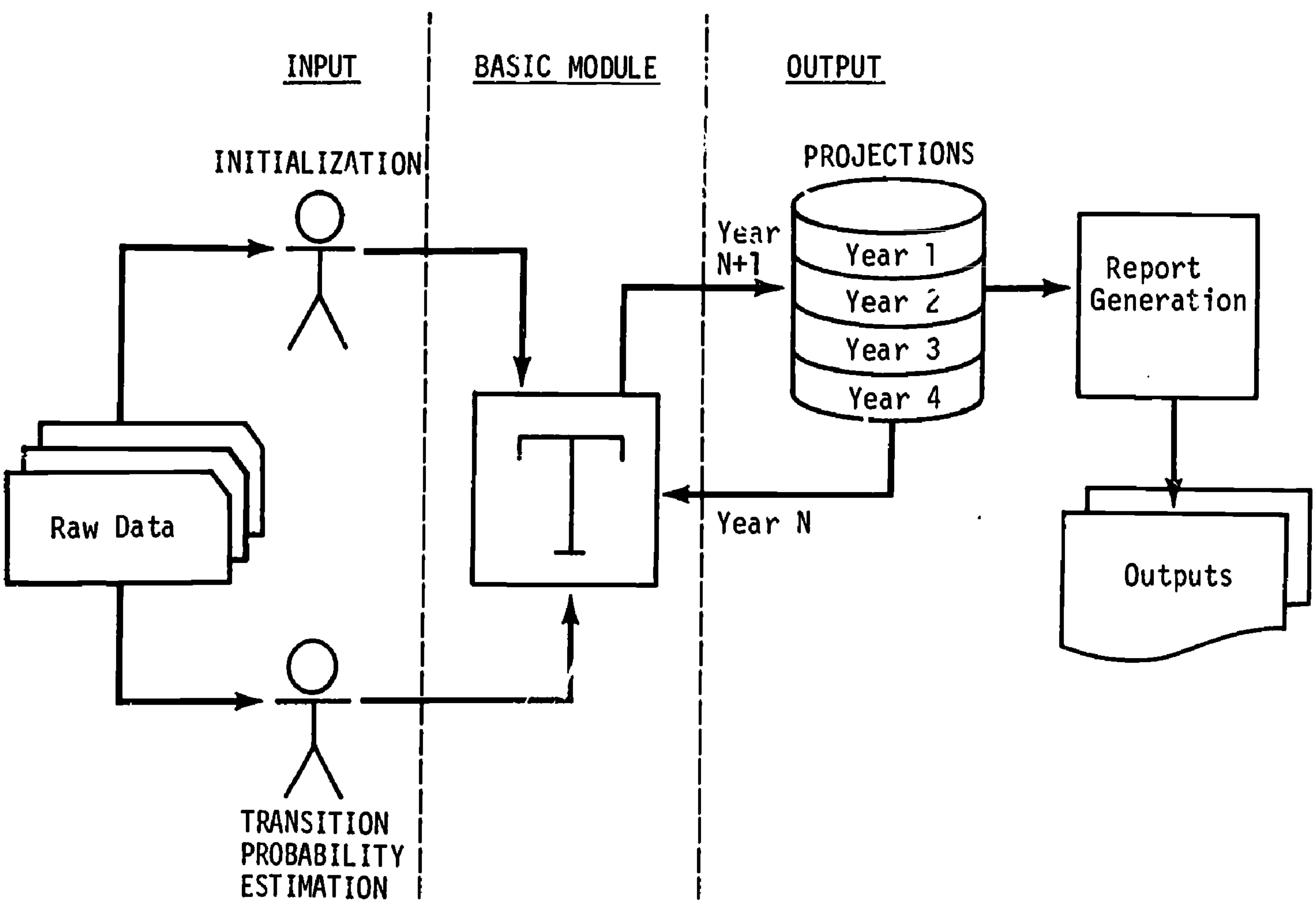
For the purposes of this section, the computational portion of the model will be considered as simply a transformation routine that computes all appropriate transitions between levels, majors, types of status such as entering, continuing, or departing, etc. This transformation and the manner in which it is applied to data will be referred to as the basic module. The basic module will be discussed further in a later section.

The diagram in Figure 9 depicts the relationship between the basic module, inputs and outputs, and related systems.

The model is iterative in nature -- that is, projections for one year provide the input for projections in a subsequent year. The model discussion presented here will concentrate on each aspect of the diagram in Figure 9, exclusive of the basic module itself.

Figure 9

RELATIONSHIP OF MODEL SUBPROGRAMS



Data Structure

Because of the iterative nature of the model, the input and output student projection data will be structured alike. The data that comprise the input or output are broken down into a sequence of data elements. A list of these data elements is provided in Table 11. In addition, the categories for each data element are included.

Table 11

DATA ELEMENTS AND CATEGORIES

	Minimum	Preferred*	An Alternative Example
STUDENT STATUS	1. New Student 2. Continuing Student 3. Returning Student 4. Departing Student	1. New Freshman 2. Returning Student 3. Transfer Student 4. New Grad. Student 5. Continuing Student 6. Program Completion 7. Dropout 8. Forceout	1. Full-Time Student 2. Part-Time Student 3. Program Completion 4. Other Departure
STUDENT LEVEL	1. Lower Division 2. Upper Division 3. Graduate	1. Freshman 2. Sophomore 3. Junior 4. Senior 5. Grad-1/Professional 6. Grad-2 7. Special	1. Academic Student 2. Vo-Tech Student 3. Continuing Education Student
FIELD OF STUDY (Major)	5 schools	33 Major Fields including other and undeclared	Up to 80 areas of concentration

The projection input and output data will be maintained as a sequence of records, each containing all data elements. A typical data record would appear as in Figure 10.

Figure 10

BASIC MODEL DATA RECORD

STATUS	LEVEL	MAJOR	NUMBER OF STUDENTS
5	3	12	200

*Preferred, here refers to the fact that this list is compatible with the default option of RRPM-1.

Data representing the potential transferring, returning, and new students (student status 1, 2, and 3) will be structured in essentially the same manner. However, those data elements for which the specific category values are unknown will be left blank.

For the purpose of computing the transition probabilities to be used in the model, it will be necessary to have data on each student in a sequential sample. Both the sample ratios and the input student record discussed in the previous paragraph can be derived from individual student data records. It should be noted that sample transition ratios as described in this proposed design cannot be computed from records of the type discussed above. Ratios computed from accumulated data as in these records are called class-rate-progression ratios, and they are not estimates of probabilities. Thus it will be necessary to have a record on each student in the sample for each term or year that student was in attendance with his status, level, major, and an identification code in order to obtain sample probabilities.

It should also be noted that it is not necessary to have longitudinal records on every student. An appropriate sample of the historical enrollment of the institution will suffice for most purposes. Various sampling techniques exist to assist in selecting the most appropriate sample. The technique and specific manner in which a sample is selected is left up to the individual institution.

In summary, the data file will contain a sequence of records, each containing a set of data elements identifying a collection of students along with the number in that collection. The model will project the new numbers for the next year for that category; and standard outputs will be presented showing degrees, other departures, and enrollments by level and major. Special output formats can be specified at the option of the user. If historical data are to be used to compute the probabilities, a sample containing the records of individual students will be necessary.

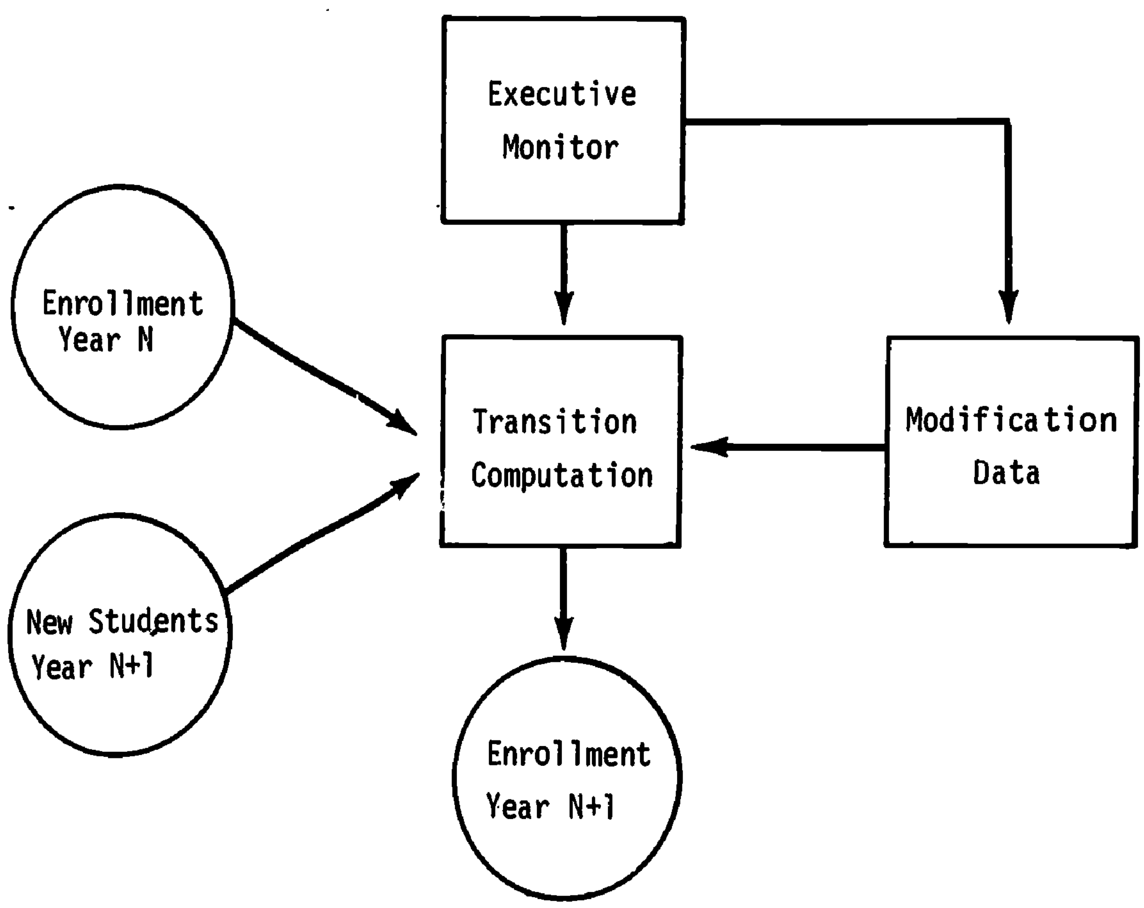
Transformation Modification

The basic module is made up of several components. For the purpose of this discussion, it is sufficient to view this module as depicted in Figure 11.

The transition computation block in this diagram represents the transformations of the admissions and enrollment modules that are applied to the input data. The set of transition probabilities that goes into these transformations is exhaustive. That is, all possible transitions between combinations of categories are included. The modification data are used to modify the transitions so as to simulate the effect of exogenous influences or changes in the system. The executive routine monitors the interaction between the modification data and the projection computations. For example, a possible modification may be an anticipated change over some time period in demand for a specific major. The modification data would be a series of adjustments to the transition probabilities for that major. The executive routine monitors the application of the adjustments making sure that other related transitions are kept in balance with respect to numbers being projected.

Figure 11

COMPONENTS OF THE BASIC MODULE



Examples of the kinds of influences that might be of interest to some institutions are listed below:

Enrollment Limits by Major

Effects of Changes in Admissions Standards

Effects of Financial Assistance

Changes in Manpower Demands

Change in the Economy

The last two items on the list are clearly exogenous. However, while not controllable by the institution, they often exert some influence on the system. The model design is indifferent to this type of distinction, and, therefore, the user may take advantage of this routine to account for the effect of exogenous as well as endogenous influences.

Ancillary Systems

The Student Flow Model will include two data systems in addition to the projection model. The requirements are a tabulation program for extracting and tabulating the sample ratios for making probability estimates and a generalized report program to select and accumulate data for various output displays from the admissions and enrollment projections.

It is assumed that institutional data will be available by individual student. Records from institutional data should have the same information as Figure 10 with an additional piece of information added -- a student identification number, preferably his social security number.

The first program will provide both the initial tabulations from this historical data to start the projection process and the tabulations required to make the estimates of the various transition probabilities.

The identification number will be used for determining such things as the number of students present in one year and absent the next. This item will be dropped from the data when the data is aggregated.

In making estimates of probabilities from the sample ratios to use in the model, it would be useful if the institution had a set of analytical packages, such as the UCLA Biomed[8] package or the University of Illinois SSUPAC.[39] A complete package would contain regressions, both standard and stepwise, an analysis of variance, a factor analysis, time series analysis, and a histogram program for reproducing distributions. These techniques would be used for evaluation and for making more complete and accurate decisions on the correct estimates to be used in making projections. Implementation and pilot testing of the basic model should include concomitant evaluation of the auxilliary statistical programs appropriate for data reduction and analysis of the enrollment projection parameters. It is possible that for many institutions, such programs themselves will, in fact, represent a great step forward in understanding and projecting their student enrollments.

It is assumed that in the implementation of such a system, an experienced analyst will be an integral part of the effort. The state of the art of artificial intelligence is not such that we are yet able to replace the human in the process of determining what is a reasonable output of the basic analysis and a reasonable input to predictive or projective models. This situation is not unique to this model; it is characteristic of every information system that the heart and soul lie with a qualified analyst.

THE STUDENT FLOW PROCESS

The discussion thus far has dealt with the movement of groups of students into, through, and out of the institution with no distinction between individual students other than "location" within the system. However, for certain planning purposes it is desirable to know how particular students or groups of students differ from others in their choices and persistency. Two major types of planning were discussed earlier that are concerned with these differences. They are educational opportunity planning and manpower planning. These introduce the requirement to consider two additional aspects of the student decision process. The first deals with those characteristics of the individual student that appear to be associated with different behaviors and the second with the types of factors that influence students to continue or change their behavior. These factors and characteristics are interrelated in that a given influencing factor may affect students with different characteristics in different ways.

From another point of view, the student characteristics may be considered as input variables to the system of higher education. These are the attributes the student brings to the institution that are not changed by the institution but, in some way, condition or affect the way he moves through the system. The influencing factors can be divided into two categories -- those that can be controlled by the decision-maker and those that are exogenous to the institution. The first of these are control variables and the second are exogenous variables or influences.

Table 12 provides a list of examples of each of these three classes of variables.

Table 12

SYSTEM VARIABLES

Input Variables	Control Variables
Sex	Fees
Family Income	Institutionally Administered Aid
Father's Educational Level	Admissions Decisions
Mother's Educational Level	Major Field Requirements
Religion	Degree Requirements
Race	
Father's Occupation	**Exogenous Influences**
Residency	
Age	Employment Opportunity Costs
Marital Status	Economic Indicators
Housing	Non-institutionally Administered Assistance
Previous Occupation	Applicant Pool
Father's Occupation	
Extent	
Source	

Clearly, not all of these are equally important to a particular institution, and a list of the most important ones for one institution will not necessarily be appropriate for some other institution. Further, some of these are correlated and may in some cases even act as proxies for one another.

The manner in which these variables are related and the manner in which they jointly affect such things as choice of field of study, persistency to the degree, time required to complete the degree, etc., are not generally known. In addition, these relationships may not be consistent from institution to institution. Therefore, before the general effect of combinations of these variables can be accounted for in evaluating or predicting student flow, the significant variables must be determined and estimates of their specific and joint effects must be made relative to particular institutions.

It would probably be premature to attempt to design a generalized model at this time, even for some subset of the institutions of higher education, which would allow for evaluation of effects of "significant" economic influences and student characteristics. Such a model would have to be very general and each institution would still need to determine the specific relationships between factors before it could be used. Any model designed to account for all factors, leaving the choice of which ones to be actually included to the institution would be so large as to be impractical and would still leave unanswered the question of which variables were significant for that institution.

Because of these problems, economic and student characteristic effects on student flow are not being included in the original design of the NCHEMS Enrollment Projection Model. Instead a second document is proposed that will deal with these aspects of student flow. This contiguous publication will present the problems that are associated with predicting student flow in light of institutional differences, identifying the data necessary to address these problems adequately, and demonstrating various methods for solving these problems.

In addition, possible new techniques to assist in the study and prediction of student flows will be identified with respect to the specific problem areas identified.

Suggested Model Modifications for Student Flow

There are a variety of questions with respect to resource planning that institutions must address at the present. Some of these influences may have to do with student characteristics and may interact with the economic aspects of student flow. However, they are directly related to enrollment projection and, therefore, need to be considered here. For example, the introduction of a new program or the emergence of a new segment of the institution's constituency have resource implications. These influences must be dealt with in resource planning whether the socio-economic relationships to individual student decision making are addressed or not.

The Enrollment Module thus far described is not a dynamic model nor is it an interactive analysis model. However, it can be used to assist in addressing some of the planning questions that derive from planned changes. A list of changes that have a significant impact on some aspects of resource planning are listed below:

New Programs

Phasing Out an Old Program

New Constituency

Effect of an Institution Constraint or Encouragement (e.g., Grading Standards)

Admissions Standards

Enrollment Limitations within the System (as opposed to entry)

Exogenous Impacts

All of these situations can be theoretically addressed in part by the model. However, the key point is that information peculiar to each situation must be obtained external to the model. One technique that can be applied is to segment the basic input data into categories and make separate projections. For example, if the institution had previously been all male and planned to become coeducational, it would be appropriate to obtain data on the female population of another similar institution and make projections separately for males and females. However, the previous data on males would not reflect any interactive effect that females might have on the male data.

Similar situations exist in considering a new program or elimination of an old program. Specific information can be found to reflect the direct effects, but the interaction between, say, a new program and existing programs would not be addressed.

The specific technique for dealing with the elimination of an old program or creation of a new one is somewhat different from the technique discussed in the previous paragraph.

In these cases the user will want to alter the various transition probabilities during the years of creation or elimination to reflect the alterations in program choice associated with the change. The model is designed to allow the user either to replace or modify a probability during any year or sequence of years in the projection period. However, the user needs to estimate how the change is likely to affect the choice patterns of the students. Therefore, great care must be taken in using the model to assist in addressing this class of questions and the ancillary information necessary to use the model for this purpose is the responsibility of the user.

CONCLUSION

The model presented in this paper is designed to assist in making basic enrollment projections for resource planning purposes. The model will provide projections of applicants, admissions, enrollments, and departures. It may be used to address questions associated with changes in the <u>status quo</u> through the process of data modification and segmented multiple projection. However, the validity of projections of this type lies primarily with reliability of the information used to make modifications and the extent to which interactions associated with the changes have been accounted for.

A companion publication is proposed to supplement the model design. This document will address the student characteristics and economic aspects of student flow with particular emphasis on their relationship to change. Methods and techniques for dealing with this class of problems will be identified and explained with case study examples. This second publication is also intended to explain how to identify, extract, and use information in conjunction with the initial model to address questions associated with change in the most appropriate manner.

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