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ABSTRACT

The primary objectives of this manual are to provide enrollment forecasting practitioners with guidance about the use of specific forecasting techniques and procedures and to foster greater understanding of these important planning tools. In addition to general discussion of such topics as accuracy, uses, assumptions, and data requirements, the manual provides illustrations of the application of several of the most widely used techniques. A review of the literature is provided in an appendix. (Author)

HIGHER EDUCATION ENROLLMENT FORECASTING

A Manual for State-Level Agencies

Paul Wing

1974

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NATIONAL CENTER FOR HIGHER EDUCATION MANAGEMENT SYSTEMS

at Western Interstate Commission for Higher Education

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- provide improved information to higher education administration at all levels.
- facilitate exchange of comparable data among institutions.
- facilitate reporting of comparable information at the state and national levels.

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PREFACE

This document has been prepared as part of the Statewide Analysis project of the National Center for Higher Education Management Systems (NCHEMS) at WICHE. It has been developed by the NCHEMS staff, reviewed by a small number of persons outside NCHEMS knowledgeable about enrollment forecasting, and approved for limited distribution by the NCHEMS Board of Directors.

This manual is one of two related to state-level analysis of higher education enrollments developed at NCHEMS. The other (Martin and Wing, 1973) discusses possible applications by state agencies of a computer-based student flow model (SFM-IA) developed at NCHEMS. The two should serve as guides for state-level planners and analysts in estimating future enrollment levels.

Originally, it had been anticipated that this manual would focus on medium- and long-range forecasting. However, careful consideration of the objectives, assumptions, tools and techniques of forecasting has led to the realization that forecasting of higher education enrollments is a subject that needs close, careful scrutiny from all sides. Thus, the discussion does not dwell on medium- and long-range forecasting, but examines techniques that (at least theoretically) are applicable in a wide variety of situations. It is hoped that the discussion provides a comprehensive treatment of the subject which will be of value to enrollment forecasting practitioners at higher education institutions and national agencies, as well as those at state agencies.

Although a reader needs some background in quantitative analysis to be able to digest completely the contents of the manual, much of the discussion is nontechnical and does not presume that the reader has technical background. The manual has been designed so that if a reader with limited experience or interest in computational procedures skips to the next section when faced with the mathematical portions of a section, he or she will be exposed to most of the qualitative insights that are presented. Hopefully, this will permit policy makers with overall responsibility for obtaining and using enrollment forecasts, as well as the technicians with direct responsibility for designing and applying the procedures, to use and benefit from the manual.

The numerical results provided in the illustrative examples in Chapter II have been double-checked, and to the best of our knowledge they are correct. Should anyone detect or suspect an error, we would appreciate hearing of it so that appropriate corrections can be made.

A number of individuals have contributed to the development of this manual. Special thanks are due to Yung-mei Tsai (now Assistant Professor of Sociology at Texas Tech University) who was heavily involved in the preparation of several of the early versions of the manual. Thanks are also due to Arthur Ashton of the Colorado Commission on Higher Education; Robert Judd of Troy State University; Sheldon Knorr of the Maryland Council of Higher Education; Anne Winchester, now with the Office of Community Development in the State of Washington; Robert Newton of Pennsylvania State University; and Robert Gray, Wayne Kirschling, James McLaughlin, Leonard Romney, and Richard Williams of the NCHEMS staff.

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CHAPTER I

INTRODUCTION

The principal concern of higher education enrollment forecasting is the accurate prediction of future enrollments in specific higher education programs and/or institutions. The tools of the forecasting trade include a wide variety of computational and statistical techniques that, depending on the kinds of assumptions made about trends in enrollment, are appropriate in an equally wide variety of situations.

The primary objectives of this manual are to provide state-level enrollment forecasting practitioners with guidance about the use of specific forecasting techniques and procedures and to foster understanding of these important planning tools. Although the manual has been developed primarily for a state-level audience, much of the discussion is relevant to practitioners at institutional and national levels as well. Their problems relative to enrollment forecasting differ from those of state agencies primarily in level of aggregation. The same techniques can be used in all three areas, assuming, of course, that the appropriate assumptions are not violated.

GENERAL CONSIDERATIONS

Before turning to specific descriptions and discussion of particular forecasting procedures, some general questions regarding the nature, use, and value of enrollment forecasting will be explored. The remarks that follow, though general, point up some of the subtleties and difficulties inherent in enrollment forecasting.

Accuracy and Evaluation

The ultimate test of any forecasting procedure is its accuracy. Unfortunately, in situations where uncertainty is involved (and enrollment analysis is certainly one of them), one cannot assess accuracy until actual reference data are available. Thus to a large extent prior assessment of the accuracy of a particular forecast must be based on such things as the accuracy of similar forecasts in the past, the reputation and persuasiveness of the individuals responsible for the forecasts, and judgments about the likelihood that underlying assumptions will approximate reality. Needless to say, the validity of any set of underlying assumptions about the future of higher education is quite uncertain at this particular time. Since this uncertainty makes comparisons with similar forecasts in the past rather tenuous, one usually is left with only the reputation of the individuals handling the forecasting as the primary basis for prior evaluations of forecasting procedures or estimates. This situation necessarily fosters uneasiness, particularly if the projections are to be used as the basis for important plans and decisions.

Related to this problem of evaluating forecasting procedures is the general relationship between prior certainty about the accuracy of a particular forecast and the time horizon involved. Few would dispute that as one moves from short-range to long-range forecasts, one becomes less certain about accuracy. Figure 1 presents a schematic representation of this phenomenon. It is not difficult to see why this is true in higher education at the present time. There are many possible courses that events may take, depending on such things as federal financing plans, student attitudes, judicial decisions concerning residence status, and other factors too numerous to mention; and the uncertainty about these factors increases as the time horizon is extended. This raises important questions about applications and uses of existing techniques, particularly when projections span more than five or six years. It also suggests the need for estimates of the margin of error involved with particular forecasts.

Applicants versus Openings

Another important factor that can have a significant impact on enrollment forecasting efforts is the general relationship between the number of qualified applicants and the number of available openings for students. Depending on which of these is larger, one may face substantially different forecasting problems. Where applicants exceed openings, it may suffice to project the supply of openings for students. Where openings exceed applicants, however, it will probably be necessary to focus on applicants and student demand for admission, which is a difficult task at best. In situations where additional policy guidance is desired, it would be appropriate to develop forecasts for both applicants and openings. This would permit analysis of the discrepancies which would give policy makers additional information about both the extent to which problems exist and the causes of the discrepancies.

In terms of obtaining numerical estimates of future enrollments, the important thing to note is that there are likely to be differences between projections based on supply of openings and those based on demand for admission. Different techniques may be applicable and different numerical results probably will be obtained.

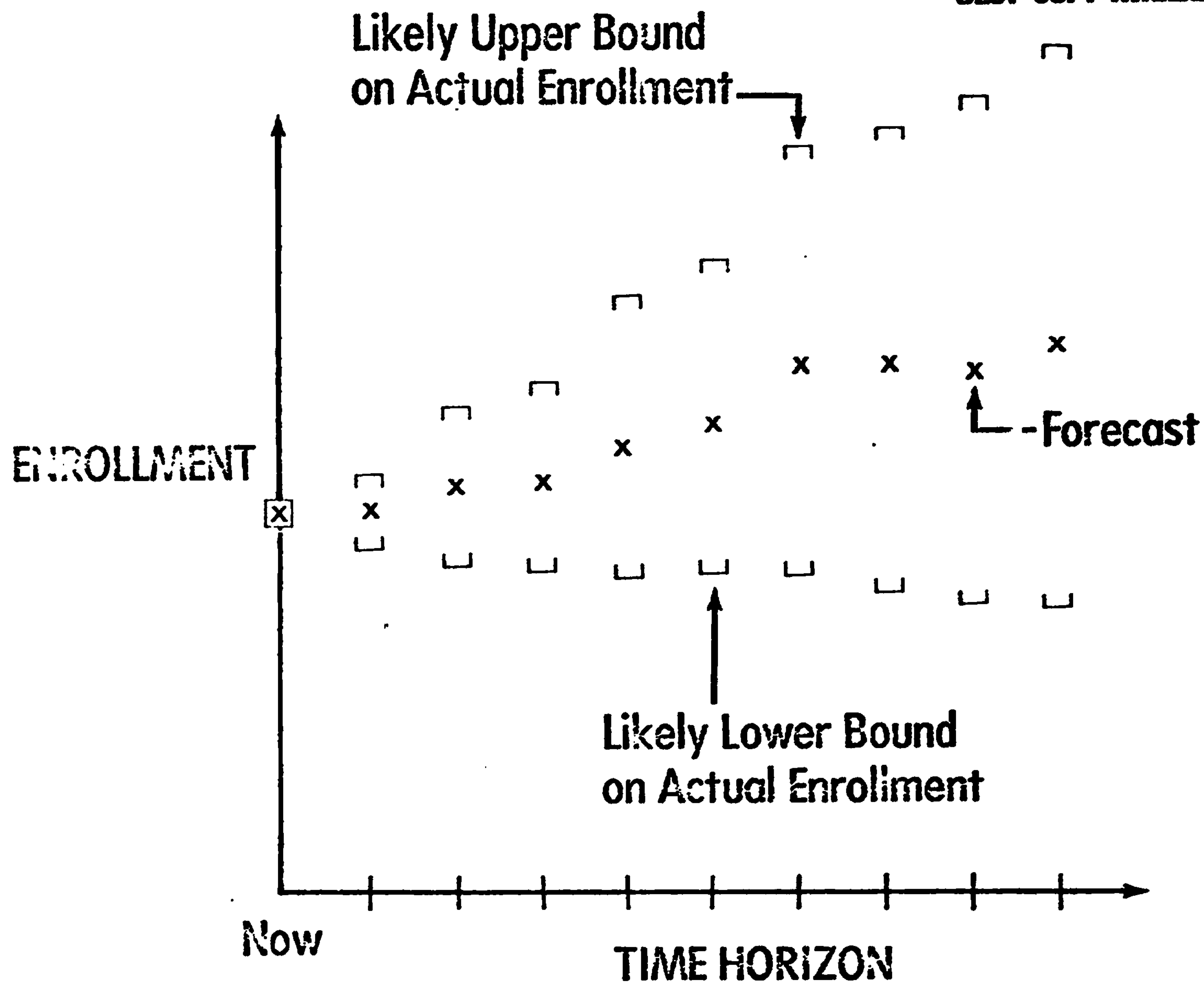

Figure 1. GENFRAL RELATION BETWEEN ACCURACY OF ENROLLMENT FORECASTS AND THE NUMBER OF YEARS INTO THE FUTURE FOR WHICH ENROLLMENTS ARE BEING FORECAST

Uses of Enrollment Projections

There are two general classes of uses of enrollment projections:

(1) Short- and medium-range forecasts can be used as a partial basis for a variety of planning and management activities (for example, budgeting).

(2) Long-term forecasts provide a means for altering or reinforcing general expectations for the future, which if properly followed up enable policy makers to adjust their priorities and frames of reference gradually, over a period of years.

Although both of these purposes are important, it is probably the former that has provided most of the impetus for the increased state-level activity in enrollment forecasting in recent years. State agencies are anxious to be able to estimate more accurately future resource requirements of higher education programs and institutions; and since resource requirements are quite closely related to enrollments, this in turn translates into an interest in accurate enrollment projections. However, this should not cause one to forget the importance of the second class of uses.

Although the two general reasons given above would suffice as a basis for further discussion, the following list of more specific uses of enrollment projections may help to clarify further their potential role in planning and management processes. These are related primarily to the first general class of uses mentioned above.

(1) Capital planning and budgeting. Contrasting projected enrollments with the current and projected capacity of physical facilities can provide a basis for capital investment decisions.

(2) Operating budgets for institutions or programs. Projected enrollments can serve as a basis for short- and medium-range budgetary estimates.

(3) Support for other management systems. Enrollment projections can be applied in analyses of such things as intersegmental student flows (for example, junior college transfers), unit costs of instruction, student access to higher education, impact of instructional programs on labor markets, different strategies for allocating resources, and funding requirements.

This list is certainly not exhaustive, but it does suggest some of the possible uses of and justifications for enrollment forecasting. It should provide also an indication of why there has been growing interest in the subject by institutions and federal agencies, as well as by state agencies.

Total Enrollments versus Initial Enrollments

For most purposes it is desirable to have projections of total enrollments, perhaps disaggregated by such characteristics as level of student (for example, undergraduate and graduate) or type of institution (for example, community colleges and major universities). Most of the techniques outlined in Chapter II of this manual can be used to obtain these projections directly. It also is possible to obtain projections of total enrollments using a two-stage procedure: first, estimate initial (for example, freshman) enrollments; and then, based on past experience with student progression and attrition, estimate the numbers of these entering students who will continue to be enrolled in later years. The sum of the estimates of initial enrollment plus continuing enrollments for the appropriate years then is the desired estimate of total enrollments. This two-stage procedure would be appropriate particularly if one had special knowledge or insights about future progression and attrition rates of enrolled students.

In the discussion of specific forecasting techniques in Chapter II, total enrollments are used in some examples and initial enrollments are used in others. It is assumed where initial enrollments are used that some appropriate method of extending the results to total enrollments (for example, the student flow model discussed by Martin and Wing !19731) will be used.

Level Being Forecast

The level of aggregation for which the forecast is developed is relatively straightforward. In terms of forecasts developed for use by state agencies, four major levels probably are relevant:

Level	Example
Institution	University of Denver, Colorado
System or District	University of Wisconsin System
State or Region	All Higher Education Institutions in Tennessee; All Private Higher Education Institutions in New England
National	All Postsecondary Institutions in the U.S.

For some specific purposes, one could disaggregate forecasts at the institutional level in terms of colleges or departments. For example, it may be of interest to examine future requirements for faculty and staff or the types of instructional and/or research facilities that are implied by certain enrollment projections. It also might be useful to disaggregate the forecasts in terms of public and private institutions, or four-year and two-year institutions, or some other institutional characteristics.

Student Characteristics

It may be appropriate also to develop separate forecasts for different categories of students, perhaps by sex, race, age, or socioeconomic status. This would be appropriate if one knew or suspected there were different trends and factors influencing the different categories of students. If this were the case, different models or techniques could be used for projecting enrollments for each of the different student categories. The separate forecasts then could be aggregated as appropriate to obtain estimates of total enrollment.

Source of Data

All enrollment forecasting techniques require data of one sort or another as the basis for estimating parameters or developing models. However, depending on the forecasting procedures being applied, different kinds of data may be appropriate and these data can come from several sources: higher education institutions, state agencies, federal agencies, or directly from students and/or potential students. The particular technique or model chosen for an enrollment forecasting study usually will dictate the specific data requirements. In some situations, however, analysts will not find precisely the data required for a particular procedure and will have to initiate a special data collection effort, identify a source of surrogate data, or select a different forecasting procedure.

Data about such things as the supply of openings, costs of attendance, and so forth probably are best collected at the institutional level. These data then can be aggregated to any higher level (for example, state-level averages) as appropriate. Data about such things as recent higher education participation patterns of high school graduates probably should be collected from or through the high schools. These data can be aggregated and averaged as necessary.

The important thing to note here is that all the data required to support the various techniques discussed in the following chapter probably are not readily available in one neat package. Some data may come from institutions in the state, some from the U.S. Census Bureau, some from the state department of education, and some from other sources. It also may be necessary to use surrogate data; for example, a five-year-old report of a survey of high school seniors might be the only source for a rough estimate for one of the parameters in a technique chosen as part of a forecasting procedure. It may even be appropriate to rely on the subjective judgment of an expert to fill in some of the gaps in a historical time series. Careful consideration should be given to the risks of error that may be introduced by the use of such surrogate data.

Segment of Postsecondary Education

Another potentially important characteristic of enrollment forecasting procedures is the segment of postsecondary education involved. It is very likely that different assumptions about participation rates, reasons for attending, and so forth may hold in the different segments. For example, community/junior colleges probably draw their students from segments of society different from private liberal arts colleges; and therefore different models, different parameters, and different data sources may be appropriate for each segment. In developing aggregate statewide enrollment forecasts it may be appropriate to develop independent forecasts for each of the major segments of postsecondary education of concern, and then sum the projections for all of the segments to obtain the desired aggregate forecasts. This would be appropriate particularly if the models used to develop the projections included policy parameters (such as tuition levels) that might impact differently on the different segments. The models then would be more closely related to changes that might occur in such policy parameters, and then might even be used to analyze the impact of changes in related policies on enrollments.

Interstate Migration

The migration of students across state lines has important implications for many states in terms of total enrollments, revenues generated by out-of-state tuition, and so forth. It also poses a number of problems for enrollment forecasters who generally do not have access to data on the total pool of potential out-of-state applicants. They may know where all the out-of-state students in their state come from in a particular year, and they may even have information about out-of-state applicants that did not enroll, but this information is not an adequate basis for developing accurate estimates of future student demand. Without information on the total pool of potential applicants and the factors that have an impact on application and enrollment decision, analysts are at a distinct disadvantage in trying to develop estimates of out-of-state student enrollments.

One way to deal with this problem would be through a cooperative interstate effort to collect and share information about application and enrollment patterns of in-state residents. This information on migrants then could be analyzed in much the same way that information on in-state students is analyzed to provide insights into why particular kinds of people migrate. Analyses such as the ones performed by Fenske, Scott, and Carmody (1974) on data collected by the American College Testing Program might be appropriate.

It would be possible also for an individual state to undertake a study such as the ones done in Wisconsin (Hawthorne and Lins, 1971), Pennsylvania (Hoffman, 1970), and New Hampshire (Educational Research and Services Corporation, n.d.). Such studies can provide valuable information about student migration patterns for a particular state, and might yield insights into the reasons for migration that would be helpful in enrollment forecasting studies.

If an analyst does nothing else related to interstate migration, he or she should refer to the statistics compiled by the National Center for Educational Statistics (1970 and 1971). These data, which are developed every five years, provide bench marks that can be used if no other data are available.

CURRENT ENROLLMENT FORECASTING PRACTICES AT THE STATE LEVEL

Although forecasting techniques and procedures have been under development for several decades by analysts and researchers in a number of fields, the application of the various forecasting techniques to the specific problems of higher education enrollment forecasting have lagged far behind the technical developments. With very few exceptions state agencies and institutions alike are not faring well in their attempts at applying these techniques to the problem of estimating future enrollments. This is due in part to apparent shifts in public and student opinion about higher education which have created a very difficult environment for enrollment forecasting practitioners. It can be related in part also to the fact that many states have only recently begun to consider enrollment forecasting as a serious problem. In many cases the agencies involved have not had sufficient time to develop the technical expertise and data bases necessary to do adequate enrollment forecasting.

Readers interested in more detail about enrollment forecasting practices of state agencies are referred to the report of a survey conducted in the summer of 1972 (Wing and Tsai). That report provides a rough picture of the state of the art as of 1972.

ORGANIZATION OF THE MANUAL

The remainder of this manual is organized into three major sections. Chapter II discusses a number of enrollment forecasting techniques, with illustrative applications for some of the more widely used ones that include specific discussion of assumptions, computational procedures, input data requirements, and remarks about applicability, accuracy, and so forth. Chapter III attempts to synthesize the discussion of the first two chapters into some general guidelines for constructing an overall forecasting procedure, including recommendations about choice of techniques, estimation of possible forecasting errors, and interpretation of projections. Chapter IV provides a brief summary of the most important points discussed in the manual. The appendices provide an extensive, though not exhaustive, review of the literature.

CHAPTER II

DISCUSSION OF ALTERNATIVE ENROLLMENT FORECASTING TECHNIQUES

There are many techniques that can be used to forecast enrollments in higher education, each of which has advantages and disadvantages in different situations. The appropriateness of each technique depends primarily on how closely the assumptions required by the technique correspond to the actual situation under study.

Four broad classes of forecasting techniques will be discussed in this chapter:

(1) Curve-Fitting: Techniques and models that produce forecasts based primarily on historical enrollment data.

(2) Causal Models: Techniques and models that produce forecasts based on historical relationships between enrollments and other parameter(s) or variable(s) (for example, high school graduates).

(3) Intention Surveys: Techniques based on surveys of the intentions of potential students, producing forecasts or suggesting adjustments to forecasts developed using other techniques.

(4) Subjective Judgment: Those elements and aspects of forecasting procedures based on the judgment of the forecaster rather than some quantitative technique or procedure.

These four categories subsume many specific techniques, the most important of which will be discussed in this section of the manual. The discussion covers such things as the mathematical equations, data requirements, specific assumptions, and where appropriate, illustrative examples.

NOTATIONAL CONVENTIONS

In the illustrative applications of forecasting techniques that appear below the following notation is used:

E = actual, historical enrollment

$\hat{E}$ = estimated enrollment

a,b,c,d,e,f,g = actual parameters in different forecasting techniques and models

$\hat{a},\hat{b},\hat{c},\hat{d},\hat{e},\hat{f},\hat{g}$ = estimates of those parameters

t = Year

Σ = sum of items that follow with subscript i

Actual enrollments are shown as integers (for example, 420), while estimated enrollments are shown to the nearest tenth (for example, 420.0) to emphasize that they are estimates. In some of the examples more than one decimal place is carried in intermediate steps in the computational procedures to provide more accurate final results.

CURVE-FITTING

Enrollment forecasting using curve-fitting techniques assumes that a particular pattern or trend exists in past enrollments. Projections are made on the assumption that this pattern or trend will continue to hold until the year for which the enrollment projection is desired. Thus there is an implicit assumption that the past is indicative of the future. One of the attractive features of curve-fitting procedures is that the only input data they require are historical enrollment statistics.

Despite the fact that curve-fitting techniques require the strong assumption that trends of the past will continue in the future, there are two general situations in which it is appropriate to use them: when it is believed that the trends of past will in fact continue in future; and when too little is known about causal relationships affecting enrollments to permit the development of appropriate causal models. It may be quite appropriate, for example, to use a curve-fitting technique for forecasting the values of certain parameters in causal models, such as participation rates of high school graduates in higher education.

Seven specific curve-fitting techniques will be discussed below: simple averages, moving averages, exponential smoothing, first-order and second-order polynomial models, exponential models, and spectral analysis. An attempt will be made to illustrate the sensitivity of these techniques to changes in some of their operating parameters. An eighth technique, the Markov transition model, also falls into the curve-fitting category since the estimates it produces are based entirely on previous enrollments. It will be discussed and illustrated in the causal model section of this chapter, however, since it fits nicely into a sequence of techniques that might be used in actual practice.

All the curve-fitting examples in this section will be based on data shown in Table 1, which permits some limited comparisons of the results obtained using the different curve-fitting techniques. The 1973/74 enrollment figure

Table 1. HYPOTHETICAL DATA USED IN CURVE-FITTING EXAMPLES

Year	Historical Enrollments
1966/67	74,285
1967/68	83,313
1968/69	93,309
1969/70	102,822
1970/71	114,490
1971/72	121,609
1972/73	128,160
1973/74	127,724

is used in the examples only as a validation point for checking the results obtained using the various techniques. In practice, of course, all available actual data would be used, although some similar validation procedure would certainly be appropriate.

It should be noted that the data in Table 1 indicate a changing trend in enrollments which violates the basic assumption for curve-fitting models. Readers should consider the results of the calculations below very carefully in light of this, and consider whether they would be willing to use the forecasts developed by any of these techniques.

Simple Averages (SA)

The simple averages technique uses the average or mean of past enrollments as the forecast of the enrollment in the next time period. Depending on the availability of past enrollment data, the average can be based on long or short time periods. The underlying assumption that should be met to justify the use of this technique is that enrollments remain essentially constant throughout the entire time period covered by the average and the projection period. Since this assumption is seldom, if ever, met, the simple average technique generally is not a good choice.

Moving Averages (MA)

The moving averages technique is similar to the simple averages technique except that a fixed number of past enrollment figures as used is estimating the future enrollments, which has the effect of relaxing the assumption about long-term constancy of enrollments (see Figure 2). The moving averages procedure does assume, however, that enrollments are constant over the period covered by the moving averages.

The only parameter under the control of the user of the moving averages forecasting technique is the number of historical data points to be included in the averages. As trends and patterns in enrollments become more pronounced, fewer data points should be included in the moving average. To illustrate that this parameter can have a significant impact on the results, calculations will be performed for three different cases: 5 data points, 3 data points, and 1 data point. Using 5 historical data points the equation would be:

$$\hat{E}_{1973/74} = (E_{1972/73} + E_{1971/72} + E_{1970/71} + E_{1969/70} + E_{1968/69})/5$$

$$= 112{,}078.0$$

For three data points the equation would be:

$$\hat{E}_{1973/74} = (E_{1972/73} + E_{1971/72} + E_{1970/71})/3$$

$$= 121{,}420.0$$

Finally, for one data point the result would be:

$$\hat{E}_{1973/74} = (E_{1972/73})/1$$

$$= 128{,}160.0$$

One conclusion can be drawn from these three cases: in times of continued expansion (or contraction) of enrollments, moving averages is not an appropriate technique.

To illustrate how one might use the moving averages technique to project enrollments for several years, the following example using three data points is provided:

$$\hat{E}_{1974/75} = (E_{1973/74} + E_{1972/73} + E_{1971/72})/3$$

$$= 125{,}831.0$$

$$\hat{E}_{1975/76} = (\hat{E}_{1974/75} + E_{1973/74} + E_{1972/73})3$$

$$= 127{,}238.3$$

The question raised by these figures, of course, is whether or not one would base a major budget decision on them. If a user were faced with

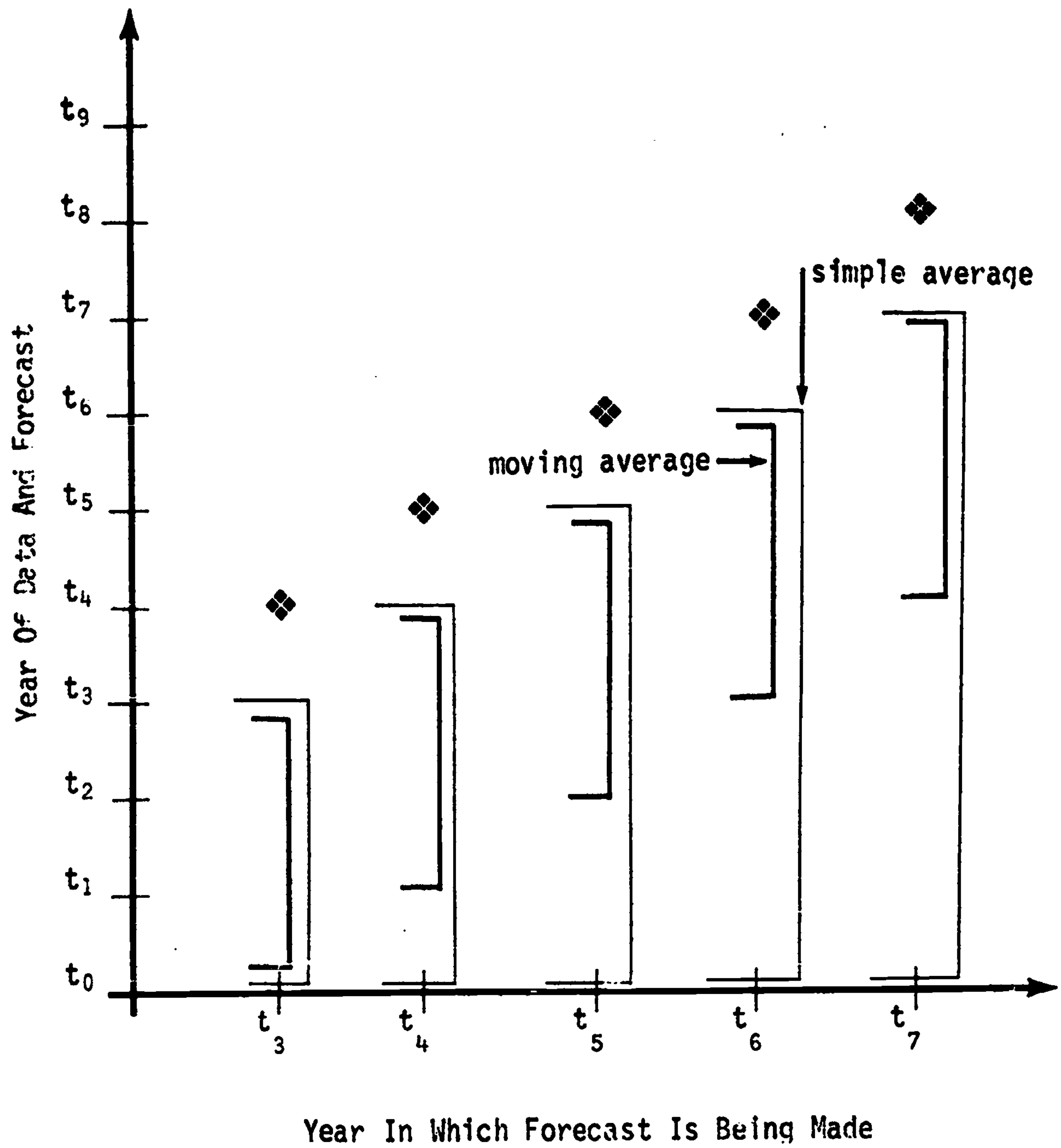

Figure 2. A SCHEMATIC COMPARISON OF THE SIMPLE AVERAGES AND MOVING AVERAGES TECHNIQUES

Notes: Brackets indicate years included in computing the averages.
❖ indicates the year for which enrollments are being forecast
t_0 is the first year to be included in the averages.

an obvious break in the trend of historical data such as appears in Table 1, it would be best to look for additional corroborative evidence.

Exponential Smoothing (ES)

Exponential smoothing is a variation of the averaging techniques in which the most recent historical enrollment figure is weighted most heavily and each successively earlier data point is weighted less than the previous one. This leads to the desirable feature that recent trends in enrollments dominate earlier trends. Unfortunately, since this procedure relies on an averaging procedure, it shares the deficiencies of both the simple and moving averages techniques in periods of continued expansion (or contraction) of enrollments.

The actual weighting factors for each of the historical enrollment figures in this technique have the following exponential pattern:

$$a;\ a(1-a);\ a(1-a)^2;\ a(1-a)^3:\ \ldots;\ a(1-a)^n;\ \ldots$$

where $0 < a < 1$.

The parameter of interest in exponential smoothing is 'a' the smoothing constant. The value chosen for 'a' determines the rate at which the weights on successively earlier data points declines: a larger 'a' results in a faster decline in the weights and more weight on recent data points. Thus, choosing a larger value for 'a' has the same general effect for exponential smoothing as does using a smaller number of historical data points for the moving averages technique.

Several examples are provided below to illustrate the impact of changing 'a' on the resulting forecasts. The general formula that is used is:

$$\hat{E}_{1973/74} = aE_{1972/73} + (1-a)S_{1972/73}$$

where S is the "smoothed" projection for the previous year.

In order to start the computational process it is necessary to make a series of substitutions for $S_{1972/73}$ to arrive at the appropriate initial equation:

$$\hat{E}_{1973/74} = aE_{1972/73} + a(1-a)E_{1971/72} + (1-a)^2S_{1971/72}.$$

Successive substitutions of this sort lead to the following formula:

$$\hat{E}_{1973/74} = aE_{1972/73} + a(1-a)E_{1971/72} + a(1-a)^2E_{1971/72} +$$

$$a(1-2)^3E_{1969/70} + a(1-a)^4E_{1968/69} + a(1-a)^5E_{1967/68} +$$

$$(1-a)^6E_{1966/67}.$$

Notice that since historical data are available (in this example) back only to 1966/67 that the last coefficient appears as $(1-a)^6$ rather than $a(1-a)^6$, so that the sum of the coefficients is one (which is convenient for comparisons with other averaging techniques).*

To project the enrollments for 1973/74, one need only substitute the appropriate values in the last equation and perform the indicated arithmetic. Performing

*Brown (1963; p. 102-3) suggests an alternative start up procedure.

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these calculations for four different values of 'a' yields the results shown in Table 2. It is easy to see from these results that increasing 'a' does have the same impact on the forecasts as reducing the number of data points in the moving averages procedure.

Table 2. ENROLLMENT FORECASTS BASED ON THE EXPONENTIAL SMOOTHING TECHNIQUE FOR FOUR VALUES OF THE SMOOTHING CONSTANT, 'a'

a	$\hat{E}_{1973/74} = S_{1973/74}$	$\hat{E}_{1974/75} = S_{1974/75}$
0.25	107,331.0	112,429.3
0.50	120,598.2	124,161.1
0.75	125,845.8	127,254.5
1.00	128,160.0	127.724.0

The next iteration of the procedure is much simpler, since the general formula

$$\hat{E}_{1974/75} = aE_{1973/74} + (1-a)S_{1973/74}$$

can be used. Substituting the appropriate values from Tables 1 and 2 into this equation, the enrollment projections for 1974/75 are obtained. These are shown in Table 2 also.

When one uses this technique to forecast more than one time period into the future the equation yields a single value since independent estimates of the most recent enrollment will not be available. For example, for 1975/76 the equation becomes:

$$\hat{E}_{1975/76} = aE_{1974/75} + (1-a)S_{1974/75} = \hat{E}_{1974/75} = S_{1974/75}$$

Since actual data for 1974/75 do not exist, the estimate for $E_{1974/75}$ (that is, $S_{1974/75}$) must be used.

Higher-order smoothing procedures also are available and typically are more responsive to change than the first-order smoothing procedure. They require the same basic assumptions, however, and they will not overcome the fundamental shortcomings of the procedure. Readers interested in the details of higher-order smoothing procedures can consult Brown (1963, esp. Chapter IX).

Polynomial Models (PM)

While the simple averages, moving averages, and exponential smoothing techniques require the assumption that enrollments will remain constant, the polynomial models technique relaxes that assumption so that, depending on the specific polynomial form chosen by the analyst, a wide variety of enrollment trends and patterns can be reflected. The basic form of the model is:

$$\hat{E} = a + bt + ct^2 + dt^3 + \cdots$$

where $\hat{E}$ is the desired forecast; a, b, c, and d are parameters that must be estimated based on past enrollments, and t is the year for which the forecast is made. (Actually, the averaging and smoothing techniques discussed earlier are special cases of the polynomial model in which $\hat{E} = a$ is the form of the model.)

In this section of the paper first-order and second-order polynomial models will be illustrated. There also will be a brief discussion of some general considerations regarding the use of polynomial models. One restrictuion that applies to all polynomial models is that there must be at least as many historical data points available as there are parameters to be estimated in the model.

1. First-Order Polynomial.

The general form of the first-order polynomial model is:

$$E = a + bt$$

where a and b are unknown parameters to be estimated, and t represents time.

The estimates of the two parameters, a and b, in this model are based on historical enrollment data. In this example the estimates will be based on five data points, which meets the requirements for the technique.

Although the parameters can be estimated using a standard least squares estimation procedure on a computer, the discussion here will outline procedures that can be implemented by hand, preferably with the aid of a desk calculator. For the first-order model the two parameters, a and b, can be estimated by the following two equations:

$$\hat{b} = \frac{n \cdot \Sigma(E_i\ t_i) - (\Sigma E_i)\ (\Sigma t_i)}{n \Sigma t_2^i - (\Sigma t_i)^2}$$

$$\hat{a} = \frac{\Sigma E_i - \hat{b} \Sigma^t}{n}$$

where all the summations are over all the data points, five in this example.

Substituting the appropriate numbers from Table 3 into these equations the following estimates for a and b are obtained:

$$\hat{b} = \frac{(5x1,769,659)-(560,390x15)}{(5x55)-(15x15)} = 8,848.9$$

$$\hat{a} = \frac{560,390 - (8,848.9x15)}{5} = 85,531.3.$$

Now these estimates for a and b (that is, $\hat{a}$ and $\hat{b}$) can be used to estimate the enrollments for 1973/74 and 1974/75 (that is, for t = 6 and t = 7) by simple substitution in the original formula:

$$\hat{E}_{1973/74} = \hat{a} + \hat{b}t =$$

$$= 85,531.3 + 8,848.9x6 = 138,624.7$$

$$\hat{E}_{1974/75} = 85,531.3 + 8,848.9x7 = 147,473.6$$

Table 3. SUPPORTING DATA CALCULATIONS FOR THE FIRST- AND SECOND-ORDER POLYNOMIAL MODEL EXAMPLES

Year	t_i	t_i^2	t_i^3	t_i^4	E_i	$E_i t_i$	$E_i t_i^2$
1968/69	1	1	1	1	93,309	93,309	93,309
1969/70	2	4	8	16	102,822	205,644	411,288
1970/71	3	9	27	81	114,490	343,470	1,030,410
1971/72	4	16	64	256	121,609	486,436	1,945,744
1972/73	5	25	125	625	128,160	640,800	3,204.000
Sum (Σ)	15	55	225	979	560,390	1,769,659	6,684,751

It should be emphasized that estimates, $\hat{a}$ and $\hat{b}$, are subject to error, and therefore the enrollment estimates are subject to error also. It is possible in these regression models to estimate the errors associated with these estimates; this will be discussed briefly in Chapter III.

2. Second-Order Polynomial.

The general form of the second-order polynomial is

$$E = c + dt + et^2$$

where c, d, and e are the unknown parameters to be estimated. The procedure for estimating these parameters is very similar to that for the first-order case. Unfortunately, the solution does not reduce to equally simple equations. In fact, the most convenient procedure for solving the second-order case by hand involves the solution of a set of three equations with three unknowns (as in Merrill and Fox, 1970, p. 391ff):

$$\hat{c}\cdot n + \hat{d}(\Sigma t_i) + \hat{e}(\Sigma t_i^2) = \Sigma E_i$$

$$\hat{c}(\Sigma t_i) + \hat{d}(\Sigma t_i^2) + \hat{e}(\Sigma t_i^3) = \Sigma E_i t_i$$

$$\hat{c}(\Sigma t_i^2) + \hat{d}(\Sigma t_i^3) + \hat{e}(\Sigma t_i^4) = \Sigma E_i t_i^2$$

where the summations are over all data points as before.

Substituting the appropriate numbers from Table 3 yields the following set of three equations:

$$5\hat{c} + 15\hat{d} + 55\hat{e} = 560{,}390$$

$$15\hat{c} + 55\hat{d} + 225\hat{e} = 1{,}769{,}659$$

$$55\hat{c} + 225\hat{d} + 979\hat{e} = 6{,}684{,}751$$

Eliminating $\hat{c}$ from the last two equations, by subtracting appropriate multiples of the first leaves the following two equations:

$$10\hat{d} + 60\hat{e} = 88{,}489 \text{ [new second equation]}$$

$$60\hat{d} + 374\hat{e} = 520{,}461 \text{ [new third equation]}$$

Eliminating $\hat{d}$ from this new third equation by subtracting six times the new second leaves:

$$14\hat{e} = -10{,}473$$

or $$\hat{e} = -748.1.$$

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Now, substituting this into the new second equation yields:

$$\hat{d} = \frac{88,489 + 60x748.1}{10} = 13,337.5.$$

And finally, substituting these values for e and d into the original first equation yields:

$$\hat{c} = \frac{560,390 - 15x13,337.5 + 55x748.1}{5}$$

$$= \frac{401,473.0}{5} = 80,294.6.$$

Developing enrollment forecasts from these parameter estimates is now simply a matter of substituting the appropriate value for t (t = 6 for 1973/74, and t = 7 for 1974/75) into the original model:

$$\hat{E}_{1973/74} = \hat{c} + \hat{d}t + \hat{e}t^2$$

$$= 80,294.6 + 13,337.5 \times 6 - 748.1 \times 36 = 133,388.0$$

$$\hat{E}_{1974/75} = 80,294.6 + 13,337.5 \times 7 - 748.1 \times 49 = 137,000.2$$

3. Higher-Order Polynomial Models.

Depending on the nature of the trends in enrollments, it may be appropriate to consider higher-order polynomials as the basis for projections. Conceptually, there is little difference between a higher-order model and the second-order model outlined above. However, the calculations are more laborious and probably best handled by a least squares estimation computer program.

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One of the complications related to higher-order models that should be kept in mind is the variety of curve forms that can be represented. Just because a particular curve form is "well behaved" for the particular set of numbers corresponding to the historical enrollments being analyzed does not guarantee that the curve will not change shape substantially for the forecast years. Frankly, unless one is quite convinced of the nature of the current enrollment trends, higher-order polynomial models should probably be avoided.

Another thing that should be kept in mind is that the number of data points always must be at least as large as the number of parameters to be estimated in the model. If the two numbers coincide, the model will fit the historical data points exactly. However, this by no means guarantees that the model will fit future data points as can be seen in Figure 3.

One general problem with polynomial model forecasting techniques is that one usually is not certain ahead of time which specific polynomial form should be used. It could be linear (that is, first order), quadratic (that is, second order), or some more complex form. There is also the important question whether it is appropriate to assume that the trend or pattern of past enrollments (assuming that it can be fit by some polynomial model) will continue in the future. If, as in many states in the early 1970s, this is not the case, polynomial models are not entirely appropriate.

Exponential Models (EM)

The general form of exponential models is:

$$E = f \cdot g^t$$

where f and g are parameters to be estimated and t represents time. The fact that the parameters in the model are multiplied together rather than added provides opportunities to reflect more accurately some situations in which the rate of growth or shrinkage of enrollments is constant (that is, when the percentage change in enrollments is constant from year to year).

It is difficult to estimate the parameters for this model directly; however, by performing a logarithmic transformation of the model it is possible to obtain the following equivalent model:

$$\ln(E) = \ln(f) + t \cdot \ln(g) = F + t \cdot G$$

where $F = \ln(f)$, $G = \ln(g)$ and ln denotes natural logarithm. (Base 10 logarithms can be used with no change in results.)

In this form the model can be treated as if it were a first-order polynomial model, and the coefficients can be estimated using the same computational procedures. Specifically, the following equations can be used to estimate the two parameters:

$$\hat{G} = \frac{n \cdot \Sigma(t_i \cdot \ln(E_i)) - (\Sigma \ln(E_i)) \cdot (\Sigma t_i)}{n \Sigma t_i^2 - (\Sigma t_i)^2}$$

$$\hat{F} = \frac{\Sigma \ln(E_i) - \hat{G} \Sigma t_i}{n} .$$

All that remains then to obtain the estimates of f and g required for the original model is to take the antilogs of F and G, respectively.

Using the data in Table 4 the following results are obtained for this example:

$$\hat{G} = \frac{5x175.10935 - 58.102271x15}{5 \times 55 - 15 \times 15} = 0.0802537$$

$$\hat{F} = \frac{58.102271 - 0.0802537x15}{5} = 11.3796931.$$

Now taking the antilogs:

$$\hat{g} = 1.083561932$$

$$\hat{f} = 87{,}526.2.$$

The final model thus is:

$$\hat{E} = 87{,}526.2x(1.083561932)^t.$$

For 1973/74 (t = 6), which is the check year in the current example, and for 1974/75 (t = 7) the model yields the following enrollment estimates:

$$\hat{E}_{1973/74} = 87{,}526.2x(1.083561932)^6 = 141{,}664.3$$

$$\hat{E}_{1974/75} = 87{,}526.2x(1.083561932)^7 = 153{,}502.1.$$

Notice that since $\hat{g}$ is greater than one, the model will generate larger enrollment estimates for each successive year in the future. In fact, each successive estimate will be approximately 8.4 percent larger than the previous one. Since the actual enrollment had turned down in 1973/74, this model almost certainly is inappropriate for the current circumstances.

Table 4. SUPPORTING DATA AND CALCULATIONS FOR THE EXPONENTIAL MODEL EXAMPLE

Year	t_i	t_i^2	E_i	$\ln E_i$	$t \cdot \ln E_i$
1968/69	1	1	93,309	11.443672	11.443672
1969/70	2	4	102,822	11.540755	23.081510
1970/71	3	9	114,490	11.648243	34.944729
1971/72	4	16	121,609	11.708566	46.834264
1972/73	5	25	128,160	11.761035	58.805175
Sum (Σ)	15	55	560,390	58.102271	175.109350

Spectral Analysis (SP)

Spectral analysis involves a special form of polynomial model in which trigonometric functions (sine and cosine) replace 't' in the equations. It is mentioned here only to indicate that it is very unlikely that this technique will be appropriate fcr enrollment forecasting. To obtain sufficient statistical reliability with this technique requires a minimum of (approximately) 25 historical data points. Not only is this amount of data generally not available, but also if it were, the assumption of continuing pattern of enrollments undoubtedly would be violated.

Unfortunately, because of the complexity of the mathematics that underlies spectral analysis techniques, there are no simple texts or references on spectral analysis. Readers interested in more information on the subject can try Anderson (1971) or Blackman and Tukey (1959).

A Comparison and Summary of the Curve-Fitting Techniques

The critical question that remains for enrollment forecasting practitioners is which, if any, of these curve-fitting techniques should be used in actual practice. The answer to this question will depend in large part on the nature of the enrollment trends in the state. If they are unstable, as appears to be the case in the situation covered by the data in Table 1, then it would probably be best to avoid all of the curve-fitting techniques. Of course, if one is quite certain about the nature of the instability and therefore can calculate appropriate adjustments, one of the polynomial models may be acceptable.

Figure 3, which summarizes the results of the five curve-fitting examples, illustrates the variety of results that can be obtained by the different techniques. Given this variety it is clear that analysts cannot simply select a method at random. They must give careful attention to the assumptions required by each technique and how the assumptions correspond with the situation in their own states. If the match is good, the technique deserves careful consideration; if it is not, the technique should be avoided.

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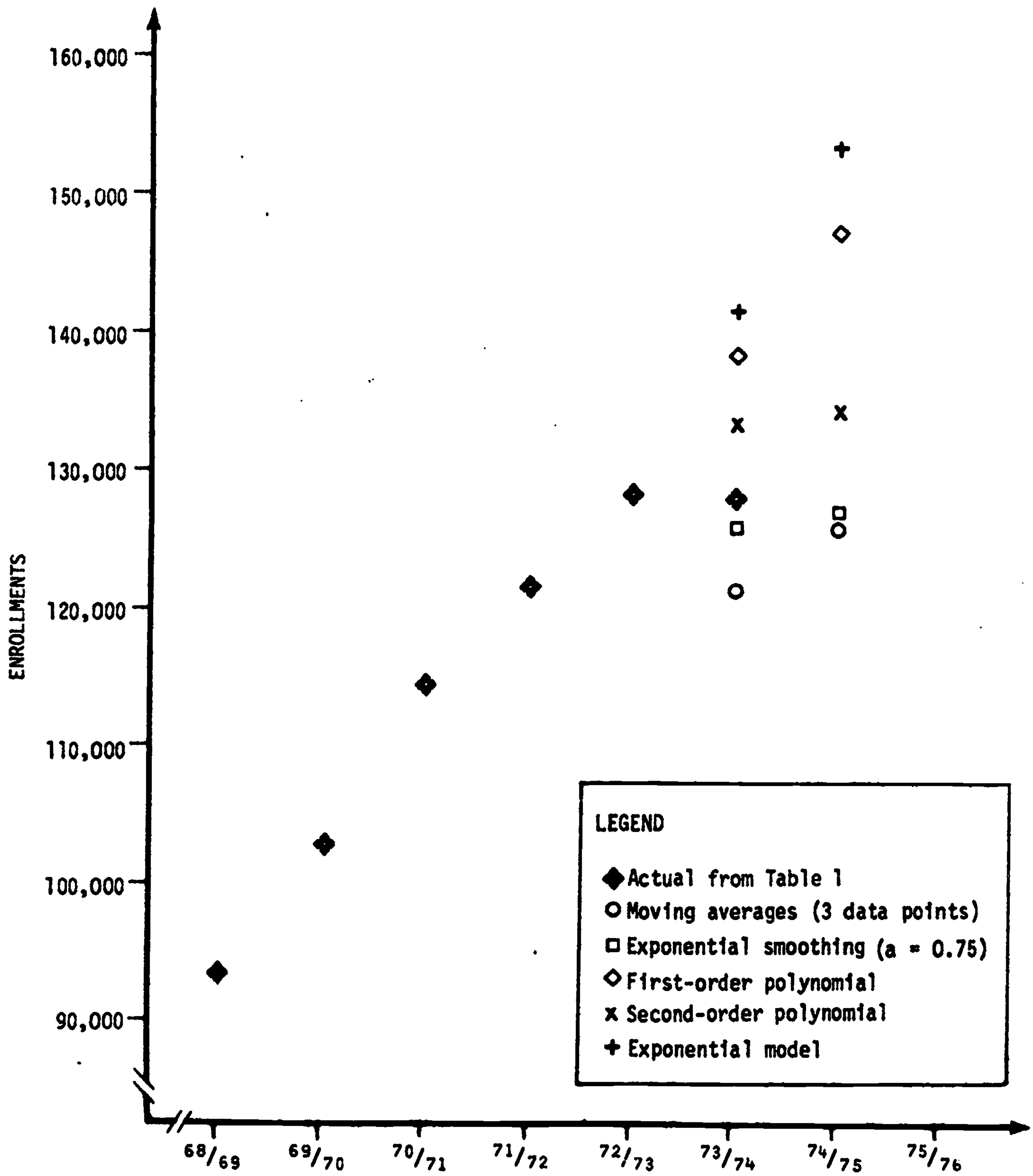

Figure 3. COMPARISON OF THE ENROLLMENT PROJECTIONS OBTAINED BY FIVE DIFFERENT CURVE-FITTING TECHNIQUES

CAUSAL MODELS

In situations in which it is possible to identify relationship(s) between higher education enrollments and other independent factors (such as high school graduates), analysts should give serious consideration to one or more of the causal models that are available. If, for example, it is felt that first-time college enrollment is related closely to the number of high school graduates in earlier years, a cohort-survival technique may be appropriate. If a significant and stable proportion of new college enrollees are women between 35 and 45 years old, a ratio method may be appropriate.

Two general considerations should be kept in mind when evaluating causal models:

(1) Is the independent factor in the model (high school graduates and women between 35 and 45 years old in the previous paragraph) really related to enrollments?

(2) Is the relationship between the independent factor(s) and enrollments stable and predictable?

(3) Can the independent factor be forecast reliably?

If these questions can be answered affirmatively, then one of the causal models probably is an appropriate basis for enrollment forecasting.

One more general observation seems appropriate: the same causal model may not be equally appropriate for all forecasting situations. In one state a cohort-survival model may be appropriate for projecting first-time enrollments in four-year colleges and universities, a ratio model may be a better choice for community colleges, and a Markov transition model may be a good choice for estimating persistence patterns of students already admitted. Other techniques may be more appropriate in other states.

Five causal models are discussed below: cohort-survival techniques, ratio methods, multiple correlation and regression methods, path-analytical models, and systems of equations. Illustrative applications are provided for the cohort-survival and ratio methods techniques. In addition, an illustration of the use of a Markov transition model, which is a curve-fitting technique, is provided.

The cohort-survival technique is illustrated by forecasting the number of new freshmen who were high school graduates in the state in the previous year. A ratio method then is used to forecast all other new freshmen. And, finally, a Markov transition model is used to develop estimates of total undergraduate enrollments based on the forecasts of new freshmen obtained from the first two examples.

Cohort-Survival Technique(s) (CS)

A cohort is a group of individuals having some common classification trait or traits. For example, a cohort could be defined as all the women born in Massachusetts in 1953. Another cohort might be all those persons who were in first grade in Missouri in 1961. Cohort-survival techniques are based on the premise that the survival or transition patterns of the particular group of individuals in the designated cohort will be the same as those for other similar cohorts.

In practice the reference cohorts often are taken to be the children enrolled in first grade in a state in several successive years. The survival rates of these cohorts from grade to grade are computed for successive years and trends are identified. Then projections for later years are made assuming that the trends in survival rates for the reference cohorts will continue to hold in the future for additional cohorts. This particular approach using grade-to-grade survival patterns usually is referred to as the grade-progression or class-succession method.

It sometimes is appropriate to use the people born in a particular year as the reference cohort, and to estimate the extent to which this group survives by year of age, from birth through college graduation. This variation is referred to as the age-survival method. Using either of these methods at the state level requires the assumption that net migration, mortality, and school attendance patterns remain stable over time. If these assumptions are not valid, special attention must be given to identifying the original cohort and/or estimating the extent of the trends in migration, and so forth so that appropriate adjustments in the survival rates can be made.

The particular cohort-survival technique that will be illustrated is the grade-progression method, which will be used to estimate the number of new freshmen who were in-state high school graduates in the previous year. To

TABLE 5. AVERAGE GRADE-PROGRESSION RATIOS (GPRs)
FOR ELEMENTARY AND SECONDARY GRADES IN A STATE
BASED ON HISTORICAL ENROLLMENTS AND GRADE PROGRESSIONS

ACTUAL ENROLLMENTS AND GPRs

YEAR	GRADE LEVEL 1	2	3	4	5	6	7	8	9	10	11	12
1969/70	33,712	32,715	31,523	31,564	30,877	30,198	30,148	29,460	28,594	27,561	25,346	23,852
		0.946	0.964	0.950	0.961	0.958	0.976	0.962	0.969	0.986	0.959	0.949
1970/71	32,767	31,878	31,545	29,933	30,322	29,568	29,466	29,001	28,535	28,204	26,437	24,047
		0.968	0.991	0.973	0.990	0.981	0.999	0.988	0.997	0.979	0.955	0.958
1971/72	31,815	31,718	31,583	30,679	29,637	29,769	29,528	29,103	28,915	27,931	26,924	25,330
		0.974	0.992	0.975	0.992	0.994	1.008	0.989	0.992	0.971	0.947	0.939
1972/73	30,672	30,984	31,475	30,807	30,442	20,445	30,001	29,216	28,872	28,065	26,445	25,291
AV. GPR		0.963	0.982	0.966	0.981	0.978	0.994	0.980	0.986	0.979	0.954	0.949

NOTES: The figures on the diagonals are the Grade Progression Ratios (GPRs). They are the ratio of an actual enrollment in one grade level and year to the enrollment in the next earlier grade level and year. For example, the three computed GPRs for movements from grade 7 to grade 8 are: 29,001/30,148 = 0.962; 29,103/29,466 = 0.988; 29,216/29,528 = 0.989. The average GPR is the average of the three actual GPRs for the same grade level.

illustrate how the technique can be used to develop long-range enrollment forecasts, grades one through twelve are included in the calculations, which permits the development of relatively long-range enrollment forecasts.

The first step in the grade-progression method is the construction of a table of Grade-Progression Ratios (GPRs), which are the fractions of students in one grade level that continue on to the next grade level in the next year. Table 5 shows the required calculations for a hypothetical state for grades one through twelve. The table also carries the process one step further by computing the average GPRs for all progressions. This is done on the assumption that the GPRs are stable over time. If trends in the GPRs were apparent, it would be appropriate to consider one of the previously discussed curve-fitting techniques for estimating future GPRs.

Readers should be aware of several assumptions implicit in the calculations in Table 5. For example, it is assumed that the general patterns of grade repeating are stable over time; it is assumed that interstate migration patterns are stable and will not distort the GPRs; and it is assumed that the fluctuations in the GPRs are random occurrences and not part of any trend over time. In actual practice users must determine whether these are valid assumptions, and, if they are not, make appropriate adjustments in the calculations. (If, for example, there were a significant trend in a state toward a smaller number of grade repeaters, one should try to quantify the impact of this trend on the GPRs using an appropriate forecasting technique.)

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TABLE 6. PROJECTIONS OF ELEMENTARY AND SECONDARY ENROLLMENTS BASED ON GRADE-PROGRESSION RATIOS FROM TABLE 5

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YEAR	GRADE LEVEL 1	2	3	4	5	6	7	8	9	10	11	12
1972/73	30,672	30,984	31,475	30,807	30,422	29,445	30,001	29,216	28,872	28,065	26,445	25,291
AV. GPR		0.963	0.982	0.966	0.981	0.978	0.994	0.980	0.986	0.979	0.954	0.949
1973/74		29,537	30,426	30,405	30,222	29,753	29,268	29,401	28,807	28,266	25,774	25,096
1974/75			29,005	29,392	29,827	29,557	29,574	28,683	29,007	28,202	26,965	25,409
1975/76				28,019	28,933	29,171	29,379	28,983	28,281	28,398	26,905	25,590
1976/77					27,486	28,199	28,996	28,792	28,577	27,687	27,092	25,533
1977/78						26,882	28,030	28,416	28,389	27,979	26,414	25,710
1978/79							26,721	27,469	28,018	27,793	26,690	25,067
1979/80								26,186	27,084	27,430	26,514	25,329
1980/81									25,819	26,516	26,168	25,162
1981/82										25,277	25,296	24,833
1982/83											24,115	24,006
1983/84												22,885

NOTES: The enrollment estimates for a particular grade level and year are computed by multiplying the enrollment in the next earlier grade level and year bv the appropriate average Grade Progression Ratio (GPR) from Table 5. For example, the grade 11 enrollment in 1981/82 is equal to the grade 10 enrollment in 1980/81 times the grade 10-11 GPR (25,296 = 26,516 x 0.954).

Given the average GPRs for all grades and the current enrollments in grades one through twelve, it is possible to estimate twelfth grade enrollments for eleven years into the future. Table 6 illustrates the calculations assuming that 1972/73 is the last year for which actual enrollment data are available.

The last two steps in the procedure, which are illustrated in Table 7, are to estimate the number of in-state high school graduates and finally the number of first-time freshmen. The estimates of the number of future high school graduates are obtained in much the same way as the grade enrollment estimates: an estimate of the graduation rate is obtained by taking the average of the actual graduation rates for the last four years for which actual data are available. This average graduation rate then is multiplied by the appropriate twelfth grade enrollment estimates for future years to obtain the estimates of the in-state high school graduates. The calculations for the estimates of the number of first-time freshmen are exactly analagous to those for high school graduates.

It is important to note that it is "first-time freshmen from in-state high schools in the previous year" that is being estimated in this particular example. The new freshmen from other sources (for example, returning military personnel, graduates of out-of-state high schools, older members of the population returning to school) must be estimated separately.

In practice, the categories of entering freshmen for which separate forecasts can be developed may be limited by the kinds of data about

Table 7. PROJECTIONS OF FIRST-TIME FRESHMEN FROM IN-STATE HIGH SCHOOLS IN PREVIOUS YEAR BASED ON PARTICIPATION RATES OF IN-STATE HIGH SCHOOL GRADUATES

	YEAR	IN-STATE GRADE 12 ENROLLMENTS	HIGH SCHOOL GRADUATION RATE	IN-STATE HIGH SCHOOL GRADUATES	HIGH SCHOOL PARTICIPATION RATE	FIRST-TIME FRESHMEN FROM IN-STATE HIGH SCHOOLS IN PREVIOUS YEAR
ACTUAL	1969/70	23,852	(0.988)	23,566	(0.552)	13,008
	1970/71	24,047	(0.991)	23,831	(0.567)	13,512
	1971/72	25,330	(0.985)	24,950	(0.558)	13,922
	1972/73	25,291	(0.989)	24,820	(0.553)	13,728
	AVERAGE PERCENTAGES		(0.9883)		(0.5575)	
ESTIMATED	1973/74	25,096	↓	24,802	↓	13,827.1
	1974/75	25,409		25,112		13,999.9
	1975/76	25,590		25,291		14,099.7
	1976/77	25,533		25,234		14,068.0
	1977/78	25,710		25,409		14,165.5
	1978/79	25,067		24,773		13,810.9
	1979/80	25,329		25,033		13,955.9
	1980/81	25,162		24,868		13,863.9
	1981/82	24,833		24,542		13,682.2
	1982/83	24,006		23,725		13,226.7
	1983/84	22,885	(0.9883)	22,617	(0.5575)	12,609.0

NOTES: The average percentages are the mean of the four corresponding actual percentages. The estimated In-State Grade 12 Enrollments are from Table 6. The estimated In-State High School Graduates are the product of the estimated Grade 12 Enrollments and this appropriate average Graduation percentage. The estimated First-Time Freshmen are the product of the estimated High School Graduates and the appropriate estimated High School Participation Rate.

the sources of new freshmen that are available from the institutions in the state. In some situations, data for more than one set of entering student categories may exist. Unfortunately, it probably is not possible to determine in advance whether the choice of categories in such a situation will have a significant impact on the accuracy of the resulting forecast. In general one would expect more categories to contribute to more accurate forecasts, but this rule of thumb would have to be validated by empirical study. Regardless of these matters, it is extremely important to make adjustments for any known trends in grade-progression patterns that may have an impact on the desired forecasts.

Ratio Methods (RM)

Ratio methods produce enrollment projections based on trends in ratios of enrollment to such other variables as the number of individuals in the geographic area who are between 18 and 24 years old. For projections of enrollments in the traditional four-year colleges and universities, this is probably inferior to the grade-progression method mentioned above because of the strong relationship between high school graduates and college and university enrollments. However, for certain segments of the population, such as housewives returning to school or senior citizens, this probably is a very appropriate technique. Variables other than numbers of individuals in particular age categories (for example, state revenues for higher education) also can be used, but any ratio method should be validated using recent historical data prior to using the resulting forecasts as the basis for important decisions.

To illustrate the use of the ratio method, the technique is used to develop estimates of the number of new freshmen in the state not included in the previous example (that is, the number of new freshmen in the state who were not in-state high school graduates in the previous year). It is assumed that, based on previous experience or an educated guess, "State Population 25 and Older" is closely correlated with the number of "New Freshmen Other than In-State High School Graduates in the Previous Year."* It is also assumed that independent projections of this state population statistic are available as in Table 8.

Given these data, calculations for the ratio method are straightforward: for a number of recent years, four in the example of Table 8, the ratio of "New Freshmen Other than In-State High School Graduates in the Previous Year" (the dependent variable in the model) to "State Population 25 and Older" (the independent variable in the model) is computed. This set of ratios then is projected into the future using some forecasting procedure, simple averages in the example. And finally, the desired forecasts of "New Freshmen Other than..." are obtained for each year out to 1983/84 by multiplying the "State Population 25 and Older" figures by the ratios for the corresponding years. The results of the calculations in this example are shown in Table 8.

It is important to note that in any causal model it must be possible to obtain reliable projections of the other variable (in this example,

*This particular example may be quite unappealing to someone from a state that has large numbers of students from other states. In formulating the example, it was assumed implicitly that few out-of-state students were involved.

Table 8. RATIO METHOD USED TO FORECAST NEW FRESHMEN WHO WERE NOT IN-STATE HIGH SCHOOL GRADUATES IN THE PREVIOUS YEAR

	YEAR	STATE POPULATION 25 AND OLDER (A)	RATIO OF (B) TO (A)	NEW FRESHMEN OTHER THAN IN-STATE HIGH SCHOOL GRADUATES IN THE PREVIOUS YEAR (B)
ACTUAL	1969/70	250,640	0.01724	4,320
	1970/71	255,780	0.01900	4,860
	1971/72	258,120	0.01908	4,925
	1972/73	263,200	0.01881	4,950
	AVERAGE RATIO		(0.01853)	
ESTIMATED	1973/74	265,350	↓	4,916.9
	1974/75	270,100		5,004.9
	1975/76	273,520		5,068.3
	1976/77	279,300		5,175.4
	1977/78	288,420		5,344.4
	1978/79	291,350		5,398.7
	1979/80	294,700		5,460.8
	1980/81	301,715		5,590.8
	1981/82	305,620		5,663.1
	1982/83	307,290		5,694.1
	1983/84	312,800	(0.01853)	5,796.2

NOTE: The estimated state population 25 and older has been obtained from an independent source.

"State Population 25 and Older"). The same general procedures described in this manual can be used for this task.

Markov Transition Model (MT)

As indicated earlier, the Markov transition model actually is a curve-fitting model since it relies on historical enrollment data only. In fact, it requires the assumption that enrollments in one year are dependent only on the enrollments in the previous year. It is discussed and illustrated at this point in the manual because it completes a sequence of techniques started by the two previous examples.

The example uses a Markov transition model to extend the forecasts of new freshmen developed above into forecasts of total undergraduate enrollments. The process involves the application of a transition matrix to produce estimates of the numbers of students enrolled in each of the student levels in the next time period. Successive applications of the procedure can be used to develop forecasts as far into the future as data on new entering students exist (assuming, of course, that the underlying assumptions required by the technique are fulfilled).

The transition matrix used in this example is shown in Table 9. The entries in the matrix, which are the estimated probabilities that students at different levels will move to other levels in the next year, reflect student progression for the state as a whole. For example, the table indicates that 71.3 percent of all sophomores in the state will move on to become juniors at some institution in the state.

Table 9. PROBABILITIES THAT STUDENTS AT DIFFERENT LEVELS WILL MOVE TO OTHER LEVELS IN THE NEXT YEAR

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(FROM STUDENT LEVEL)	TO STUDENT LEVEL								EXIT CATETORY	
	NEW ENTRANTS	FRESH-MAN	SOPHO-MORE	JUNIOR	SENIOR	UNCLASSI-FIED	GRADUATE	PROFES-SIONAL	COMPLETED	EXIT
FRESHMAN	0.000	0.090	0.605	0.011	0.000	0.000	0.000	0.000	0.000	0.294
SOPHOMORE	0.000	0.008	0.137	0.713	0.043	0.000	0.000	0.000	0.021	0.078
JUNIOR	0.000	0.000	0.007	0.118	0.705	0.000	0.002	0.026	0.057	0.085
SENIOR	0.000	0.000	0.000	0.011	0.119	0.000	0.025	0.021	0.783	0.041
UNCLASSIFIED	0.000	0.010	0.009	0.080	0.007	0.332	0.000	0.000	0.312	0.250
GRADUATE	0.000	0.000	0.000	0.000	0.000	0.000	0.293	0.013	0.175	0.519
PROFESSIONAL	0.000	0.000	0.000	0.000	0.000	0.000	0.027	0.457	0.285	0.231

NOTES: The sum of the entries in each row of the matrix should be 1.0. The entries in the matrix are the probabilities that students at different levels (row labels) will move to other (or the same) levels (column labels) in the next year. For example, the table indicates that the probability that a sophomore will become a junior in the next year is 0.713. Put another way, there is a 71.3 percent chance that a sophomore will become a junior in the next year. The sum of the values in each row must equal 1.

Several assumptions have been made in setting up this hypothetical transition matrix that readers should consider as they evaluate the utility of this approach in their own situations. First, it has been assumed that the chosen set of student levels and exiting categories is appropriate for planning purposes and feasible for data collection purposes. Second, it has been assumed, primarily to simplify the computations, that a single transition matrix for the entire state is more appropriate than one that identifies the student levels for different segments of higher education or even individual institutions. Third, the possibility of interstate migration of students has not been provided for, again to simplify the computations. Fourth, it is assumed that the transition probabilities are independent of transitions that may have occurred in previous years. And finally, and most importantly, it is assumed that the transition probabilities in Table 9, which in practice would be based on historical student transitions, will continue to reflect student transitions in the future. Adjustments and modifications can be made relative to the first three assumptions; analysts must use their judgment about the risks associated with the last two.

Assuming that the potential benefits related to obtaining the enrollment forecasts using this technique outweigh the risks, the example can be carried through. Starting with the actual 1972/73 enrollments, and assuming for simplicity that there are no unclassified students, successive applications of the technique yield the enrollment forecasts for total freshmen, total sophomores, total juniors, total seniors, and total undergraduates through 1983/84 as shown in Table 10.

Table 10. FORECASTS OF UNDERGRADUATE ENROLLMENTS IN A STATE BASED ON A MARKOV TRANSITION MODEL

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	YEAR	TOTAL NEW FRESHMEN (1)	TOTAL FRESHMEN (2)	TOTAL SOPHOMORES	TOTAL JUNIORS	TOTAL SENIORS	TOTAL UNDERGRADS
ACTUAL	1972/73	18,678	20,475	14,320	13,115	11,530	59,440
ESTIMATED	1973/74	18,744.0	20,701.4	14,441.0	12,109.8	11,234.0	58,486.2
	1974/75	19,004.8	20,983.4	14,587.5	12,079.9	10,530.5	58,181.3
	1975/76	19,168.0	21,173.3	14,778.1	12,027.0	10,396.7	58,375.1
	1976/77	19,243.4	21,267.2	14,918.7	12,303.3	10,351.7	58,840.9
	1977/78	19,509.9	21,543.2	14,996.7	12,736.6	10,547.2	59,523.7
	1978/79	19,209.6	21,268.5	15,175.2	12,513.1	10,667.8	59,625.6
	1979/80	19,416.7	21,452.3	15,034.0	12,647.7	10,743.7	59,877.7
	1980/81	19,454.7	21,505.7	15,126.8	12,565.8	10,841.6	60,039.9
	1981/82	19,345.3	21,401.8	15,171.3	12,624.1	10,799.6	59,995.8
	1982/83	18,920.8	20,968.4	15,115.0	12,660.9	10,837.6	59,581.9
	1983/84	18,405.2	20,423.3	14,845.3	12,620.9	10,865.5	58,755.0

NOTES: (1) "Total New Freshmen" is the sum of the forecasts of "First-Time Freshmen from In-State High Schools in Previous Year" from Table 7 and "New Freshmen Other Than ..." from Table 8.

(2) "Total Freshmen" is the sum of "Total New Freshmen" and those students who repeat the freshman year and drop back from sophomore year. See Table 11.

The specific calculations that must be performed to arrive at the estimates in Table 10 are illustrated in Table 11, which shows the detailed calculations performed to extend the actual enrollments of 1972/73 to the estimated enrollments of 1973/74. It is important to note that in general the total enrollment at each student level is the sum of enrollments from several sources. In Table 11 the estimated total freshman enrollment is the sum of new entering freshmen (18,744.0), plus 9 percent of the 1972/73 freshmen (.090 times 20,475 = 1,842.8), plus 0.8 percent of the 1972/73 sophomores (.008 times 14,320 = 114.6). (The percentages are taken from the transition matrix of Table 9; and the 1972/73 enrollments are taken from Table 10.)

Similar calculations were performed in succession for each of the eleven years in Table 10. Since actual enrollments are not available after 1972/73, the calculations for each year after the first one require the use of the enrollment estimates for the previous year.

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Table 11. SAMPLE WORKSHEET FOR MARKOV TRANSITION CALCULATIONS
EXAMPLE FOR THE YEAR 1973/74

	ESTIMATED 1973/74 ENROLLMENTS			
SOURCE	FRESHMEN	SOPHOMORES	JUNIORS	SENIORS
72/73 FRESHMEN	1,842.8	12,387.4	225.2	0
72/73 SOPHOMORES	114.6	1,961.8	10,210.2	615.8
72/73 JUNIORS	0	91.8	1,547.6	9,246.1
72/73 SENIORS	0	0	126.8	1,372.1
SUBTOTALS	1,957.4	14,441.0	12,109.8	11,234.0
NEW ENTRANTS	18,744.0	0	0	0

GRAND TOTAL 58,486.2

NOTE: To simplify the calculations it has been assumed that there are no unclassified students and that there are no new entrants at levels other than freshman.

Multiple Correlation and Regression Methods (MC)

Multiple correlation and regression procedures attempt to determine the association between enrollments (dependent variable) and one or more independent factors or variables. Depending on the strength of the relationship among these variables, and the extent to which the historical relationships are expected to continue, this technique can be used to develop enrollment projections.

There are many similarities between multiple correlation and regression methods and the polynomial models technique. Whereas polynomial models use powers of time as the independent variables, multiple regression can accomodate a wide variety of independent factors, such as high school graduates, per capita income, and ethnic background. Despite similarities in computational techniques, however, multiple correlation and regression require a number of assumptions that have important implications for the interpretation of the resulting estimates.

The critical area in which multiple correlation and regression appears to have the most potential for assisting enrollment forecasting practitioners is student demand estimation. As indicated in the first chapter, one can estimate the supply of openings in higher education institutions and/or the demand for admission by potential students. Without an understanding of both, however, the chances of being able to develop reliable enrollment forecasts in periods of change like the early 1970s are greatly diminished. Unfortunately, the ability of analysts to estimate student demand is lagging far behind their ability to estimate either the supply of openings or final enrollments. A great deal of "research and development" effort is required to develop an understanding of student demand and the factors that influence it.

One of the important tools for carrying out this kind of research is the multiple correlation and regression technique. One of the advantages of this technique is that it permits the development of models of student behavior patterns that reflect knowledge and intuitions about the reasons for students' enrolling in higher education programs and institutions. Whether these "more realistic" models lead to more accurate enrollment forecasts is something that has yet to be demonstrated.

It is beyond the scope of this manual to provide a detailed example of the application of regression analysis. Several examples can be found in the two reports by Haggstrom (1971a and 1971b). Draper and Smith (1966) presents a good basic introduction to regression analysis while Wonnacott and Wonnacott (1970) has a more detailed discussion of the technique, including some of the possible sources of error, such as autocorrelation and multicollinearity.

Path-Analytical Models (PA)

Path-analytical models are extensions of multiple correlation and regression models. The basic difference between the two is that path-analysis requires the a priori identification of the causal relationships between the dependent variable (college enrollment in this case) and the relevant independent variables such as grade point average, ethnicity, income, and so forth. It also allows for the specification of intermediate causal relationships that can reflect actual situations and behavior patterns more accurate . Readers interested in more detail about the theoretical and computational aspects of path-analysis can refer to either Duncan (1966) or Van de Geer (1971). As with regression analysis, this technique probably is best suited for the study of student demand rather than direct applications for enrollment forecasting. An application of the technique to the problem of identifying factors important in determining whether high school graduates go on to college can be found in the report by Tsai (1973).

Systems or Equations (SE)

In some situations it may be appropriate to develop more complex techniques and models to describe the interrelationships among enrollments and other external and internal factors. This can be done by developing a system of equations that describe in quantitative terms the linkages between the different parameters of interest. Such a system of equations can be treated as either an optimization model or a simulation model, depending on the specific objectives of the user. Because of the difficulty of designing such models and explaining their operation to policy makers, very few such models have been developed that could be used in an enrollment forecasting situation.

A good example of such a model is the National Planning Model developed at NCHEMS (Huckfeldt, 1973) as an experimental research tool. This model has been designed to study the impact of alternative federal higher education financing plans on both student demand for higher education and the institutional supply of openings. Although the model has not been designed for the purpose of forecasting enrollments, it does provide estimates of future enrollments as one of its outputs.

Student flow models (for example, NCHEMS Student Flow Model SFM-IA !Martin and Wing, 19731) also might be classified as systems of equations, since they often combine several of the techniques described above, although they might be classified as Markov models. A paper by Gray (1974) describes some extensions of the typical student flow models that easily qualify as systems of equations. The extensions involve the incorporation of goal seeking features that cause a student flow model to compute enrollment levels that reflect a variety of policy constraints and relative priorities.

INTENTION SURVEYS

All of the techniques and models discussed above have one thing in common: they rely on historical data and assume that the conditions and trends present when the historical data were generated will continue until the time for which the enrollment forecasts are desired. Of course, there always are some deviations from historical trends, but if they are small enough, the errors introduced into the projections may fall within tolerable limits.

What happens, however, in periods like the mid-1960s when the Viet Nam war broke out and the early 1970s when the attitudes of society and potential students toward higher education changed substantially? The impact on enrollment projections was all too obvious: projections developed for the mid 1960s typically were lower than actual enrollments and those for the early 1970s typically were higher than the actual enrollments. These are clear cases of shifts in fundamental attitudes that resulted in a violation of the assumptions required by the various techniques employed.

How can such a situation be avoided or mitigated? One possible way would be to develop some indicators of the attitudes of potential students toward higher education and of their enrollment intentions. And one way to develop such indicators is to survey the potential students: ask high school seniors or even high school freshmen or sophomores what they intend to do in the future.

It should be recognized that running such a survey only once probably will not provide much assistance relative to enrollment forecasting. Only after data have been collected for several years can trends in attitudes and intentions be compared with trends in participation and enrollments to yield more accurate projections. In fact, although it cannot be guaranteed ahead of time, it does seem reasonable to suspect that such surveys would result in more accurate projections.

Secondary education agencies in some cities and states do follow-up on their high school graduates. Typical of the reports produced is the one by the Denver Public Schools (1972) which tabulates the postgraduation activities of Denver high school graduates. More important in an enrollment forecasting context are reports such as the ones by the Florida Board of

Regents (1972) and the Virginia Department of Education (1969) which seek to provide some insights into student preferences and aspirations that may be used in a number of planning contexts, ranging from enrollment forecasting to developing new programs to meet emerging student interests.

Actually, a survey of the intentions of potential students is only one way for a state agency to broach the problem of estimating student demand for higher education. It is emphasized in this manual because it does seem to offer more potential for providing assistance in enrollment forecasting in the short run than some of the more theoretical approaches that have emerged in recent years. This is not to downplay these recent developments; in fact, studies such as the ones by Campbell and Siegel (1967), Galper and Dunn (1969), Radner and Miller (1970), Hoenack (1971), Miller (1971), and Kohn, Manski, and Mundel (1973) offer considerable promise for improved understanding of the factors that influence student demand for higher education. Hopefully, in the future there will be more cooperation between state agencies concerned with planning for higher education and researchers addressing these and other topics that are so fundamental to our understanding of the underlying relationships.

SUBJECTIVE JUDGMENT

Using subjective judgment in forecasting the future, though not scientific and objective, may sometimes provide a useful complement to other forecasting procedures, especially when objective criteria are lacking. It may be necessary, for example, to rely heavily on the judgments of experts to estimate the impact on enrollments of such things as shifts in federal financing patterns, changes in student attitudes, and judicial decisions concerning residence status. In all such cases, caution should be used by analysts in applying their intuitions and subjective judgments, since they can be very wrong. It also may be difficult to convince a budget analyst or legislator to accept an enrollment projection based even in part on intuition.

It should be emphasized that subjective judgment and intuition are recommended here only as supplementary procedures and not as the principal forecasting procedure. It is recommended also that analysts work diligently to identify systematic, quantitative procedures to substitute for their intuition wherever possible. A study by Armstrong and Grohman (1972) indicates that in the area of stockmarket forecasting the quality of forecasts improves as intuitive procedures are replaced by technical procedures.

There are, however, some areas where subjective judgment will be required for some time to come. For example, in selecting the particular polynomial form to be used in a curve-fitting model, it may not be possible to identify a quantitative criterion for making the choice. Or in order to incorporate the findings of a survey of the future intentions of high school students, an analyst may have to apply his or her judgment in estimating the appropriate quantitative adjustments.

Judgment or prior information can also be incorporated into many statistical procedures using concepts attributed to the eighteenth century Scottish pastor, Thomas Bayes. Bayesian counterparts have been developed for many of the techniques described earlier in this chapter. Because of their greater complexity specific examples are not provided in this manual. Readers interested in more background on the subject may refer to Winkler (1972). Readers with a strong background in statistics may find the Bayesian version of regression analysis described by Tiao and Zellner (1964) of some interest.

Another method of applying subjective judgment in a forecasting context is the "Delphi survey." Very briefly, a Delphi survey is an analysis of the opinions about the future of a "panel of experts" related to the problems under investigation. The Delphi survey done at NCHEMS concerning possible future changes in postsecondary education (Huckfeldt, 1972) is an example of this method. In the context of enrollment forecasting, this technique probably does not have any direct applications. However, the opinions of the panel may have an impact on policies related to enrollments or provide indications of future trends that ought to be considered in enrollment forecasting procedures.

CHAPTER III

CONSTRUCTING AN ENROLLMENT FORECASTING PROCEDURE

The discussion in the preceding chapters has described a series of pieces of what might be thought of as an enrollment forecasting "Erector Set," with little reference to how they might be assembled to obtain an operational enrollment forecasting procedure. In this chapter an attempt will be made to provide some guidance to analysts who must face the problem of designing and synthesizing complete forecasting procedures.

Before proceeding it is important to indicate that it is not possible to specify a single forecasting procedure that will serve in all situations. Differences in organizational arrangements, public preferences and priorities, and institutional offerings (among a myriad of possible factors) create situations in different states that can be dealt with only on state-by-state or agency-by-agency bases. This does not mean that occasionally more than one agency may not find the same procedures to be appropriate; however, the same procedure certainly cannot be applied in all forecasting situations.

For this reason no attempt will be made in this manual to specify a single all-encompassing forecasting procedure. Instead, the emphasis will be on providing very general guidelines to analysts for constructing their own enrollment forecasting procedures based on the particular situations that exist in their states, agencies, and institutions.

GUIDELINES FOR CONSTRUCTING A FORECASTING PROCEDURE

The five-step procedure outlined below is suggested as a point of departure for analysts facing the task of designing an enrollment forecasting procedure. Each of the steps will require some tailoring for specific states or agencies, but the general procedure should be applicable in a wide variety of situations.

1. Partition the population of students and potential students into categories based on characteristics of both individuals and institutions that are suspected to have an impact on enrollments. It should be possible to obtain data for these different categories.

   Among the student characteristics that should be considered are enrollment status (for example, currently enrolled versus not enrolled), residence status (that is, in-state resident versus out-of-state resident), and, for those not currently enrolled, high school status (for example, high school senior versus "adult"). Institutional characteristics that should be considered are type of institution (for example, major research university, four-year college, community/junior college), and general type of program (for example, general academic, vocational/technical, adult/continuing).

   There are, of course, additional characteristics that could be used. Recent studies (for example, Miller, 1971) suggest that income and ability are the most useful student characteristics, and cost to the student is the most useful institutional characteristic in terms of estimating the demand for higher education.

In some states other factors, such as geographic location, sex, race, and academic or vocational discipline, may deserve consideration also.

2. Identify the most appropriate forecasting technique(s) for each of the categories of students and potential students that have been identified. The final selection will depend on factors too numerous to specify in this manual; however, the following general guidelines are suggested as a point of departure.

   a. First, try to identify a causal model that corresponds to the situation for the particular category of students under consideration. In practice, causal models have proven to be better than curve-fitting models in most forecasting situations, particularly when enrollment patterns are changing.

   To identify an appropriate causal model, one must identify factors related to enrollment patterns of individuals in each category of students or potential students. For example, the number of in-state high school graduates often is closely related to freshman enrollments in a state. If the relationship between the factor(s) and enrollments is stable over time (which would have to be verified empirically), the relationship can be translated into a causal model as in the example of the ratio method in the previous chapter.

b. If no other factor(s) related to enrollments can be identified, or if data corresponding to the factor(s) are not available, one should consider one of the curve-fitting models. By plotting both historical enrollment data for the category of students or potential students and the data points obtained for a number of different curve-fitting models (as in Figure 3), one can develop a crude basis for comparing and evaluating different curve-fitting models. The final choice must necessarily be based in part on the analyst's judgment about which of the enrollment patterns is more likely to continue to be valid in the future.

3. The next step in the general procedure is to perform the calculations required for each of the categories of students and potential students. This is one time at which to make judgmental adjustments in the numerical results based on such things as the results of a continuing survey of high school seniors or the expected impact of a change in tuition levels or program offerings at specific institutions.

4. The final step in the procedure is to compute the total enrollment figure by summing the estimates for each of the individual categories.

5. Before using the resulting forecasts as the basis for some important decision, it is appropriate to perform some sort of validation of the results. This could be done by performing the entire forecasting procedure substituting data for the prior year so that the most recent

year's actual enrollment data can be used as a check (as was done in the curve-fitting examples in this manual). It also could involve more elaborate procedures to estimate possible forecasting errors such as those suggested in the following section of the manual.

It should be emphasized that the general procedure outlined above has been suggested only as a point of departure and not as a strategy that must be followed in all situations. It is anticipated that the discussion will be of particular interest and value to analysts who are new to the enrollment forecasting game. As analysts become more familiar with both specific enrollment forecasting techniques and enrollment patterns in their states, they will find themselves increasingly able to develop and tailor their own forecasting strategies and procedures, and will have to rely less and less on this and other enrollment forecasting manuals. But no matter how experienced in enrollment forecasting analysts are, they cannot ignore the continual need for empirical studies to corroborate forecasts, to test the validity of models, and to seek new, more accurate models. Ideally, enrollment forecasting should be undertaken on an ongoing basis with as little staff turnover as possible. Otherwise, there is little chance that the analysts involved can develop the kind of understanding and judgment required for good, sound enrollment forecasting.

ESTIMATION OF POSSIBLE FORECASTING ERRORS

Although there generally is no confusion or argument about the fact that enrollment forecasts are estimates subject to error, there is a tendency to take forecast data too seriously in some situations, particularly when only one set of projections is available. While this is understandable, it does on occasion create situations in which users of the enrollment forecasts take uninformed risks by basing important decisions on single forecasts. A complete discussion of procedures that might be used to estimate the magnitude of forecasting errors is beyond the scope of this manual. It is possible, however, to provide a few general guidelines that can be applied in a variety of situations.

One possible way to make more explicit some of the possible risks that users may be facing is to provide explicit estimates of "maximum likely" and "minimum likely" enrollments along with the "preferred" estimates. The general procedure recommended involves the estimation of likely upper and lower bounds for the key parameter(s) used by the particular forecasting technique. These extreme values for the parameter(s) then can be used in place of the "preferred" values to permit the calculation of upper and lower bounds for the enrollment forecasts. These upper and lower bounds can be displayed along with the "preferred" forecast to provide at least a rough idea about the likely range of actual enrollments.

Unfortunately, few of the forecasting techniques illustrated above include explicit procedures for estimating the upper and lower bounds on the key parameters. There are, however, some general guidelines that can be followed to obtain the desired values. For example, in the averaging procedures, it would be appropriate to compute the standard error associated with the mean value of the parameter used to generate the enrollment forecast. Then by adding (subtracting) an appropriate multiple* of this standard error to (from) the mean value, the upper (lower) bound on the forecast could be obtained. In the case of the grade-progression technique, one might consider using the maximum and minimum values of the historical Grade-Progression Ratios (as shown in Table 5) as a basis for developing the respective maximum and minimum estimates of new entering freshmen. And for the polynomial models, one could use the estimates of the standard errors of the parameters (computed as part of standard multiple-regression procedures) to compute extreme values for the enrollment forecasts.

In all these cases, once the maximum and minimum values for the parameters have been obtained, they can be substituted for the "preferred value(s)" of the parameter(s) to obtain the desired maximum and minimum values for the enrollment forecasts. These upper and lower limits provide potential users with at least a rough quantitative estimate of the reliability of the forecasts.

A second general approach, which does not necessarily involve the specific estimation of forecasting errors, would be to develop a set of enrollment forecasts, one for each of a set of assumptions about the state of the world as it relates to enrollment, as does the Census Bureau when it provides

*Larger multiples of the standard error will lead to larger upper bounds and smaller lower bounds for the enrollment forecasts. The size of the multiple that should be used will depend on the confidence that the user wishes to have that the actual enrollment will fall within the upper and lower bounds. It is beyond the scope of this manual to develop these ideas in detail; interested readers may refer to the discussion of confidence intervals in most introductory statistics texts for more details.

alternative population projections for different assumptions about fertility and birth rates. This "gaming" approach to presenting alternative enrollment forecasts can often be used to advantage in times of uncertainty. For example, one might present one set of enrollment projections assuming that student preferences remained constant, one assuming a 5 percent decline in student demand, and one assuming a 5 percent increase in student demand. One might attempt also to estimate the impact of such things as changes in tuition levels, opening a new institution, or eliminating certain programs on a campus.

A third possibility could be used if the same forecasting procedure had been used for several years. The first step would be to tabulate the forecasting errors obtained using the procedure. These errors then could be examined for trends and patterns in much the same way that the enrollments had been. If a trend or pattern is detected (and the same enrollment forecasting procedure is to be used in future years), the error could be forecast so that either an appropriate adjustment could be made in the forecasts or the forecasting procedure could be modified.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Enrollment forecasting is a subtle craft, perhaps more subtle than many of us realize. As in any field that brings together technicians, planners, and policy makers to deal with common problems, the tools, implications, and constraints are not always well understood by all the parties. Nevertheless, interest in enrollment forecasting is definitely on the rise, stimulated by growing uncertainty about future enrollments and financial support at institution, state, and federal levels.

Hopefully, this manual provides some useful insights into general issues related to enrollment forecasting as well as the application of a number of specific enrollment forecasting techniques. Since the discussion has covered a large number of topics, not all of which are equally important, it seems appropriate to conclude the manual with a brief summary of the most important points:

1. Satisfactory forecasting generally is a result of applying several different forecasting techniques, each of which has relevance to a particular segment of the overall enrollment situation.
2. In most situations, one of the causal models will be a better choice than one of the curve-fitting methods as the primary forecasting technique. Causal models generally are more intuitive and easier to explain than curve-fitting models. Also, there is a much better chance that a causal model will anticipate a change in enrollment

patterns than will a curve-fitting model. There are two general situations in which one of the curve-fitting models probably should be chosen: when one cannot identify an appropriate causal model, and when one is quite certain that a particular trend in enrollments is going to continue in the future.

3. More use should be made of surveys of the intentions of potential students with appropriate validation. Such surveys are one of the important ways that state-level analysts can obtain insights into shifts in the attitudes of potential students about higher education and resulting changes in enrollment patterns. They also provide one of the few obvious mechanisms for improving our understanding about the linkages between secondary and postsecondary education.

4. More attention should be devoted to the study of student demand for higher education, particularly the identification of factors that have an impact on student demand.

5. Enrollment forecasting should not be dealt with on a one-shot basis. Forecasting models must be validated and "tuned" over a period of years. The ability of an analyst to recognize fundamental changes in trends, and convince the right people that they will occur, probably can come only with experience.

6. Estimates, either qualitative or quantitative, of the reliability of enrollment forecasts should be provided along with the "preferred

values" whenever possible. Important long-range decisions often are based on enrollment forecasts that technically are quite unreliable. Policy makers deserve to know the risks that may be involved.

APPENDIX A

REVIEW OF THE LITERATURE

This section is a brief review of the literature of enrollment forecasting, with an emphasis on actual enrollment forecasting projects. No attempt has been made to ensure that the list of studies is exhaustive, but it does cover a number of important studies. Further insight into current enrollment forecasting practices of state agencies can be obtained from the survey report by Wing and Tsai (1972). Additional studies and reports are cited in the bibliography in Appendix B.

The summary of each study in Table A-1 in this section covers the following types of information: (1) the level being forecast; (2) the technique or method employed; (3) whether the study was descriptive or included actual application of forecasting techniques; (4) a brief description of the study; (5) the source of the basic data used or required; and (6) an evaluation of the study on several criteria. There are several purposes of presenting the summaries in this way. First, readers can select the most appropriate study or studies for their purposes by looking across the summary description of the study or studies. Second, readers can compare among the studies on certain (or all) characteristics in which they may be interested. Finally, the items covered suggest the kinds of information the author feels should be included in any complete report of an enrollment forecasting study or project.

The summary table is arranged first in chronological order by year, and then in alphabetical order by the principal author's name. This will provide the reader with a historical perspective of the efforts in the field.

The categories in the summary table covering the level being forecast, the source of basic data, and the general and specific procedure(s) follow the terminology outlined in Chapter II of this report. The two evaluation categories summarize: (1) the reported accuracy in terms of percentage deviation, if available; (2) the type of information provided by the study; and (3) cost of the study, if available. These evaluation categories are important in the sense that they provide some basis for the readers and potential users to decide whether or not certain technique(s) should be adopted in their respective situations.

TABLE A-1

SUMMARY OF SELECTED ENROLLMENT FORECASTING STUDIES

<u>Note</u>: There is some room for interpretive error in identifying the specific procedure used in a particular study. An attempt has been made to be consistent with the discussion in Chapter II of this manual. Where more than one method is identified, the study may have developed several complete forecasting models, or some of the methods may have been used in minor ways to support the major procedure.

CS--Cohort-survival
EM--Exponential models
ES--Exponential smoothing
MA--Moving averages
MC--Multiple correlation and regression
MT--Markov transition model
PA--Path analysis
PM--Polynomial models
RM--Ratio methods
SA--Simple averages
SE--Systems of equations
SJ--Subjective judgment
SP--Spectral analysis
SS--Student survey

TABLE A-1
SUMMARY OF SELECTED ENROLLMENT FORECASTING STUDIES

(1) Report or Study	(2) Level of Forecast	(3) General Forecasting Procedure (See Note)	(4) Nature of Study	(5) Brief Description
Lins (1960)	Institution (fictitious name used)		Descriptive only	The models presented are linear regression method with respect to time: 1. $E = a + bt$ 2. $E = ab^t$ 3. $E = a+bt+ct^2$
	State	CS RM MC		Using age 18-24 population and ratio of college enrollment with respect to this age group
New York State Education Department (1968)	State (New York); also at program level (e.g., 2-year, baccalaureate, undergraduate, etc.)	RM SS	Descriptive, plus estimation of parameters and some evaluation	Using ratio of full-time undergraduates to high school graduates in the past four years as input rate. The rate is revised annually with respect to actual enrollment data. Three projections reported: 1. "Basic" conservative minimum 2. Planning current rate 3. Potential maximum expected
Oliver (1968)	Institution	MC	Descriptive	The method is a modified ratio or grade-progression and also might be considered as MT
Colorado Commission on Higher Education 1970 and 1971	Institution (and state as the sum of the institutions in the state)	RM	Descriptive plus estimation	Projection based on past enrollment of each institution with consideration of enrollment ceiling of some institutions
Educational Research and Services Corporation (n.d.)	State (New Hampshire)	RM	Estimation	Using age 18-24 and forecast high school graduates as base
Newton 1969	State University System (Pennsylvania State University System)	RM	Descriptive plus some estimation	1. Using live birth and migration to forecast high school graduates. Then used to estimate enrollment ratio 2. Using percent of U.S. enrollment as rate

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(6) Source of Data	(7) Input Data Requirement	EVALUATIVE INFORMATION (8) Reported Accuracy	(9) Information Yield
Institution and/or state	At either institution or state level. Data on past enrollments over a period of time. Using least square method to estimate a, b, c, in each of the three models	Not available	1. Forecasts of institution or state enrollments 2. Forecast in two types of systems: a. with enrollment ceiling b. without enrollment ceiling 3. Forecast for single institution
State and Institutions	1. High school graduates in state 2. Past participation rate of the high school graduates 3. Institution's new program and planning as growth factor for projection 4. Population pool used for "potential" projection	Ranging from 0.4 to 3.5 percent	1. Statewide college enrollment forecasts (1968-1980) 2. Forecasts by program level (see level being forecast [2]) 3. Annual increase of full-time enrollment forecast 4. Forecasts by type of institution (public vs. private) 5. Forecasts of high school graduates
Institution (University of California)	1. New entrants 2. Historical grade-progressions	Not Available	1. Institution's total enrollment 2. Forecasts of student flow within the postsecondary institution
Past individual institution enrollments (State of Colorado)	1. Institution's past enrollments	Not Available	1. Institution's enrollment forecasts (1970-1980) 2. State total as the sum of each institution in the state (of Colorado)
1. Total state high school graduates 2. Ratio of high school graduates to current enrollment	1. 18-24 age population forecast of the state 2. Public high school graduates	Not Available	1. Forecasts of total state enrollment between 1961-1976
High school graduates in Pennsylvania. Live birth in Pennsylvania	1. Live birth data of the state 2. Migration data of the state 3. High school graduates of the state 4. Ratio of high school graduates to college enrollment 5. Ratio of U.S. high school graduates	Not Available	1. Forecasts of Pennsylvania State University System to 2000

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TABLE A-1
SUMMARY OF SELECTED ENROLLMENT FORECASTING STUDIES (CONTINUED)

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(1) Report or Study	(2) Level of Forecast	(3) General Forecasting Procedure (See Note)	(4) Nature of Study	(5) Brief Description
Banks and Hohenstein (1970)	State (Georgia)	RM MC	Estimation	(1) Using ratio and simple linear regression model (2) Included in-state, out-of-state enrollment data
Degnan (1970)	College Systems (public vs. private in Connecticut)	MA	Descriptive plus estimation	Using moving average method to estimate ratio of high school graduates participation rate
Evans (1970)	Institution, college system state wide (in California)	CS SJ	Descriptive plus some estimation	Using county high school graduates enrollment ratio and survival ratio of primary and secondary schools for longer term project in actual procedures of projection and not included in the report
Thompson (1970)	Types of college of ea:h state in U.S.	SA CS	Descriptive plus estimation and some evaluation	Using simple average and grade progression in terms of the rate of participation of 18-21 age group
Washington State Office of Planning and Fiscal Management (1970)	State (Washington)	RM MT	Descr'ptive	The basic model is Markov chain model but for forecast of freshmen it should be cl. .sified as 2(b). Some brief literature review on methods
Jewett (1971)	One institution (Ohio Wesleyan University)	MC	Descriptive	Probability function of college enrollment in terms of individual's sex, test score, and ability to pay
Mathematica (1971)	National	MC	Descriptive plus estimation	Multiple regression model in terms of several variables
Purves (1971)	State (California)	RM	Descriptive	Estimated historical participation rate and patterns of migration

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(6) Source of Data	(7) Input Data Requirement	EVALUATIVE INFORMATION (8) Reported Accuracy	(9) Information Yield
State (see column 7 for detail)	(1) State total high school graduates (2) Total first-time freshmen enrollments (3) Total state enrollment in post-secondary education (4) Out-of-state first-time freshmen enrollment (5) In-state first-time freshmen enrollment	Total state enrollments in postsecondary education institutions in Georgia	
State high school graduates	State high school graduates and the past or historical postsecondary education participation rate	Not Available	10-year forecasts of public and private postsecondary education enrollment in Connecticut
County's high schools' past college enrollment, out-of-state	County high school to college enrollment ratio and/or individual institution past enrollment	Within 1%	California state college system and University of California freshmen FTE, headcount enrollment
Historical enrollment data of the types of institution in each state	(1) Total births 18-21 years earlier in a given state (2) Past participation of 18-21 age group in public and private institutions in each state	Can be compared with the actual data for 1970-72 period of each state	Forecasts of private and public postsecondary education institution enrollments in each state from 1970-1989
High school graduates, potential military students, population age 18-29 other than HSG, out-of-state students	Historical enrollments and rates among 4 categories: (1) High school graduates (2) Population age 18-29 other than high school graduates (3) G.I. (4) Out-of-state students	Not Available	Forecasts of state total enrollments in postsecondary education institutions with breakdown of in-state, out-of-state
Individual students, institutional and national fee structure	(1) Individual's sex, SAT test score, his ability to pay (2) Tuition cost structure of the institution	Not Available	(1) Forecast of institution's enrollments (2) Some indirect estimation of national high school graduates, their income level and test score distribution
Several national longitudinal surveys	Longitudinal cross-sectional data on high school graduates' sex, income, year of graduation, and past enrollment rate	Not Available	Total national enrollments in different types of institutions
State with national as reference	Historical postsecondary education participation rates and patterns of migration. *The author argues that "migration seems to account for most of the variation in forecasts in California." Some determinants are discussed	Not Available	Forecast of state total enrollment

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TABLE A-1
SUMMARY OF SELECTED ENROLLMENT FORECASTING STUDIES (CONTINUED)

BEST COPY AVAILABLE

(1) Report or Study	(2) Level of Forecast	(3) General Forecasting Procedure (See Note)	(4) Nature of Study	(5) Brief Description
Zimmer (1969) and (1970)	State college system (Minnesota)	PM CS RM MT MC	Descriptive plus estimation and evaluation. (Provided very practical procedure for evaluation)	26 variables were used in multiple regression model. 9 states were selected in Markov model
Coffman (1972)	State (Mississippi)	SA CS	Descriptive plus estimation	Using simple average and grade-progression methods
Committee on Enrollment Planning Maximums (1972)	Types of college and college (Illinois and U.S.)	CS	Description, estimation and partial evaluation (for two years)	Using grade-progression concept treating the transition from secondary to post-secondary education as a grade-progression
U.S. Bureau of Census (1972)	National	RM	Descriptive plus estimation	Using 1950-70 rate as base and a constant rate by sex and age to forecast national PSE enrollments
Hassel (1972)	Institution and/or a system of institutions. (Alabama) Including student flow within the postsecondary education institution	Combination of CS and RM ES and RM	Descriptive plus estimation Descriptive only	Names used in the original document are "exploding and netting models." Using ratio matrix and exponential smoothing
Orwig et al. (1971)	Departments in an institution (Kansas State University)	SA MA CS MT	Descriptive plus estimation and evaluation	Estimate past enrollment and future growth. Also use discriminant analysis

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(6) Source of Data	(7) Input Data Requirement	EVALUATIVE INFORMATION (8) Reported Accuracy	(9) Information Yield
Secondary institutions and their students' postsecondary education participation time series data	(1) Grade succession in primary/secondary institutions in the state from grade 1 through 12 (2) Postsecondary education participation or ratio for the 5-year pool in the state college system (3) Transferred students	Provides very specific procedure for objective evaluation. For methods 2(a), 2(c), the errors range: 3.34, 1.53, and -2.94% For method 1(c) the errors range: 3.5, 2.46, 2.94, 6.88% For method 2(d) the errors range: 1.5, 1.6, 1.56, -6.2?% For method 2(c) the errors range: .08, -1.45, -0.3, -1.9%	(1) Total enrollments in a state college system (2) Total enrollments in a state collect system with the following breakdown: freshmen, sophomores, juniors, seniors, and graduates and transfers into and out of a state college system (3) Costs of forecasting errors
State	Past grade-progression and simple average rates from elementary to secondary to postsecondary in the state	Not Available	10-year forecasts of total state postsecondary education enrollments (out-of-state not considered)
State total	Total state high school graduates and their past participation rate in different types of postsecondary education institutions and grade-pro gression rate	4-5% deviation for (1970-72) absolute deviation 12,000-18,000 students (overestimated)	Institutional types and classes forecasts (1972-1989) 17 years' forecasts
National	(1) National enrollment rate with respect to population (2) Population forecasts	Not Available	Forecast of national total post-secondary education enrollment for the period 1971-2000
State population structure of 16-35 age See column (7)	Participation ratio of the age structure 16-35 to a given institution or a system of institutions Birth rate of the state, population structure or demographic composition. Annual enrollments of institution(s)	Not Available	Total enrollments (student demand) to one institution or a system of institutions.
Institution's past total enrollments	(1) Past departmental enrollment trend (2) Past total institution enrollments (3) Student's intended and actual selection of major or department	1-6% using mean square error and absolute error	One year departmental forecast

TABLE A-1
SUMMARY OF SELECTED ENROLLMENT FORECASTING STUDIES (CONTINUED)

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(1) Report or Study	(2) Level of Forecast	(3) General Forecasting Procedure (See Note)	(4) Nature of Study	(5) Brief Description
Prestage (1972)	Postsecondary education institutions (in Louisiana)	SA CS	Descriptive plus evaluation	Basically using grade-progression method
Springer and Strumwasser (1972)	State (Nebraska)	CS MT PM	Descriptive, estimation and evaluation	Separate estimations for entering students, inter-institutional transfers, and continuing student
Thompson (1972)	State supported college (Kentucky)	RM	Descriptive plus estimation	Using ratio of high school graduates to college enrollments

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(6) Source of Data	(7) Input Data Requirement	EVALUATIVE INFORMATION (8) Reported Accuracy	(9) Information Yield
Parish grade progression	(1) Parish live birth (2) Grade progression	Not Available	16 years' forecasts of institution's enrollments and classes in each institution
Institutions and state	(1) High school graduates (2) Past grad school enrollments (3 years) (3) Statistics on continuing students (4) Statistics on inter-institutional transfers (5) Statistics on out-of-state entering students	1.3% to 6.8% for sample schools used in the validation	Forecasts by institution by year and by level of student
County high school graduates in the state	(1) High school graduates in each county of the state (2) Past enrollment rates of county high school graduates to each institution	Not Available	Enrollment forecasts of each institution in the state of Kentucky

APPENDIX B

APPENDIX B

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