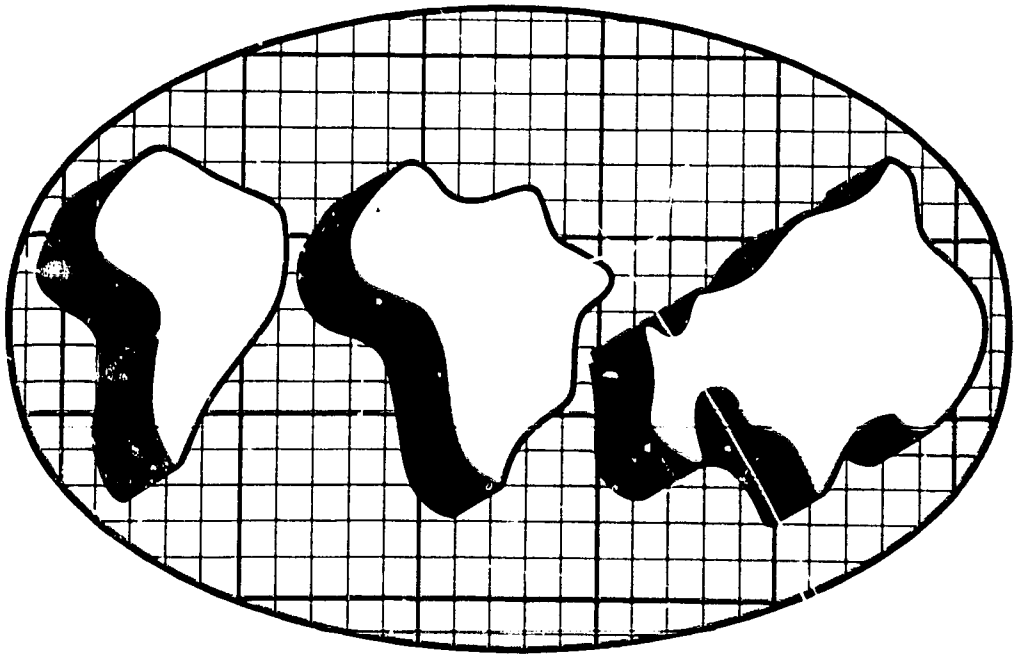
Planning Education for Development:

Volume II
Models and Methods for Systematic Planning of Education

RUSSELL G. DAVIS



Center for Studies in Education and Development
Harvard University, Cambridge, Massachusetts

Planning Education For Development

Volumes I-IV

Volume II

Models and Methods for Systematic Planning of Education

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to my daughters, Ahva Teresa Davis and Lisa Mary Davis.

VOLUME II

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Foreword to Volume II

The second volume of this work on the planning of education in developing countries deals with the basic techniques of planning. This volume was designed with the following objectives in mind:

First, to provide a more detailed elaboration of planning issues raised in the first volume. One basic issue, only briefly mentioned, underlies the whole purpose of planning, that of cost-effectiveness and financing. Formal schooling expands at a frantic pace in developing countries in response to social demand, but resources do not grow in proportion, and the burden becomes crushing. A huge burden and scarce resources provide the basic reason for applying the methods of planning (Davis 1966). This volume deals with those methods.

Secondly, to provide instruction on how some of the basic methods of systematic analysis and planning are applied in educational planning. The material on methodology is designed to instruct, although it is not a how-to-do-it manual for uneducated beginners.

Finally, to build a methodological framework for planning that will support the elaboration of research methods and data analysis techniques to be developed in the two volumes that will follow.

There are **five major parts** to this volume. **Part One** deals with systems models for educational planning. Chapter 1 opens with a discussion of systems models and rational planning and includes a critique of the limitations of rational planning. There is a short review of the development and use of systems models in educational planning, and a discussion of the types of models used in planning. A distinction is drawn between heuristic and algorithmic models. The first type discussed in Part One are heuristic models used to graph organizations and systems characteristics. A discussion of algorithmic models then begins with a presentation of black-box systems graphs and models. Models for projection and target setting, which include population, enrollment, and manpower forecasting, are discussed, and Chapter 1 closes with a systems graph of a compound manpower and educational planning model.

Chapter 2 offers a more detailed treatment of a comprehensive systems model used to plan educational development in Chile. The treatment of this model avoids technical detail and focuses instead on the usefulness of the model for addressing educational planning goals. An

appendix to Chapter 2 discusses regression models and path models used to analyze educational effects or outcomes. This treatment might more logically have come in Chapter 1, but it was deferred to Chapter 2 to cut down the overload of learning required by Chapter 1 materials. Chapter 3 of Part One is an optional chapter which explores some of the simpler mathematical ideas that lie behind programming models. This chapter can be safely skipped without any loss of essential planning knowledge.

Part Two will take up the projection methods introduced in Part One and give detailed instruction on the methodology. Part Three will continue this topic. Planning deals with the near future, and one of the planner's major technical tasks is developing, adapting, or applying projections of population, enrollment, and manpower requirements. The first topic of Part Two is demographic analysis and population projection. The second topic is the use of enrollment flow models for enrollment projection, and the third is a description of various methods for analyzing educational data to derive the educational systems flow rates of promotion, repetition, and drop-out. Because extrapolation based on curve fitting is used in many forecasting and projection exercises, there is a special section dealing with curve-fitting techniques at the end of Part Two.

Part Three presents instructional units on manpower requirements forecasting methods. A basic method and an alternative method are taught in instructional units and illustrated in case analyses. The weaknesses and the criticisms of manpower planning have been discussed in Volume I. All social science methods have weaknesses. Manpower planning is still used, and the results are still useful, and because this is so, a substantial segment on manpower planning models and methods is offered in the instructional materials of Part Three.

Part Four presents several short treatments of useful techniques for educational planners. The first topic is scheduling and the development and use of critical path analysis and project charting. The second is project costing, cost-effectiveness, cost-benefit, and cost-efficiency analysis. A third topic describes some of the heuristic modeling and forecasting techniques used by futurists and offers an extensive comparison between the Delphi approach and COMPASS, a compact methodology for assessing policy options.

The last section of this volume, **Part Five,** gets away from planning techniques which are applied mainly at the national or systems-wide level and deals with the problems of area planning and school mapping. The topic is presented through a review of the field of school mapping and area planning, a detailed discussion of the small amount of systematic methodology actually developed and used in school mapping, and a case exercise on how school mapping was applied in educational planning in Chile. The International Institute of Educational Planning has accomplished definitive coverage of school mapping in cases based on work in a dozen or more developing countries. The coverage in these chapters is modest, but they do present some viewpoints by experienced planners which differ from the IIEP approach.

The treatment of cost-analysis and futurology in this volume is admittedly not in proportion to the importance of these topics in the general field of planning. There are reasons for the brevity of the treatment of these two topics. In general, there is always a space limitation imposed, because the field of educational planning is so vast that even four volumes do not do it justice. In this four-volume set we have chosen to present the rational approach and the major criticisms of it. We have also chosen to offer some context for the application of rational methods. The critique of rational methods and the context of planning applications have taken up valuable space.

In introducing heuristic and futurist methods the treatment is relatively brief in this volume because there is not much systematic methodology to discuss. Futurology does not have a great deal of unique methodology; most of it is borrowed from statistics and other analytic approaches in general social science. Heuristic methods in general do not feature elaborated models and methods. Our offering in Chapter 15 of Part Four is designed to serve as a reading guide and methodological introduction for those who wish to consult more complete works on heuristic methods. Delphi is a broad subject in itself, and in Chapter 15 we have dealt only with the Delphi exercise. There are also more elaborate versions of policy Delphi and computerized and panel forms of Delphi.

In the case of cost-analysis, the topic is treated only briefly because the coverage of costing methods in planning was not a major part of this project. The topic was covered in USAID-sponsored companion projects to this one. The materials on costing appear in volumes produced independently of the four volumes in this project, but conceived by William Charleson of USAID as part of a general series on educational planning in the developing countries. The two volumes on costing are:

1) Jamison, Dean T., Steven J. Klees, and Stuart J. Wells, *The Costs of Educational Media: Guidelines for Planning and Evaluation*, Beverly Hills, Cal.: Sage Publications, 1978. This is based on an earlier publication by the same authors entitled, *Cost Analysis for Educational Planning and Evaluation: Methodology and Application to Instructional Technology*. (produced by the Economics and Educational Planning Group, Princeton, N.J. 1975).

2) International Office, Educational Testing Service, *A Manual for the Analysis of Costs and Outcomes in Nonformal Education*. Princeton, New Jersey: Educational Testing Service, 1979.

The four volumes in this series and the two volumes cited in the previous paragraph represent the published work on educational methodologies based on research sponsored by USAID. The four volumes in this set are only a fraction of the material developed in the USAID/Harvard Planning Methodologies Project. These materials are listed at the end of Volume IV. Computer codes, computer program

documentation, and program listings were developed for population projections, enrollment projections, and manpower projections, but they could not be included in this volume because of excessive bulk. A large number of major case analyses on planning also had to be left out of the published work. This is regrettable, because some experiences cannot be transmitted through anything but case descriptions and analysis, and some things can only be learned from experience and practice.

Part One: *Systems Models and Methods for Educational Planning*

CHAPTER 1

Systems Models and Methods for Educational Planning: Unit One

1.0 *Rational Planning Described and Defined*

The first chapter of Part 1 will provide general background information on systems models and methods used in educational planning. Because there are many different versions of planning and many varieties of models and methods, educational planning should be defined. Beeby (1965) coined a brief but broad definition: "Educational planning is the exercise of foresight." In planning, the foresight must be applied *rationally,* and Allison (1969) defines this quality in planning, "Rationality refers to consistent, value-maximizing choice within specific constraints." Educational planning is a form of general social planning, and systematic social planning is *rational foresight applied to stimulate and guide social action toward articulated objectives.*

When social planning is applied to teaching/learning activity that is organized into programs, institutions and education and training systems, then comprehensive, rational educational planning consists of: the development and statement of goals; analysis of costs and resources; determination of policy and program alternatives given specified constraints; evaluation of outcomes or effects: and the monitoring of allocations decisions and implementation activity. Results of this last step are fed back into what is a continuous process. This is the rationalistic view of planning. There are other views which we will note briefly, and then return to rational planning, the approach that will predominate in this book.

1.1 *Other Planning Approaches Briefly Noted*

Critics fault the way rational models and planning methods portray the processes of policy analysis, planning, and decision making. Rational planning models may ignore the organizational and political context and portray a process that is free of controversy, ordered and based on reason. Rationality in organizational pocesses is limited, or *bounded,* according to March and Simon (1958). Conflict is omnipresent

in organizational and political transactions; and judgments are not based on reason and evidence. In the organizational and political world, according to Lindbloom (1965, 1968), policy planning and decision making do not proceed in an ordered and reasoned progression. The process is disjointed. Planners should design and build programs in small steps or increments.

Others criticize rational models and methods, and the experts who apply them, because of failure to consider the views of all participants affected in the social process. The poor, the powerless, and the isolated are left out of the scheme. Marxians and radicals claim that this flaw is inherent in planning within the capitalist political structures of Western democracies. According to Bowles (1979), rational planning in the capitalist West has failed and always must fail. Other critics believe that the failure can be overcome by changing the social process through participatory planning. Groups affected by plans and policies should actively shape these plans and policies, according to participatory planners Altshuler (1965, 1970) and advocacy planner Alinsky (1972). The ignored poor should be the central participants in the planning process. Planners should be advocates of these groups and their interests.

From the criticism of rational planning come proposals for alternative styles and sometimes new methods of planning. The *advocacy* and *participatory* planners stress the social dynamics of the process, the need to move away from rational models and methods and to incorporate the views and knowledge of participants who are affected by the process of planning and management. Participation is enhanced when planners work from the *bottom up*, according to Hudson and Davis (1976), which means that analysis should begin with the needs and views of the "primary beneficiaries" (usually poor and powerless groups), rather than being based on aggregate analysis at national level, as in most rational planning. Friedman (1973) outlines *transactive* planning as a methodology for incorporating both the processed knowledge of the experts and the real world knowledge of the people to be affected by policies and plans. He advocates networks that will better circulate these different forms of knowledge, so that the views of all those affected will influence the policy planning transaction. Warwick, in Volume I, described the *transactional* model, in which planning requires the full understanding of the internal organizational and external political forces which will shape the policy planning transaction. Organizational behavior analysts Bennis (1966) and Argyris (1970) propose clinical intervention methodologies which aim at stimulating learning, development, and change among members of organizations. Dunn (1971) states that the world and society are in evolutionary process and there is no model that can portray any inevitable social future, because humans have the freedom to change and defeat planning scenarios.

Based on these criticisms of rational planning, there are alternative styles and methods of planning which have been worked out with vary-

ing degrees of rigor and completeness. None of these approaches has been worked up with the same comprehensiveness and detail as rational planning. In some cases the comprehensiveness, consistency, and detail of rational planning models are precisely what critics of the rational approach are trying to avoid.

Most criticism is aimed at what planners say rational planning is when they are attempting to describe it in retrospect and in abstract terms. What rational planners actually do when they work at their trade may be quite different. Reality modifies rationality. The following is a description of a rational planner at work in El Salvador:

> The writer would describe his approach to planning in 1971 and presently, as Street Rational, rather than Straight Rational, meaning that it is first necessary to find out what is going on, and in the terms of those it is going on for; that it is then necessary to discover if any of the goings-on are amenable to rational (read "ordered") array and analysis; and lastly to apply rational analysis methods to that part of the action where it makes sense, common and rational, to do so; and to live and work with the inevitable contradictions that result. This approach, if it can be called one, is difficult to bottle for academic consumption, in lecture or book form, but it permits a lot of room for moving in the field. (Davis 1978: 1-2)

In any field—and planning is no exception—there is always a difference between the canons and the practice of the art. This will be clearly shown by contrasting the previous quotation with material to come. The same planner has written both. In this book the models and methods of rational planning will be taught, despite the fact that stereotyped descriptions of this approach have been subjected to justifiable criticism. Here the bias is toward rational methods, and one justification of this is that they can be systematically described on paper and taught, whereas approaches to planning that emphasize intuition, social sensitivity, political skills, and continued adjustment within specific social contexts cannot be readily taught in general terms. These skills are learned on the job, largely through the practice of planning in work experience. The technical knowledge and skills required to apply rational models and methods can be developed through systematic reading and classroom instruction. This knowledge and these skills are only a part of the competence a planner requires in his work, but they do provide a basis for acquiring the political and social skills that come with work experience. This book will attempt to provide knowledge and to develop skills in rational planning. It will be limited mainly to the models and methods of this approach to planning.

2.0 *Models and Systems Planning*

Basic to the rational approach to planning is the use of systems models to frame the epistemological approach and guide the analysis of planning reality. It is around this idea of a systems model that the discussion of rational planning will be developed.

A model is designed to show the important features of reality. In developing a model, a planner singles out elements from reality. He defines and symbolizes these elements and shows them as a system of variables. He analyzes the relationships among these variables as an aid to description, explanation, and forecasting. Of late, planners talk more of projecting and forecasting than of predicting, but as long as planners have to deal with the future, an important class of models—sometimes called normative—attempts to portray the future as it is planned to be. In the planning context a model may clarify relationships between desired objectives and outcomes which are indicated by changes in the values of the variables. Additional abstract statements could be made about models, but our interest centers on how models are used in educational planning, and with that practical end in view we will move away from definitions and abstractions.

2.1 *Types of Models Used in Educational Planning*

Educational planning models can be classified according to whether they are designed to describe, explain, or forecast. These uses are not always distinct, and some models combine all three purposes. Models also differ according to the form in which they are expressed. The simplest and clearest model is usually in graphic form, and we will begin our introduction to models with this form. Many models are also expressed in words and sentences. Models are also presented in symbols, and the symbols may be incorporated into equations. We will examine a comprehensive planning model in symbolic form and use words and sentences to explain it. Models are put to different uses in educational planning. These uses include allocation, target setting, assessment of educational effects, and costing. There are also models which depict school systems and organizations in graphic form. Educational planners also use maps, and these are among the clearest kinds of models. There are also dynamic models which cover the learning process and the decision process, and these are sometimes used in educational planning.

In this volume we will deal mainly with these kinds of models:

—*Comprehensive planning models*

A comprehensive planning model may have several purposes and uses and it will include as sub-models some of the other models we will discuss as separate entities. A comprehensive model is used to analyze changes in an entire educational system over time, and to guide educational plans toward the attainment of economic and social goals. Basically, the comprehensive planning model is a set of goals for the educational system. A model is used so that the planner can keep all of these goals in mind and attempt to solve them within the same plan framework. Again, our statements are getting abstract, and we move away. A comprehensive planning model will be described in Chapter 2, which will describe in non-technical terms a comprehensive educational planning model

that was developed and used in Chile. Chapter 3 will then specify the structure of the model and the linear programming model and methods on which it is based.

Yet another purpose of the comprehensive planning model is to guide allocations decisions. In Chapter 4 the allocation component within the comprehensive Chilean model will be briefly discussed.

—Target-setting models and methods

Planners require a set of models and methods for projecting planning targets and for forecasting the development of social and economic systems over time. These include:

i) Models for demographic analysis and population projection, covered in Chapter 4.

ii) Models and methods for projecting school enrollments, covered in Chapters 5 and 6.

iii) Models and methods for projecting manpower requirements, covered in Chapters 8 through 12, which also describe general manpower and educational planning approaches.

The three targeting models can be used separately in educational planning, and can also be put together into a compound model which simply joins the manpower requirements model to an educational forecasting model. A compound model is displayed in figure 1.3 of this chapter. The targeting models can also be integrated into a large comprehensive model which is used simultaneously for allocation/goal planning and other purposes. This use will be described in the next chapter.

—Models for administration and organizational analysis

Under this heading many different kinds of models and methods are useful in planning:

i) Models to depict education systems structures and organizational hierarchies: These are the simplest form of graphic models. They may depict the levels and kinds of schooling in a system, as in the system charts that were often featured in early descriptions of national education systems. Organizational charts are also simple, and too widely known to require detailed explanation. Most ministries of education hand out charts which show the relationship of the line and staff offices of the organization. The minister's box is the top box in the chart.

ii) Decision models and decision analysis methods. These are not purely planning tools, and will be dealt with briefly in this chapter.

iii) Scheduling models and methods, covered in Chapter 13.

—Costing models and cost-effectiveness models

These will be covered briefly in Chapter 14, and in more detailed form in the companion volumes prepared by Educational Testing Service (1979).

—Models for studying educational effects

Models for studying the effects of education are important in the general field of education and development, but they are used more in educational research than in educational planning. These models will be discussed in an appendix to Chapter 2. Volume III, which discusses research methods used in planning, will deal more thoroughly with models and methods for studying the effects of education.

2.2 *Heuristic Models*

Fox (1972) classifies models into two broad groups—*algorithms* and *heuristic* aids. We will use the term *heuristic models* or *heuristic methods*. Algorithms are constructed in structured form and yield a computable solution. Heuristic models and methods are more open-ended. They are designed to explore issues and to accommodate conflicting viewpoints or uncertainty, rather than to yield a single solution or even a set of solutions. Heuristic models and methods will be dealt with briefly in this chapter and more fully in Chapter 15. Systems and organizational charts are the simplest form of heuristic models.

The list of models used in educational planning begins with comprehensive systems models and ends with heuristic models. If this chapter followed a strictly rational model, the exposition would begin with the topic of comprehensive systems models and end with heuristic models. In these first two chapters, logic will yield to pedagogy. Heuristic models in graphic form are easier to understand and make a more comfortable opening topic. Hence, we will begin with a review of simple graphic models. We will then review target-setting models, which can be combined into a *compound model* for planning education according to manpower requirements. The target-setting models can also be integrated into a *comprehensive model*, but we will defer discussion of this model until the next chapter.

3.0 *Organization and System Charts: Simple Heuristic Models in Graphic Form*

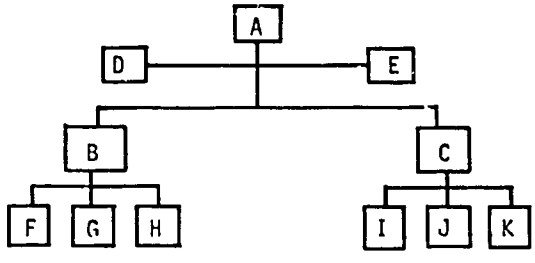
The simplest type of models used in educational planning are the organization and system charts. The traditional form of the organization chart is shown in Chart 1.1.

The model is simple, but it is useful in planning and management. A similar chart, though usually in more elaborate form, is available in most ministries of education in the world. Posts and job titles are usually shown on the chart. The conventions of the chart depict the formal hierarchy of the organization. A is the leader of all; B and C are the sub-leaders in the organization. D and E are staff members. The others are heads of the lowest-

echelon organization shown in this chart. In many charts, three or four levels of the organization are shown. Within the sub-offices detailed charts may also be drawn up.

Chart 1.1

Traditional Form of An Organization Chart



Akin to the organization chart in simplicity and usefulness is the educational systems model shown in Chart 1.2.

Chart 1.2

Educational Systems Chart

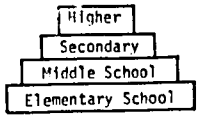
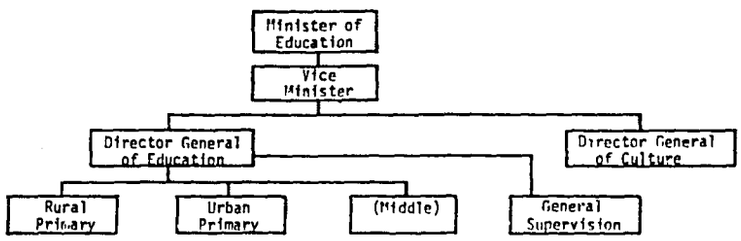


Chart 1.2 is a simple depiction of the major levels of a school system, from elementary level to higher. A more conventional school system is shown in Chart A1.1 of Appendix 1. Even the simple graphic model of an educational system is of considerable usefulness in the first step of a systems analysis and planning project. The first-stage sketch of an organization or system is an idealized drawing. It shows how the system is supposed to be structured and functioning, and not how it actually operates. The planner must find out how the system is organized and how it functions in reality. DeHasse (1979) describes this activity in planning as *morphological mapping*, which is a method for analyzing how school systems are structured and how they function. Often the major participants disagree, and their differences can tell the planner important truths about the organizational and political context. In this situation it is useful to make a number of different sketches of the system to reflect how it is viewed by different people at different times.

In the first stage of an educational planning study of primary education in Guatemala (Davis 1979), the pattern of management and supervision was straightforward. It is sketched out in Chart 1.3,

Chart 1.3

Primary Education (Based on Ministry of Education Chart)



which was based on the official Ministry of Education organization chart. The system and organization seemed simple, with administrative direction coming down from the Minister through the Vice Minister to the Director General of Education, to rural primary schools and urban primary schools; and with supervisory support coming in from the Directorate of General Supervision. Actually, the pattern was extremely complex, and there were at least six different systems of primary education functioning, with separate administrative direction, separate supervision, and different curricula. Rather than the simple pattern of Chart A1.3, it was the complex pattern shown in Chart A1.2 of Appendix 1.1. Systems and organization charts usually require elaboration in order to model the way systems actually work; official organization charts usually have insufficient detail for analyzing a systems problem. Chart A1.3 of Appendix 1.1 illustrates the minimal level of detail required.

Systems charts and organizational charts and graphs provide an easy introduction to systems modeling. Though graphic models are simple and clear, they can be used for complex analysis. The simple systems model is related to the *stage model*, which is sometimes used to clarify social theory. A stage model of human development is shown in Chart A1.4 of Appendix 1.1. Beeby (1966), Harbison and Myers (1964), and Rostow (1960) used stage models to portray levels of development of countries and school systems. The stage model is one of the simplest forms of a hueristic model.

4.0 *Black-Box Models of Systems Processes and Dynamics*

The organization chart and the systems charts are essentially static models of an educational situation. The dynamics of an organizational or educational process can be simply and graphically shown with black-box models of a system. In a black-box model, the inputs and outputs are clearly portrayed for analysis, but the central process of the system is not. R. Chin (1961) defines a system as "a collection of interrelated parts which receives inputs, acts upon them in a planned way and thereby produces cer-

tain outputs." Silvern (1972) emphasizes that a system is the structure or an organization of an orderly whole. Churchman (1968) stresses that a system is made up of a set of components that work together for the overall *objective* of that whole; and Mesarovic (1972) makes the point that a system is a relationship among objects specified or defined in terms of information processing and decision making. Systems models show the structure within the bounded system and the components or subsystems and their relationships, and define the inputs and outputs to the system and the goals of a system.

The workings of a systems process can sometimes be described with sufficient accuracy to enable the analysts to design, redesign, and, in general, to manage and control the system and its performance. Classic systems modeling has been borrowed from science, engineering, and technology, and applied to social systems analysis and planning. Some of the classic designs are shown in Figure 1.1. Hare (1967) provides a readable introduction to the general subject.

Figure 1.1 shows black-box schemes used to model systems processes. These simple systems models can be used to model aspects of an educational systems process. The input-output transformation scheme shown in (a) of Figure 1.1 is the model that underlies the production-function notion of education and the regression model used to study educational outcomes and effects. The educational process is depicted in terms of an input X, an output Y, and a transformation process which is symbolized by K. This is the classic black-box model in its simplest form. Using this model, the process of teaching/learning is not analyzed in detail, or even fully described. The process is simply modeled as something that goes on inside the box K. Clearly, the model enormously simplifies the reality of the complex process of teaching/learning which lies at the heart of an education system. The critical issue, however, is not whether the black-box model adequately describes the educational process, for indeed it does not, but whether or not the model permits the analyst to understand the system better when he is limited to observing and measuring the input(s) X, the output(s) Y and the input/output relationship which is depicted in the transfer function Y/X or K.

The simple model shown in Figure 1.1 (a) supports most of the research into the so-called effects of education, in which a regression model is applied to study what goes into the educational process (the inputs) and what comes out of the process (the outputs). This model will be examined further in Appendix 2.1 of Chapter 2 and in Volume IV. Here, we trace the black-box beginnings of models for studying educational effects, and try to raise some preliminary doubts about the validity of the black-box analysis of educational effects. The black-box model of Figure 1.1 (a) is a variant of the

models shown in Figure 1.2 (a) and Figure 1.2 (b). It is also the same model which underlies the regression and path model which is used to study educational effects in Appendix 2.1 to Chapter 2. We will return to the model shortly when we discuss Figure 1.2.

Figure 1.1

Classic Systems Diagrams

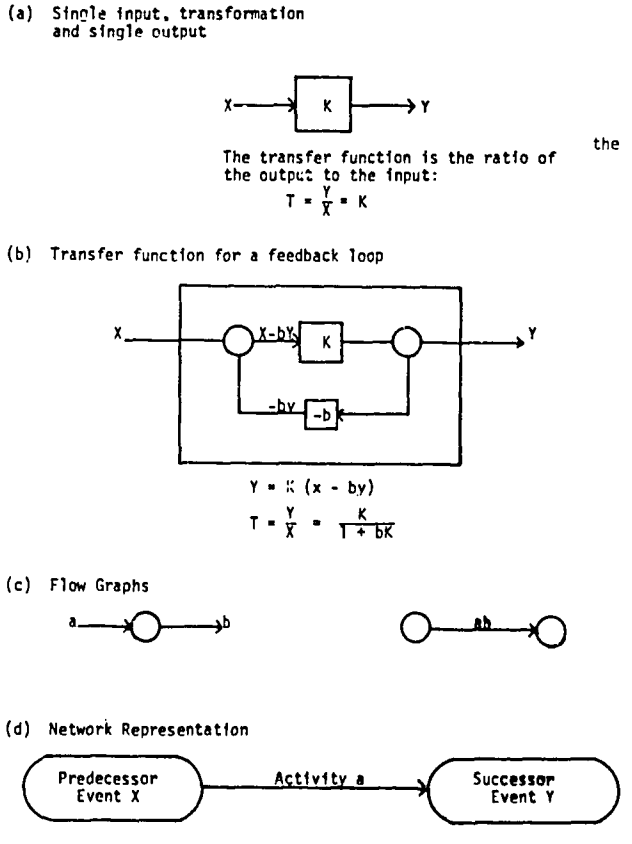


Figure 1.1 shows simple versions of the multiple-loop feedback, or dynamic model. An elaboration of this model has been extensively used by Forrester (1971) to model the dynamics of social processes. It underlies the work of Meadows and the Club of Rome (1972) in tracing future limits of growth which result from the interaction of major social, economic, and natural variables. For example, the effects of the major variables of population growth, diminishing resources, environmental pollution, and declining food production interact over time to affect each other and to limit economic growth

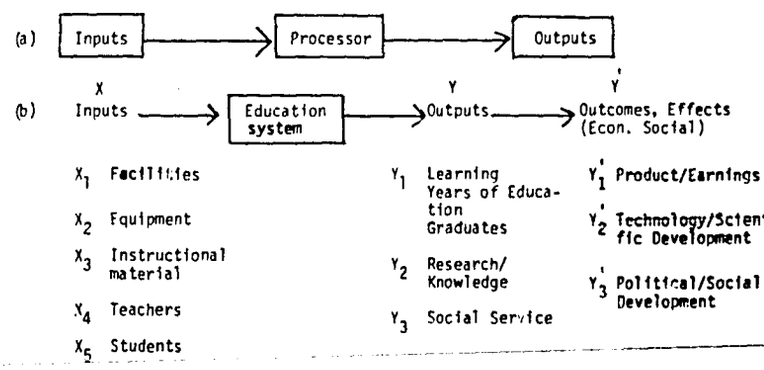
and the quality of life. Multiple-loop feedback models reflect the process of change more adequately over time, because as the variables in the system interact over time, there are changes in the coefficients which reflect the relationship between systems variables. The coefficients set at the beginning of a time period change *endogenously*, which means they change as a result of the running of the model itself, from interaction or feedback. Fixed coefficient models do not reflect this dynamic relationship, but they are the more commonly used in planning. The comprehensive model in Chapter 2 is a fixed coefficient model. The variable relationships are not changed within the model over time. The planner must estimate them and change them in advance. This point will be made more clearly when the comprehensive model is discussed.

Figure 1.1 (c) and (d) show simple flow models which are used in forecasting educational systems flow—for example, in the enrollment flow model which will be presented in Chapter 5. Flow models also are used in PERT (Program Evaluation and Review Techniques), Critical Path Analysis, and other models for systematic scheduling. These will be shown in Chapter 13. A simple but comprehensive coverage of the use of systems models in educational planning is offered in Hussein (1973).

Black-box models also can depict the relationship of school systems and surrounding social systems. Figure 1.2 (a) shows the input/output model from Figure 1.1 (a). Inputs (school facilities, teachers, curricular material) are used in a process (schooling), and there are outputs of educated people and new knowledge. Part (b) of Figure 1.2 shows the relationship of the education system in part (a) with the society and economy within which the schools operate. Educational outputs lead to outcomes in the social and economic systems within which the schools operate. This simple

Figure 1.2

Black-Box Models of An Educational System Process and Effects



systems model, which is the basis for models used to study education effects, as in education production function analysis, will be discussed further in Chapter 2.

Using the systems model of Figure 1.2, planners can analyze at highly aggregate levels the relationship of certain inputs to the outputs of the school system. The model in Figure 1.2 is a crude version of the comprehensive model which will be discussed in the next chapter. In the model shown in Figure 1.2, the amount and kinds of inputs (facilities, equipment, instructional material) can be related to measured change in the numbers of graduates or to increases in school achievement. Graduation status and measured gains in achievement which result from schooling are taken as evidence of learning. Learning is the output, and is supposed to lead to outcomes in the society and economy which surround the school. Schooling leads to learning, which leads to enhanced productive behavior, which in turn leads to increased earnings. This is the simple notion that underlies rate-of-return studies. Figure 1.2 (a), then, is a simple graphic model underlying both the notion of production function applied to education and the notion of rate of return to education. The model portrays the great simplicities of human capital theory, which is the main underpinning of the economics of education Becker (196?), Schultz (1961), Psacharopoulos (1973).

The underlying idea of the model is that schooling is a process that converts inputs (facilities, teachers' skills) to outputs (graduates and knowledge). This knowledge and learning then lead to enhanced production and earnings. Education is thus linked to individual and social development. This idea lies behind the comprehensive model. It is a black-box, planners' eye view of the educational system. Planners do not really believe that education is as simple as Figure 1.2 would indicate. The model is useful for depicting the system as a whole. By using a model, the planner can focus his attention on the salient features of the system. Most planning models have black-box features, and in reviewing other models, these features will be noted. A black-box portrayal does not destroy the usefulness of the models; it merely focuses the analyst's attention on observable features and permits a comprehensive view of a complex process in a large system.

5.0 *Models and Methods Basic to Educational Planning: Models for Target Setting*

The comprehensive planning model to be discussed in Chapter 2 has several sub-models, or methods, incorporated into the overall model structure that are basic to educational planning. In the comprehensive planning model the sub-models are linked together. They may also be used separately to accomplish other main tasks

in educational planning. Three models used for target setting will be discussed:

- models used for population projections in the social demand, or demographic, approach to planning;
- models for enrollment projection;
- models used in the manpower requirements approach to planning.

5.1 *Models for Social or Demographic Target Setting: Population Projection*

Planners require a set of models and techniques for projecting the targets and forecasting the development of social and economic systems over time. Population projections, or demographic forecasts, provide the basis for most comprehensive planning. Social and economic systems change as the size and structural characteristics of the basic population change. Demographic forecasts also provide future estimates of school entrants, and hence provide the basis for enrollment forecasting. Population projections also support many economic projections and plans. The economically active population, or workforce, can be derived from participation rates applied to the adult population. Economic growth forecasts may be related to population growth estimates in sectors where demand for goods and services by households can be related to population increase.

The basic components-model for a population projection is still a simple one (see Chapter 4). A population projection for a future year (1) starts with a base-year population structured by sex and age; (2) the age cohorts of the base-year population are multiplied by survival rates to yield the population for the following year for all age cohorts but the first; (3) females surviving into child bearing years are multiplied by fertility rates to get births; (4) births are multiplied by survival rates and added into the first age cohort; (5) migration (plus or minus) is put into the appropriate age groups. The process goes forward iteratively year by year. Mortality and fertility rates and net migration are the components which determine the forecast. Demographers have improved their methods, but not through developing new or more sophisticated models. Improvement in the art of projection comes through better research and analysis of mortality and fertility rates and the social conditions which affect the rates.

5.2 *Social Demand and Outreach: Planning to Meet Basic Needs*

Planners in recent years have carried out more detailed analysis of the social and economic structures of populations in order to

determine sub-groups served, or not served, by social and economic development programs. The attempt is to monitor how basic needs for food, shelter, jobs, health care, and education are being met. As plans, if not programs, focus more on the distribution of social and economic benefits, there has been an increasing attempt to trace differences in service and benefits to rural as well as urban groups, to ethnic groups and regional groups, to members of groups isolated by geography, deprived by poverty, or ignored because of class bias.

An immediate task for national level planning is to develop more socially sensitive indicators based on improved analysis and measurement of distribution and equity. In Volume I, distributional equity in a number of countries is assessed by using the Gini coefficient to measure the distortion between proportions of the population in different economic and social classes and proportionate education and earnings received (Snodgrass 1979). The coefficient has limited value as a measure of the dynamics of social processes, but it serves as a starting point for static analysis. An increasing number of analysts and social scientists would hold that improvement will come not so much through improving modeling and analysis as through a reorientation of planning approaches to make them more sensitive to local needs and more open to local participation (Hudson and Davis 1977).

6.0 *Models for Forecasting Education Systems Flow and Supply*

Planners have evolved a useful set of models, usually stated in the form of a markovian process, for projecting the flow of students through an education and training system, and for estimating educational *supply* for comparison with the manpower requirements. These models are incorporated as sub-models in the comprehensive model which will be discussed in the next chapter. The flow of graduates into the work force is the "supply" which is compared to the "demand" projected by manpower requirements models. Flows are estimated in sub-models in the compound models—for example, in Block III of Figure 1.3. Chapters 5 and 6 in this volume describe flow models and give instructions on how to use them.

In simplest form the methodology is similar to cohort survival methods used in demographic projections. An entering cohort of students is *survived* through the various levels of the education system by multiplying the entrant numbers (which is usually the result of a demographic projection of children attaining school entrance age) by a survival proportion or ratio which yields the numbers at the next level of the system in the next period. In graded school systems, flow through the levels is determined by three rates: promotion, repetition, and drop-out, or desertion from the system. The rates are multiplied by enrollments by levels; new entrants are added in; and the result is an estimate of enrollment

for the following year. As in cohort survival methods used in population projection, the process is iterative year-by-year to whatever plan target date is set.

The basic flow model has not been much improved over the version which appears in Schiefelbein and Davis (1974). UNESCO has a computerized flow model called ESM. Both World Bank and the General Electric Demos models developed for USAID have versions of the same basic flow models (Truesdell and Hyde 1979). The accuracy of flow model forecasts depends on the basic demographic forecasts of entrants and on the estimates or the promotion, repetition, and drop-out rates that govern flow. In most developing countries repetition rates have been badly underestimated. Schiefelbein has worked on methods to improve the estimates by simulating flows and checking the results against expected age-group distributions, and these are discussed in Chapter 6.

7.0 *Manpower Requirements Planning Models: The Compound Model*

Figure 1.3 sketches out the basic model used in the planning of education on the basis of manpower requirements. There are essentially four blocks in the model shown in Figure 1.3. The manpower requirements forecasts are accomplished in Block II. The models and methods for accomplishing these forecasts are developed and illustrated in Chapters 8, 9 and 10 of this volume. Chapter 11 is a case study of the basic method of manpower requirements planning. The basic method is the approach which is modeled in Block II of Figure 1.3, and will be treated in detail in Chapters 8 and 9.

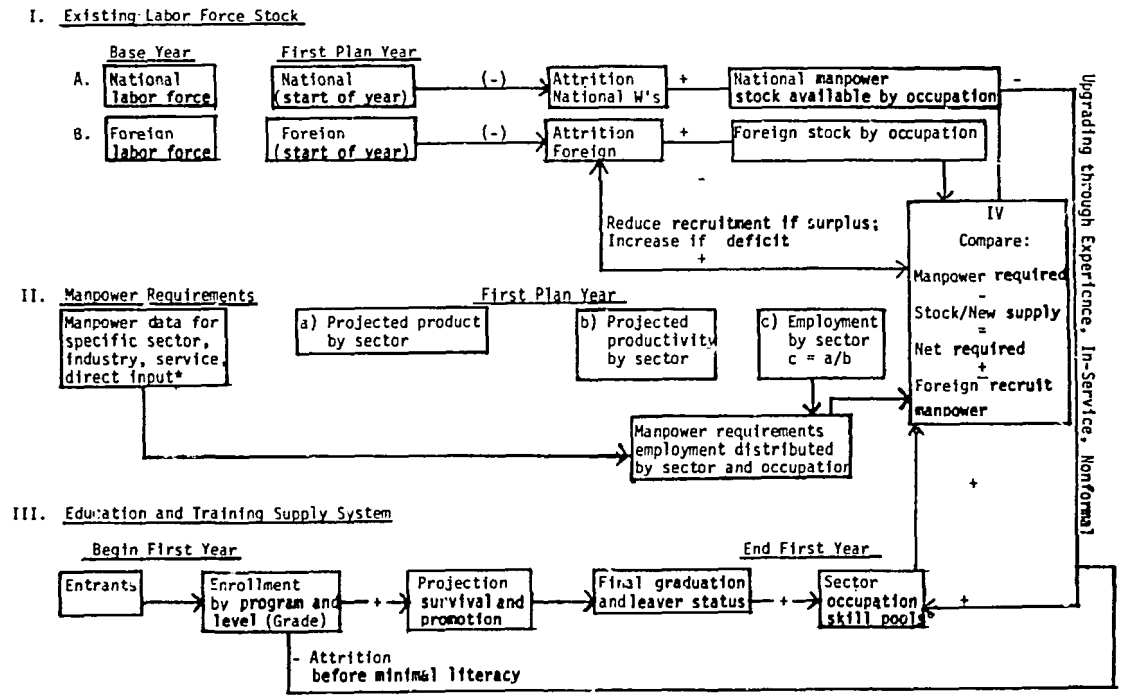
Block I shows the workforce stock classified by national (A) and foreign (B). National (A) workforce stocks suffer loss from death, retirement, and migration. This loss, or wastage, decreases the workforce stock each year. Stock is increased by new supply from Block III and foreign labor Block IA.

Block III of the model forecasts the supply of newly educated and trained workers from the education/training systems. Block III projects enrollment flows through education/training systems and on to entrance into the workforce. The projection methods are covered in Chapter 5.

Block IV of the model shown in Figure 1.3 outlines the schema for comparing manpower requirements (sometimes referred to as *manpower demand* or *economic demand*) with the output of education and training systems (sometimes referred to as *education supply*). The surpluses or deficits shown in Block IV can be used to plan education and training programs or to recruit educated foreign labor until national workers are trained. Most countries choose to educate their own workers rather than to bring in trained foreign workers.

Figure 1.3

A Compound Manpower and Education Planning Model[a]



[a]Based on modification of model used by World Bank

The model is called *compound* because it is built up of two separate parts, the manpower demand projections and the educational supply projections. These components are not as fully integrated into one model as they will be in the comprehensive model which is to be dealt with in the next chapter. Basically, however, the compound and the comprehensive models are both used for the same purpose in educational planning.

8.0 *Summary Comment on Systems Models*

The comprehensive model to be discussed in the next chapter is actually a mathematical version of the compound model shown in Figure 1.3, which in turn is an elaborated version of the black-box systems model depicted in Figure 1.2. The same sub-models are used in both the compound and the comprehensive models. The major difference is that the sub-models are better integrated in the comprehensive model and less easy to identify as separate blocks. Both the compound and the comprehensive models work iteratively, year-by-year, which means that the manpower requirements are projected and compared to the educational supply; wastage is added in; deficits and surpluses calculated; and a year-end balance is estimated. This is then carried into the next year, and the same process is repeated. In the comprehensive model there is a more integrated link between years over the period of the plan.

Compound and comprehensive models incorporate several sub-models used in planning. Generally, these are demographic projection models, enrollment projection models and manpower requirements forecasting models. The compound and comprehensive models are not complete solutions to the problems of rational planning. The models are abstract and aggregate, and the planner who uses the models takes a black-box approach to the educational system and to the surrounding social and economic systems. This black-box approach which underlies all compound and comprehensive models, has benefits and costs:

— The benefit is that the systems model enables the planner to look at effects throughout the system all at the same time. It provides a synoptic view.

— The cost is that it prevents the planner from observing all the details of the system, and it may distract attention from the human and social dimensions of the problem. For the critics of rational planning it is an unfortunate limitation, and a price to pay, but not crucial when the planner is aware of the problem. The choice of any planning approach is always both an epistemological and ethical issue.

APPENDIX 1.1

Chart A1.1

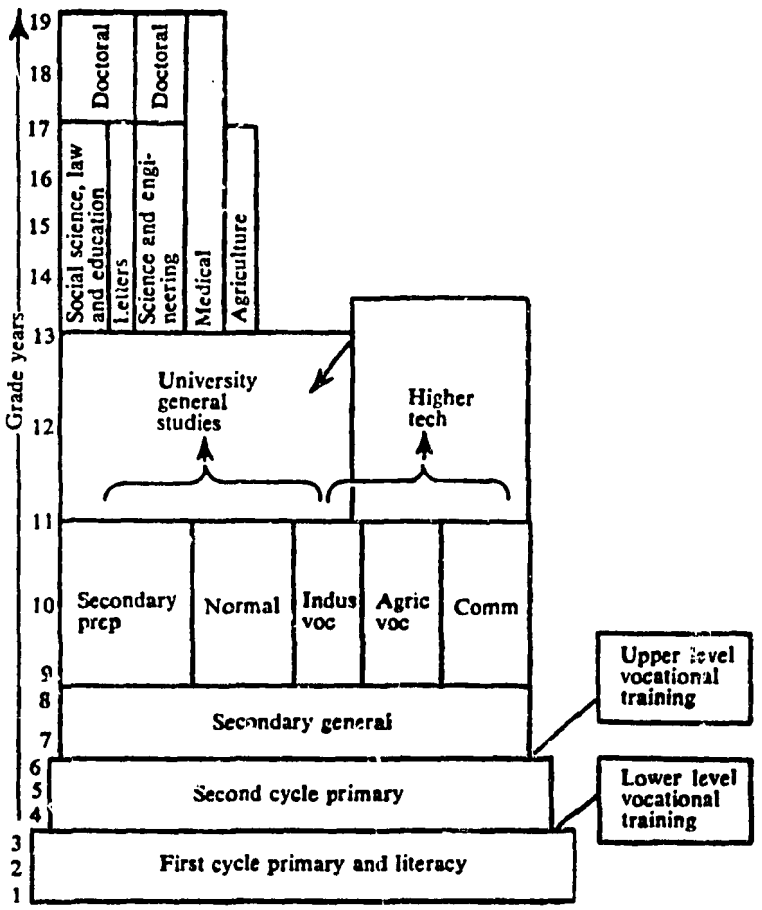
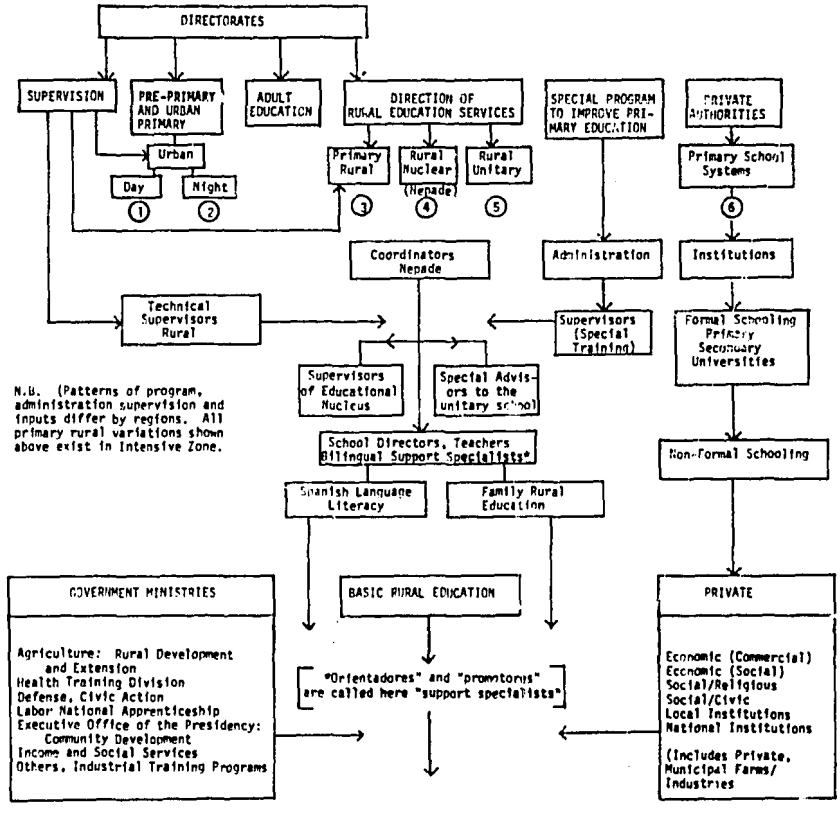


Chart A1.2

Actual Patterns of Direction and Supervision of Primary Education, Guatemala

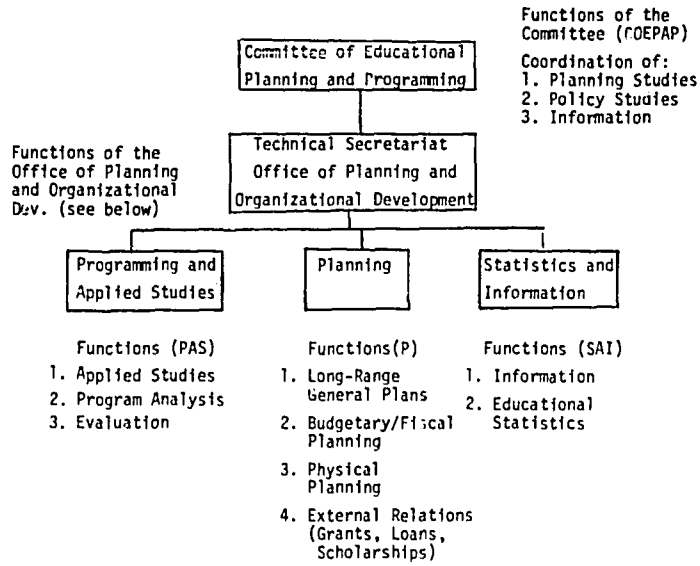


Note that there are two urban (1 and 2) and three rural primary school programs (3, 4, and 5). Private schools make a total of six different kinds of rural primary schools, each with different administration, supervision and different programs. There are also nonformal education programs, Literacy and Family Education operating in rural primary schools.

Source: Davis, Russell. "Morphological Analysis Applied to a Systems and Organization Study: The Guatemala Case." USAID/Harvard Project, Paper No. 81, 1979.

Chart A1.3

Organizational Schema of the Office (Final Version)



Functions of the Office of Planning and Organizational Development

1. Technical Advice and Information to Committee and President (Minister) that would cover:
   - A. Planning; long and short range, budgetary and physical planning
   - B. Policy Studies
   - C. Program Studies
   - D. Organizational Analysis and Organizational Development
   - E. Information and Public Affairs

Chart A1.4

Erik Erikson's Theory of Development
(Expressed in Form of a Stage Model)

A Stages	B Psychosocial Crises	C Radius of Significant Others	D Related Elements Of Social Order
1 Infancy 0 - 1 1/2	Trust vs. mistrust	Maternal person	Cosmic order
2 Early Childhood 1 1/2 - 3	Autonomy vs. shame, doubt	Parental persons	"Law and Order"
3 Play Age 3 - 5	Initiative vs. guilt	Basic family	Ideal prototypes
4 School Age 5 - 12	Industry vs. inferiority	Neighboorhood, school	Technological elements
5 Adolescence 12 - 18	Identity and repudiation vs. identity diffusion	Peer groups and outgroups; Models of leadership	Ideological perspectives
6 Young Adult 18 - 25	Intimacy and solidarity vs. isolation	Partners in friendship, sex, competition cooperation	Patterns of cooperation, competition
7 Adulthood 25 - 70	Generativity vs. self-absorption	Divided Labor and shared household	Currents of education and tradition
8 Maturity 65+	Integrity vs. despair	"Mankind" "My kind"	Wisdom

Source: Erikson, Erik. Identity and the Life Cycle, Selected Papers, New York: International Universities Press, 1959

CHAPTER 2

Systems Models and Methods for Educational Planning: Unit Two

1.0 *Introduction*

Chapter 1 began the coverage of planning models with a discussion of the simple, heuristic models used in educational planning to portray organizational and systems relationships. Similar graphic models used in systems analysis can also be used to give a general view of education input/output process. Education in an input/output model is shown in Appendix 2.1.

We will begin this chapter with a comprehensive model. The sub-models, or parts of this comprehensive model, have already been discussed. Population projection models, enrollment projections models and manpower projection models and methods can be used independently in educational planning. These three target-setting models and methods can also be joined together as in the compound model outlined in Figure 1.3 in the previous chapter. The target-setting models can also be integrated with other modeling approaches (for example, allocation models) in a comprehensive systems planning model, and this type of model will now be examined.

2.1 *The Mathematical Form of a Comprehensive Model*

We have looked at the parts of a compound systems model and have discussed systems models in general and abstract terms. Still, it is difficult to get a clear idea of what a comprehensive educational planning model is from such a discussion. Table 2.1 is a comprehensive model stated in mathematical form. Symbols, which stand for variables in an educational system, are built into equations, which describe relationships among these variables. The fifteen equations listed in Table 2.1 express in symbols and equations the same essential set of relationships which were depicted in graphic form in Figures 1.2 and 1.3 of Chapter 1. In the black-box view, schooling is a system which receives inputs, processes these inputs, and produces outputs which have outcomes

in the social and economic systems which surround the educational system. An example of an input is a teacher. The central process is teaching/learning. An example of an output is a graduate. Examples of outcomes or effects are the productivity and earnings which result from education. Viewing people as *inputs* is an unappealing way of looking at humanity, but it is useful if the planner keeps reality in mind.

Table 2.1

Tabular Summary of the Linear Model Equations and Inequations

Page References: Theory	Page References: Example	Brief Description
(1) Minimize: $C = \sum_t c_t$		Objective cost function
(2) $c_t = a_{1t}z_t + a_{2t}y_t + \delta_{1t}v_t + \delta_{2t}u_t + \epsilon_{1t}w_t$		Defining the annual cost of operations
(3) $c_t \leq \hat{c}_t$		Budget boundaries
(4) $X_t\lambda_a \leq \pi_t$		Demographic constraint
(5) $X'_t\lambda_a = z_t$		Defining the total enrollment by level
(6) $\Phi_{1t}z_t - \sum_{t=1}^{t-1}\Omega_{st}z_s - \sum_{t=1}^{t-1}u_s + \sum_{t=1}^{t-1}\Delta u_s \leq \hat{\Phi}_1$		Number of teachers required
(7) $\Phi_{2t}z_t - \sum_{t=1}^{t-1}v_s \leq \hat{\Phi}_2$		Capacity requirements
(8) $\Omega_{t-1}z_{t-1} + y_{t-1} = z_t$		Educational Technology relations
(9) $y_t \leq H_t z_{t-1}$		Limit on increments on student promotions
(10) $M_tZ_tz_t + w_t - \Delta w_t + u_t - \Delta u_t \geq \psi_{t+1}$		Manpower requirements
(11) $w_t \geq \hat{w}_t$		Limit on number of workers on-the-job trained
(12) $w_t \leq \widehat{w}_t$		Limit on number of workers on-the-job trained
(13) $x_{0t} \geq x_{0,t-1}$		Non-decreasing number of students
(14) $x_{0t} \geq \hat{x}_{0t}$		Limit on number of students in each age and level
(15) $X_t\lambda_a \geq P_t\Pi_t$		Limit on number of students in each age.

Source: Schiefelbein, Ernesto, and Russell G. Davis, Development of Educational Planning Models and Application in the Chilean School Reform. Lexington, Mass: Lexington Books, 1974.

The model in Table 2.1 appears formidable. For those who are not accustomed to dealing with mathematical models, Table 2.1 does not provide any clearer understanding of planning models than the words and abstractions of the previous chapter. The brief descriptions of the equations in the right-hand column of Table 2.1 do not help much either.

For those who are interested in following the details of mathematical modeling and programming, a detailed explanation of the model is offered in the next chapter. Chapter 3 will explain the equations shown in Table 2.1 in detail, discuss the way in which the education system is portrayed in the equations, describe linear programming in simple mathematics, and discuss how the results of such a model are computed.

Chapter 3 is optional. There is no need to wade through the mathematics of the model to understand, from an educational planning standpoint, what the comprehensive model summarized in Table 2.1 is about. Nor is it necessary to read the even more detailed technical explanation of the model in the book by Schiefelbein and Davis (1974), who describe how the comprehensive model was developed and used in Chile.

2.2 *The Equations of the Comprehensive Model: Meaning and Use*

The use of a comprehensive systems model in educational planning can be understood quite apart from the mathematical equations used to express systems relationships, and the algorithm used to solve the model. Table 2.1 is simply a set of plan goals stated as equations, or inequalities ($\leqq$ means "equal to or less than" and $\geqq$ means "equal to or more than"). The essential goals statements are:

1. Equation (1) of Table 2.1 states that the costs of running the education system over the planning period must be held as low as possible, or minimized. (In the language of linear programming this is called the *objective function*). The explicit plan objective is to minimize total costs (operations and capital) of running the system over the plan period. The goal stated in equation (1) (the objective function) suggests that the planning model is being used as an *allocations* model. Allocations models are used to make more efficient allotments of resources to various levels and kinds of educational programs, projects, or institutions. In fact, allocation was only one of the uses of the comprehensive model when it was applied in Chile.

2. Equation (10) states that manpower requirement goals must be equaled or exceeded by the output of graduates of the education and training system; or, in other words, that the education and training systems must be run during the plan period at a level sufficient to reach manpower targets. (The manpower requirements targets were projected by a separate study outside the model, and hence they are *exogenously*

derived. The manpower targets projected by the targeting model were then incorporated as part of the comprehensive planning model.)

3. Equation (3) states that the education system must operate within budgetary limits, which means be equal to, or less than, the budget that is projected. (The budgetary limits, called *budget constraints*, were also exogenously derived, or estimated outside the model itself.)

4. Equation (6) states that the school system must operate within the limits of teachers who are already available or who can be trained. (This is a resource constraint equation similar to equation (7). Equations of this type must be written for each input or resource used in the education process.)

5. Equation (7) states that the education system must operate within the limits of the classroom space that is available or that can be built. For each student enrolled, a fraction of classroom space is required as an input. When this input fraction is multiplied by the number enrolled, the total cannot exceed the total of classroom space that will be available for the system over the course of the plan. (The classroom capacity statement of equation (7) is a resource constraint equation.) Note that the equations shown in Table 2.1 are only general statements of relationships in the model. In other words, they represent whole families of equations, since separate equations may have to be written for each classroom type used in each different school type and level, and for each period of time in the plan.

6. Equation (13) states the social goal that the percentage of the age group admitted to schools, cannot decrease during the plan period. A related goal (equation 15) states that the number of children who enter school must equal or exceed a certain proportion of the population in school entry age. Social goals are written into the model to insure that children are taken into primary school without respect to their socioeconomic background, and that this is done at the same time that the manpower requirements targets are reached.

7. Certain standards of quality in education are maintained, and the flow of students through the system is governed by the quality of the educational inputs which reflect these standards. These standards are reflected in the input coefficients used in the system, i.e. the amount of a resource or input necessary to yield a year of education. If inputs are increased, then more and better education can be given, and the flow through the system will be increased. These goals are shown in equations (8) and (9) of the model.

The linear programming model is then *run*. This means solving on a computer the system of equations in the model. (The common method of solution, the algorithm, is called the *simplex*.) The solution will show the number who can be enrolled and graduated from the education system during the plan period, while the goals stated in the points 1 to 7 are attained. This means that the system is run so that:

— the costs are minimized;

— the manpower targets are attained;
— the education system operates within budget limits;
— the education system operates within space limits;
— the education system operates within limits of teachers available;
— social goals are attained, and the number of children admitted does not decline;
— standards of educational quality are maintained.

There are some other goals which will not be discussed in order to shorten our explanation of the model. We have discussed the essential goals of the model.

A comprehensive model helps the planner to plan the simultaneous attainment of multiple goals. The goals are reached in terms of the results of a model, and not in reality. Models help policy makers understand the education system. If models do this, then they have served their purpose. We will see that although comprehensive models do provide the numbers, they may provide them at such a level of generality and aggregation that they do not always tell educational managers what to do about specific programs. This is the cost of using comprehensive models. The advantage is that the planner can study changes occurring in the entire system through time. The planner cannot study each detail of the teaching/learning process. This must be done in educational research studies and not with systems models.

3.1 *The Allocation Component of the Comprehensive Model: Further Discussion*

Allocation models can be developed and used as separate entities, or incorporated as sub-parts of comprehensive models. (This is also true of targeting models.) An allocation model component is part of the comprehensive model shown in Figure 2.1, and some economists would call the entire model an allocation model. We will see that the comprehensive model was used for more than allocation when it was applied to educational planning in Chile. The basic allocation features of the model appear in the objective function of equation (1), and in the definition of costs in equation (2). The budget constraint of equation (3) and the teacher and classroom resource constraints of equations (6) and (7) are also parts of the allocation components of the model.

The manpower requirements goal expressed in equation (10) and the social goal of equations (13) and (15) are also linked to the allocation part of the model. Hence, the total model:

— minimizes the capital and current costs of the system;
— while at the same time attaining the economic (manpower requirements) and social goals of the plan;

— while at the same time staying within the budget constraints and teacher and classroom resource constraints.

Large allocations models may lump resource inputs without much qualitative distinction. In the comprehensive model, teacher types and qualities were not distinguished. Neither were different classroom types distinguished except in crude space norms by major levels of the system, i.e the per pupil classroom space ratio was larger for secondary than for primary students. Unit costs and unit allocations are lumped together and averaged, i.e. so many students per teacher and so much salary paid to the average teacher. Models become insensitive to qualitative differences, and not wholly useful for planning specific program improvements, when they are applied in aggregate form to large systems over many time periods. Rational planners who favor systems analysis and models claim that these limitations are not inherent in the nature of the models. The models can be disaggregated, or broken down into finer categories, to reflect whatever differences may interest the planner. This is indeed true in theory, but in practice each time the model is disaggregated the number of variables and equations are multiplied. The comprehensive model of Table 2.1 required 196 equations when it was appled in Chile. Even then, it was highly aggregated and quantitative. The amount of qualitative detail on inputs in most allocations models is severely limited.

An allocation model generally has this structure:

(a) There is a column of resource inputs. In education these would be teachers, classrooms, materials. . . These inputs represent constraints in that they are limits that cannot be exceeded in operating the system. (When put into a programming model, the limits of resources are written as constraint equations, and these constraints state that the system must use an equal or lesser amount of the resources available. The column of resource constraints is written in the form of a column vector on the right-hand side of the equations of the model. Hence analysts sometimes refer to them as the *right-hand side.*

Equations (6) and (7) of the comprehensive model in Figure 2.1 are typical examples of an allocation model component. The right-hand side of these equations are expressed as limits on the amount of classroom space and teacher service available. We have discussed only a few of the constraints equations on inputs that could be included in an allocation model. Clearly the planner could list any resource which was scarce enough for him to be concerned about allocating it. In an allocation model, separate equations would have to be written for each type of resource and for each different program in which it is used.

(b) Input coefficients show the amount of resource used to give a specified amount of education to a student of a given program or level. Usually this amount is a year of schooling. The coefficients show how much of the resource from the right-hand side must be used to provide a year of education. These may be called *technological coefficients*, and

they show the unit amount of resource required for giving a unit amount of education. The coefficient symbolized as ϕ_2 in equation (7) of Figure 2.1 represents the number of square meters of classroom space used per student. Note that the choice of symbols for variables and coefficients is purely arbitrary, and in this case the choice of the Greek letter phi (ϕ) is pretentious and unnecessary. In the next chapter we will change these symbols to make them easier to type.

In equation (6) the coefficient ϕ_1, is the teacher/student ratio, which, if multiplied by the number of students, will give the number of teachers, or the resource limit shown in the right-hand side of the equation.

(c) The model starts with a set of enrollments by school levels in year 1. These so-called activity variables change as enrollments increase over the years of the plan. These are the *endogenous* variables of the model, which means their values are changed within the model by running the model toward a solution. The solution gives the number enrolled at the end of the plan period. (Enrollments are shown as z_t in the equations of Figure 2.1, and appear as a column vector in the model.)

(d) The model may also have an objective function when it is cast in the form of the comprehensive model. This is shown in equation (1), where the objective is to minimize the costs of running the system. (It is usually written as a row vector.) The solution gives the minimal cost of running the system to produce the enrollments shown in (c), and within the constraints.

The allocation model can then be run as a separate entity or as part of a comprehensive model. In either case, when it is run as a mathematical programming model, the results show the number of students who will be put through the system at minimal cost, while not exceeding the resource limits specified in the constraints, and at the same time reaching other goals specified. In the comprehensive model the objective function was to minimize costs; thus, the model sought to reach its social and economic goals without exceeding resource limits, and to do this at minimal cost. This is the basic form and purpose of an allocation model.

The objective function can be put in quadratic as well as linear form. A quadratic form would be used, for example, when the costs of running the system, or whatever index is used in the objective function, do not increase (decrease) in a linear form. In Chile the first version of the comprehensive model used a linear objective function, but a second version was attempted in which the objective function was to maximize an index of learning, and this was put into quadratic form (Schiefelbein and Davis 1974). These are topics beyond the immediate scope of this book. The model can also be cast into dynamic form, so that the coefficients and parameters change as a result of running the model over time. Sensitivity analysis can be performed, in which parameter values are varied and the results are studied as in a simulation of a real system. In the United States, Hopkins (1971) offers a very simple explanation of a similar model applied to allocation in university planning. Weathersby and associates (1967) have developed and applied the model in university

planning. Other applications of programming models have been reviewed by McNamara (1971). Bowles (1969) and Schiefelbein/Davis (1974), among others, used a linear programming model for allocating resources to education. The allocation component was part of a larger comprehensive model.

4.1 *The Comprehensive Model Applied in Chile: Limitations Revealed*

The application of the comprehensive model in Chile marked a turning point in the use of systems models for planning. The experience revealed the limitations on the use of tightly structured comprehensive models. Run as a linear program model with the objective of planning the output of formal schooling and on-job training at minimal current and capital costs, the model indicated, in broad terms, the cost consequences of a large increase in the retention and flow of students in the education system. The model was mainly used for allocation, but results also indicated possible bottlenecks to goal attainment over time. Results from the model also revealed educational problems which had to be studied with more detailed analysis and research. The model showed that alternative ways of training teachers in-service had to be developed and implemented rapidly in order to serve the increased numbers of students in the upper grades during the plan years. The model also provided results that were useful for planning on-the-job training of workers. The model indicated that on-the-job training was a less expensive alternative for training lower-level workers in the short run. Higher-level workers, however, would be more expensive to train on the job in the short run. The model showed that it would be cheaper to train high-level workers in vocational schools, even though the conventional wisdom is that on-the-job training is cheaper. These results are discussed in Chapters 6, 8, and 10 of Volume I, and in Schiefelbein and Davis (1974).

Running the model also revealed three major limitations on its usefulness. One was imposed by the rigidity of the mathematical programming structure and the algorithms for computing the result. In the linear programming model it was impossible to include feedback relationships. Feedback relationships can be included in a dynamic or multiple-loop feedback model (Forrester 1971). Dynamic models require a different structure, in which variables are inter-linked so that changes in the value of one variable will link to changes in another, and then link in a loop back to the first variable. The feedback makes the system dynamic in the sense that the model may partially update itself across time periods. The model in Chile could not do this. Chilean planners had to use fixed coefficients over time, although approximations to changes could be introduced at the beginning of each time period.

A second major problem arose in applying the model in an actual policy analysis and decision-making context. The single-goal, linear programming format focuses too much attention on the goal shown in the objective function. In the Chilean model, this was to minimize the

cost of running the system. In actuality this was not as important as other goals that were also incorporated into the model but not highlighted for as much attention. Other goals that could have been important were those of the educational and social programs of the Chilean school reform. A more important plan goal would have been to increase the proportions of rural poor children brought into the school system. Or it might have been more significant for the planners to study how detailed improvements in curricula affected systems flows. Goal programming models enable the planner to focus explicitly on several planning priorities rather than on single goals, as in the Chilean model (S. Lee 1972; C. Lee 1974).

A third set of limits came in applying the model to the learning process. The model could not deal with essential qualitative relationships which are at the heart of the education process. The model fell short in providing indications of what planners, policy makers, and program developers could do about changing basic programs to improve the quality of education. A more elaborate model was developed to accommodate effects of instructional quality, but it was difficult to get this model into computable form. The promise and problems of such programming and optimizing models in actual planning are reviewed by Schiefelbein and Davis (1974), but in general the model was too rigid and too general to serve some of the practical needs of planning. More flexible models were required.

4.2 *Model Development and Limits of Black Box Analysis*

Since the Chilean model application there has been further devlopment of models for education planning, but no marked increase in real-world use. The problem of linking the changes in the general education system to teaching/learning activity has not been solved or approached, and may be beyond remedy with anything but a model that is too big and complex to manage. Comprehensive models yield useful information at a systems-wide level, but treat the central activity of education as something that goes on inside a black box. They yield few guidelines for shaping instructional or learning strategies.

At the risk of being repetitious we will state that this is not a fatal flaw, but merely a price that must be paid in much of the modeling and research analysis that goes on in social science. For this reason there have been increased efforts to develop heuristic models. These will be discussed in Chapter 15. Another alternative is to use the fuller descriptions of social dynamics and the qualitative features of education that are made possible with case analyses of problems. There have also been attempts to develop more flexible models that produce numerical solutions. The multiple-loop feedback models of Forrester (1968) are one possibility; and goal programming models are another (S. Lee 1972).

5.0 *Models for Planning and Decision Making with Multiple Goals*

The programming model described in Figure 2.1 has a major limitation because of the prominence it gives to minimizing costs, the goal which is stated in the objective function. This suggests that the planner has a single goal, or objective, in this case minimizing the costs. In planning and decision making generally, and in educational planning specifically, there is rarely a single goal. In reality, the planner must attempt to reach several goals at the same time, and because resources are always limited, there may be competition among goals. Furthermore, the objective of the game is not to optimize but rather to *satisfice*, which means to do as well as possible given the circumstances.

5.1 *Goal Programming Models*

Goal programming is the name given to a variant of the programming model shown in Figure 2.1. Actually, all programming models applied to planning are built around planning goals, as our explanation of the comprehensive model has demonstrated. But in *goal programming* proper, there is explicit consideration of multiple goals, and this is a virtue for planning. Goal programming is a satisficing format, rather than an optimizing one, in the sense that the program attempts to come as close to the target goals as the situation and competing goals warrant. Instead of the single objective function of the type shown in equation (1) of Figure 2.1, the objective function statement in goal programming would have multiple goals, and the model would be run so as to minimize positive and negative deviations from these goals. A simple goal programming objective would appear like this:

$$\text{Minimize: } d = [(P_1), (P_2), n_3], \tag{1}$$

where d = total of deviations;
P_1 = excess in variable 1;
P_2 = excess in variable 2;
n_3 = deficit in variable 3.

In this objective function the planner is attempting to minimize the positive deviations (symbolized as P_1 and P_2) from variable 1 and 2 and to minimize the negative deviations (n_3) from variable 3. If variable 1 was the number of graduates of civil engineering programs, variable 2 the number of graduates from chemical engineering programs, and variable 3 the number of graduates from mechanical engineering programs, the objective of the goal program could be stated: Run the educational system so that it does not over-produce civil and chemical engineers and under-produce mechanical engineers. Surpluses and deficits are to be minimized. Goal programming provides a more realistic model of decision making and planning. Though our purpose is not to teach goal programming techniques, we include this brief section on goal programming with suggestions for further reading. Ignizio (1976) provides a readable work linking multiple-goal programming to the

single-goal programming illustrated by the model in Figure 2.1. Charnes and Cooper (1961) laid the foundation for goal programming approaches and followed with subsequent applications (1968). Ijiri (1965) and S. Lee (1972) advanced the theory, method, and applications.

S. Lee (1972) describes goal programming as a mathematical model in which "the optimum attainment of goals is achieved within the given decision environment." The features are: multiple objectives may be incorporated into the model; the objective function may have non-homogeneous units of measure instead of a single measure expressed in utility or cost; goals can be ordered in a hierarchy of importance so that lower-order goals are only considered after higher-order ones are attained; and deviations between goals and what can be attained within constraints are minimized so as to come as close as possible to attaining the goals. The goal programming model minimizes over- or under-achievement of goals according to a statement of prioritized objectives. Goal programming can model decision structures more realistically because it permits consideration of conflicting goals and requires that the planner lay out priorities clearly. It also accommodates participant contributions in the process of specifying conflicting goals and priorities.

6.1 *A Closing Note on Other Models Used in Educational Planning*

These first two chapters have discussed some planning models, but offered only passing comment on others. Comprehensive planning models, allocation models, targeting models and compound manpower requirements and educational planning models received the major share of attention. The next chapter goes further into the mathematical features of the comprehensive model. The chapters in Part Two will offer detailed instruction on projection models. Heuristic models and methods will be described in Chapter 15. Three types of models that are occasionally used in educational planning will be briefly mentioned in this closing section.

— *Mathematical models of the learning process.* These models are essentially attempts to design a mathematical model of the learning process (Bush and Mosteller 1955; Atkinson 1965; and Suppes 1968). The models are interesting as research efforts, but there has been little application in educational planning. The more easily and precisely the learning process is made to fit a mathematical form, the less applicable the models are to educational planning. Usually, the learning task is simplified, and the learning outcome is expressed as binary, or yes/no answers. The process and the criterion test scarcely resemble any real world learning situations in which analysts are interested. The instructional models of Restle (1964) and Carroll (1963) provide quantitative indices of the outcome of learning tasks, and these indices can be used in planning models. These models have proved to be only moderately useful. An attempt to apply the Carrol learning model is described in Schiefelbein and Davis (1975).

— *Decision process and managerial models.* Decision-analysis and modeling of the decision process are relevant to planning, but the topics belong more in the field of systems management. Anthony (1965) includes planning as a sub-field of management, but that classification is not followed here. A second reason for avoiding decision models is that it is difficult to deal with the subject without becoming abstract or lengthy. For those who would read in the field on their own, Raifa (1972) has prepared a "self-instructional, self-paced" course in decision analysis. This course, in order to be simple and clear, requires ten modular volumes just to illustrate the basic concepts of decision and probability assessment.

Models for analyzing the effects of education. These models are used in educational research and planning. Further treatment of the analysis of educational effects will be offered in the volumes to follow. The essentials of the model and the approach can be presented in fairly simple and compact form, however, and this is attempted in the Appendix which follows.

Appendix 2.1
Models for Analyzing the Effects of Education

These models can be traced to the classic studies of educational antecedents and outcomes which have *enriched* the professional literature in the field of education over the past thirty years. More recently, economists have used the approach in production function analysis, and sociologists in analyzing the data of natural experiments. The lines of development are quite similar, resting on application of least-square models to regression analysis of variables measured in the cross section. We will base discussion on the model used in so-called production function analysis. As the term suggests the model depicts a functional relationship between a set of independent variables and a dependent or criterion variable. This functional relationship and the mathematical form which depicts it, is the most basic, useful and widely applicable mathematical concept applied to social processes. The functional relationship undergirds hundreds of models.

$$A = f(X_1 \ldots X_i, X_j \ldots X_q, X_r \ldots X_z)$$

Dependent Variable

A = Some measure of school output, e.g., school achievement

Independent Variables

$X_1 \ldots X_i$ Educational inputs, e.g. teachers facilities, curriculum materials;

$X_j \ldots X_q$ School or community environment, average earnings, property values;

$X_r \ldots X_z$ Prior education, or intelligence, or motivation of student

The function is fitted through least-squares, and in the resulting regression analysis there is an attempt to assess the relationship of the independent variables, the *X*'s, to the dependent variable *A*, which might be some measure of school achievement. In the usual version of this type of analysis, the investigator may be attempting to explain the differences in achievement of students, according to whether they received certain kinds and amounts of educational inputs (curriculum materials), and attempting to assess the effects of other variables on this input/achievement relationship. For example, the input/achievement relationship might be different for students in a high-income community, and it will be different according to the previous educational achievement, intelligence level and motivation of the students. Studies of Jencks (1972) and Coleman (1966) and the International Evaluation of Educational Achievement (IEA) studies reported by Purves and Levine (1975) used variants of this basic model to study the effects on educational achievement of social and economic background, educational inputs, and student characteristics.

Analysis of effects is often based on collections of social, economic, and educational data which were not gathered according to a predesigned research scheme. This kind of research is sometimes referred to as a *natural experiment*. There is no direct experimental manipulation or direct analysis of effects or outcomes as these are analyzed in control-experimental research designs applied in research and evaluation studies.

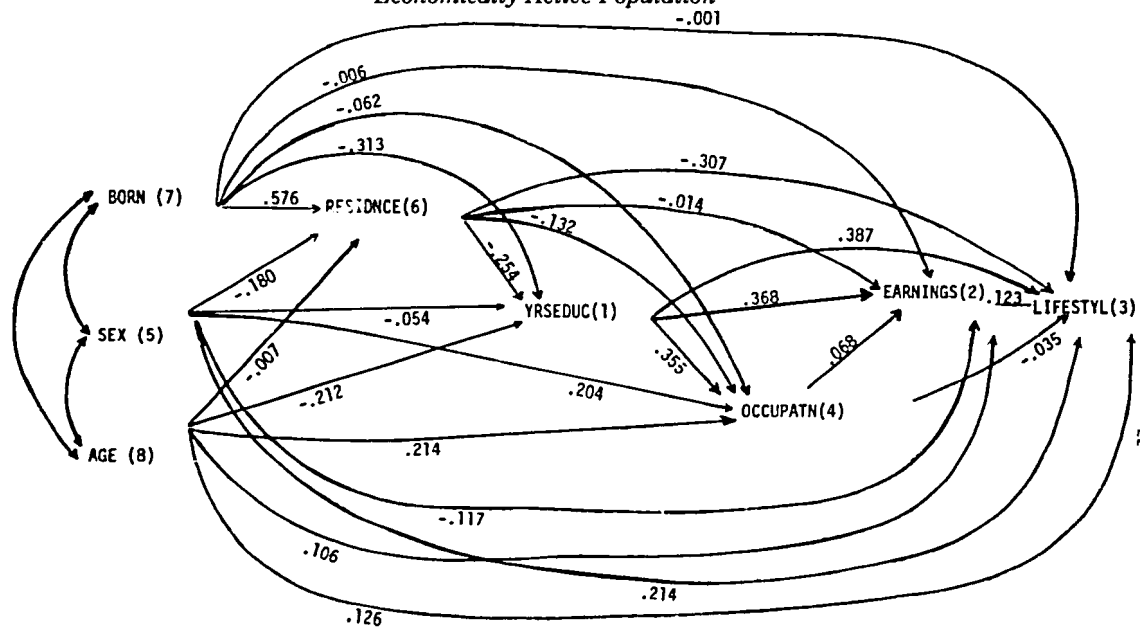
Davis has pointed out in Purves and Levine (1975) that planners very rarely use the numerical results of such research in their work, but they do sometimes make plan and educational policy recommendations on the basis of results shown by application of such models and methods. For example, a free textbook distribution program was extended to a new area of Venezuela on the basis of regression analysis, which showed a fairly high use and effect of school books distributed to the homes of poor students (McGinn and Davis 1969).

The same basic regression models and statistical methods are applied by sociologists and economists in studies of the broader relationships of demographic, social, and economic variables on education and earning. Figure A2.1 shows the application of path model and analysis to the study of the effects of social and educational variables on earnings and living standard. Path analysis attempts to get behind the cruder aspects of black-box social analysis by setting up explanatory models of effects beforehand and analyzing causal relationships somewhat more explicitly. Path analysis may sometimes improve the theoretical power of the regression model underlying the research.

Figure A2.1 shows a path model which attempts to trace the effects of education on later economic and social outcomes. It is based on a study using a large national sample of the population in El Salvador. The data were gathered in 1974 and analyzed in 1977, and the entire study is discussed in Davis and McGinn (1977). The research interest

Figure A2.1

Path Model of Relevance of Education to Economic Social Outcomes, for Economically Active Population



Source: Harvard-AID Project Analysis of Data on Relevance of Education in El Salvador (Data collected 1974, analyzed 1977). Davis and McGinn, USAID/Harvard Project Paper No. 82, 1977.

was the effects of the *education* variable (measured in number of grades or years of education successfully completed) on later *earnings* (monthly average of salaries, wages, or other remuneration) and *lifestyle* (standard of living).

The direct effect of education on earnings according to the model assumed in Figure A2.1 is shown by a path coefficient of .368. This path coefficient is also called a standardized regression coefficient, which, like the correlation coefficient, varies from about −1 through 0 to about +1. The −1 would be a high negative or inverse relationship (effect); 0 would signify no relationship and +1 shows a high positive relationship or effect. The path coefficients show the direct effect of one variable on another.

For practical purposes, and when dealing with large samples, analysts usually treat coefficients larger than .25 (plus or minus) as indicating effects that are worth commenting on in the results. Hence, in this model *education* does seem to have an important direct effect on earnings. This was assumed by the way the research analyst set up the model. He ordered the variables so that *education* came before the *earnings* variable. In other words, he modeled a process in which education affected earnings and not the reverse.

Path models attempt to explain the direct effects of one variable on another within a set of variables. The effect is shown by the size of the "path coefficient". The path coefficient is the standardized regression coefficient, and hence it shows how much one variable will change as a result of changes in another variable, when these changes are expressed in standard deviation units. (The adequacy of the path model can be tested by setting up equations in which correlation between variables is predicted based on the path coefficient and related correlation coefficients.) Here we define path coefficients in this way: path coefficients, or standardized coefficients, are estimates of the direct (causal?) effects of certain variables on other variables, given the causal ordering which is theorized by the analyst in his path model.

In Figure A2.1 the model begins with certain variables representing the initial conditions of the people in the population. They are born in rural or urban areas, are male or female, and are members of certain generations or age cohorts. As the model is set up in Figure A2.1, age, sex, and birthplace are *exogenous* variables, meaning they are not determined by other variables inside the model. In developing countries, age, sex and birthplace can affect the likelihood of the person attending school, finding a certain occupation, earning a certain amount, and living a certain lifestyle. In the model, education, occupation, and earnings are *endogenous* variables, which means they are determined by solution of other variables in the model.

The path model in Figure A2.1 allows the analyst to see how variables affect each other directly and indirectly. We will follow a few of these direct effects shown in the path model and then allow the reader to make his own interpretations. Let us examine the path Urban/Rural Birth-

place to Urban/Rural Residence to Education to Earnings to Lifestyle. There is a strong relationship between Rural Birthplace and present Rural Residence (.576), as we might presume. This tells the analyst only that people born in rural areas still tend to live in them, though there is some out-migration, shown by the fact that the coefficient is far from 1. From Rural Residence there is a fairly strong (-.254) path to, or direct effect on, Years of Education. The negative coefficient comes from the fact that the Residence variable goes on the scale from Urban *up* to Rural. Hence a negative sign means that people in rural areas have lower education. Notice, however, that there is also an even stronger negative path from Birthplace to Education (-.313). This suggests that the negative effects of rural origins are not overcome by migration to, and residence in, urban regions. In fact, very poor people forced into urban areas actually get less education than those who stay in rural and suburban areas near towns and cities. Education has a strong positive effect (.368) on Earnings, as we previously saw. In turn, Earnings has an effect on Lifestyle as we might expect. In fact, the expectation would be that it would come out higher. Note also that Rural Birthplace and Rural Residence have negative effects on Earnings, but Rural Residence has a high negative effect on Lifestyle. This occurs because the standard-of-living scale used in the study was heavily weighted toward possession of urban amenities (running water, electricity, etc.). Note also that Education has a strong effect on Occupation, as we might assume; but the effect of Occupation on Earnings is much lower than we would expect. Note also that Sex (Male/Female) has a strong negative effect on Education and Earnings, and if we combine this with Rural, then Rural Women are an enormously deprived group in the society.

The purpose in introducing the path model here is not to analyze the social and economic conditions of El Salvador. Neither is our purpose to teach the techniques of regression and path analysis. The point is that regression and path models used to study educational effects and broad social outcomes are very much black-box approaches. There is no real analysis of how rural background or sex discrimination lead to lower educational opportunities, or how education affects work, productivity, earnings, and standard of living.

The results of path analysis of aggregated variables can be used to suggest certain policies, or to support certain plans. In this case the analysis was used to show the effects of rural deprivation and the need for rural schooling assistance for females. Other policy indicators were shown more precisely in other path models, which will not be presented here. The study itself, with an appendix on the methodology of path analysis is available as part of the documents produced in this project (McGinn and Davis 1977). Duncan (1966) discusses how path analysis is applied in sociological research; and the general treatment of multiple regression analysis can be followed in Kerlinger and Pedhauzer (1973), a standard work on multivariate analysis.

CHAPTER 3

Systems Models and Methods for Educational Planning: Unit Three

1.0 *Introductory Comment*

The main objectives of this instructional unit on mathematical programming models is to give the planner a general idea of how these models are developed and used in educational planning. This chapter continues discussion of the comprehensive planning model introduced in Chapter 2. In this chapter the presentation is somewhat more technical, but the material is still designed as an introduction to mathematical modeling. The chapter is optional in the sense that planners may decide with some justification that they know enough about comprehensive planning models without going through yet another chapter on the subject. In that case readers are invited to go on to the units on demographic analysis and population projection in subsequent chapters. General references on linear programming and other mathematical programming methods will be suggested. The Appendix at the end of this chapter will present some introductory algebra to solve a simple set of equations used in a linear programming model. In the world of planning and practice, analysts do not solve linear programming problems. They usually sit down with computer specialists and prepare the problem for computer solution. A brief listing of well-known and usable computer codes will be provided at the end of Chapter 1.

In this chapter we will do three things. First, we will discuss a simple linear programming problem of the type presented as an example in books on educational planning. In fact, such simple applications do not occur in educational planning, and the presentation of such simplifications can be unhelpful as well as helpful. The exercise is unhelpful if it suggests that problems of such brevity and simplicity will actually be encountered in educational planning. The school exercise model usually has two or three variables, set into either constraint or goal equations, and a simplistic objective function. The problem falls neatly into a standard linear programming format such as the activity analysis format for an allocation problem. The problem is then graphed and the equations solved. The difficulty is that the problem solved is not like

any the planner will ever see in his work; at least he will not see one with so few equations and variables. The usual situation is that a systems planning problem, if it is real at all, may have a hundred or more variables and hundreds of equations. After studying the two-equation exercise, the learner may be staggered when he has to cope with a real programming problem. In fact, the two-equation, two-variable exercise doesn't teach or tap the skill that is required to develop and use linear programming models in planning. We will discuss what these skills are later.

Nonetheless, the small example can be helpful. The two-variable, two-equation problem can be graphed on a plane, using X and Y co-ordinates. The geometry of the solution of simultaneous equations system, and the geometry of the simplex algorithm which is used to solve linear programming problems can be shown clearly. Furthermore, the simple two-variable problem can represent the type of larger programming problem that generally requires many equations and many variables. In short, the small problem can help the learner understand what kinds of planning problems linear programming can be applied to. For this reason we will sketch out a simple educational planning situation that can be easily put into a simple linear programming format with two variables, one objective function, and two constraint equations. We will show how this is solved graphically. In the Appendix we will show the solution in linear algebra.

Secondly, we will go back to a realistically-sized model, the comprehensive model that has been discussed in the preceding chapter. We will outline this model again, as it was outlined in the text, but with specific equations to show the objective function and the target and constraint equations.

Lastly, we will attempt to offer some useful advice about how linear programming models are developed. There are two major requirements in this development:

- a clear formulation of the system goals the planner wishes to deal with in the model; and
- the description of the goals, targets, and constraints in the form of equations which describe the fundamental relationships prevailing among the key variables of the system.

If the development of the model can be begun by the planner, then other analysts with specialized knowledge can provide this additional specialized help:

- further specification of the systems planning goals;
- identification and symbolic definition of the key variables; some variables are under policy control and some are not.
- design of equations which describe the relationships of the variables of the system in terms of planning goals, systems

resource constraints, input/output or technological relationships, and relationships among elements of the system over the plan period;

— selection of a computer code and the preparation of the problem for submission to the computer according to the requirements of the computer code selected. A few of the standard computer codes used for linear programming are listed at the end of this chapter.

2.0 *A Simplified Linear Programming Problem*

Two programs in the machine trades are offered to part-time students in a training center. Two different kinds of machines are basic for training in each program. Program I requires a minimum of 24 hours a week to give a group of 10 learners sufficient supervised practice on the machines. Program II requires 23 hours a week to give 10 learners sufficient machine time. Based on curriculum and machine availability, the director decides that the appropriate machine-training mix for Program I is 4 hours on Machine Type 1 and 6 hours on Machine Type 2. The appropriate machine-training mix for Program II is 5 hours on Machine Type 1 and 4 hours on Machine Type 2. The two programs can be operated during staggered evening hours, in which machine practice is alternated with related academic studies, so the two groups can share the same machines. The hourly cost of Type I machine (for power, tending, and amortization or rental charge) is 32 units of national money. The hourly cost of Type II machine is 40 units in national money. The director wishes to determine the minimum number of machines and the minimum machine costs to serve these programs. (Note: The machines are used in other programs which are run in the center; but at the outset the director is interested only in machine availability for these two programs and the costs.)

Unreal though the simple problem is, something can be learned from following it through in linear program form. For purposes of pedagogy we will assume that this program typifies the kind of allocations problems planners encounter. There are instructional activities which can be carried out in various ways technologically, and there are costs associated with these alternative modes of instruction. There are limits on resources available and other constraints imposed by structural features and technology in the system. The goal of the director is to minimize the machine costs, and he will do this by setting up the problem in linear programming form.

2.1 *The Problem Stated in the Form of a Linear Programming Model*

To set the problem into linear programming form, the director begins with a statement of his major goal—cost minimization—in the form of an objective function statement. A simple objective function can be written, using the operating costs of the two machine types:

$$\text{Minimize machine costs: Min } C = \$32\ X_1 + \$40\ X_2 \qquad (1)$$

The director will then solve the problem to get the number of machines of type 1 (X_1) and the number of machines of type 2 (X_2) which will provide the required weekly hours of training for both programs at minimal cost.

We can put the total hours of practice required for each program in the form of minimum target to be attained:

$$\geq 24 \text{ hours (Program I)}$$
$$\geq 23 \text{ hours (Program II)}$$

These state that at least 24 hours of machine instruction and practice must be offered in Program I and 23 hours in Program II. (This is shown by the sign $\geq$ which means "equal to or greater than.") If there were a limit on machines available—for example, in the center there is installation space for no more than 10 machines—then this could be put into the problem in the form of a constraint equation where the symbol would be $\leq$ (which means "equal to or less than," e.g. $X_1 + X_2 \leq 10$). Since this limit will not affect the solution, it is not included in the problem statements.

We can write the technological requirements in equations, using data from the problem. In Program I the minimum is to be offered with 4 hours of Machine X_1 and 6 hours of Machine X_2. Hence:

$$4X_1 + 6X_2 \geq 24 \qquad (2)$$

In Program II the instruction is offered with 5 hours of X_1 and 4 hours of X_2.

$$5X_1 + 4X_2 \geq 23 \qquad (3)$$

Both types must be used, so neither X_1 nor X_2 can equal zero (a general condition in all such problems). This can be stated:

$$X_1 \geq 0 \qquad (4)$$
$$X_2 \geq 0 \qquad (5)$$

The entire problem in linear programming form would be: Minimize total weekly machine cost:

$$\$32\ X_1 + \$40\ X_2 = C \qquad (1)$$

Subject to meeting the target instructional hours weekly with the appropriate mix of machine experience:

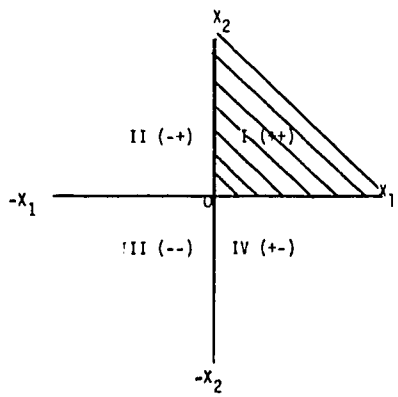
$$4X_1 + 6X_2 \geq 24 \qquad (2)$$
$$5X_1 + 4X_2 \geq 23 \qquad (3)$$
$$X_1 \geq 0 \qquad (4)$$
$$X_2 \geq 0 \qquad (5)$$

2.2 *The Graphical Solution*

The solution to this problem can first be shown graphically on the plane, using X_1 and X_2. Equations (2) to (5) are linear and can be

graphed as straight lines on a plane with X_1 and X_2 as the axes. Equations (4) and (5) tell us we will be working in quadrant I (++) because both X_1 and X_2 are equal to, or greater than, zero.

Figure 3.1



Next we graph equation (2) and see where the line intersects the X_1 and X_2 axis. Actually, though we refer to expressions (1) to (5) as "equations," they are expressions of inequalities which show a minimum that must be attained. This set of inequalities forms a boundary line when the expression is graphed. In the inequalities stated in the form "equal to or greater than (≥)," the equation line forms a lower boundary, and the solution lies on or above the line. We find where the line will pass through the X_1 and X_2 axes by setting one variable equal to zero and solving for the other. This shows us the lowest value each variable can take on. In other words, the value of the variable must be equal to or greater than that value. We do the same thing for each variable in turn. When we graph the equation with these two variables, we have a line that passes through the axis of one variable and shows the minimal value of the other variable. The solution to the equation must lie on or above this line. If X_1 is set equal to zero in equation (2), then:

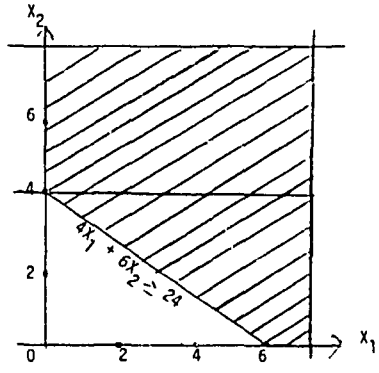
$$4X_1 + 6X_2 \geq 24 \qquad (2)$$
$$0 + 6X_2 \geq 24 \qquad (X_1 = 0)$$
$$X_2 \geq 4$$

This means that the smallest value X_2 could have in this equation is 4. When X_1 is zero, then X_2 must be equal to or greater than 4, in order to satisfy the equation. We now set X_2 equal to 0 and find where X_1 will intersect:

$$4X_1 + 0 \geq 24$$
$$X_1 \geq 6$$

Equation (2) is graphed in Figure 3.2, in which the shaded area shows where the solution must lie. This is called the feasible area. The solution must lie above the line that intersects the X_1 axis at 6 and the X_2 axis at 4.

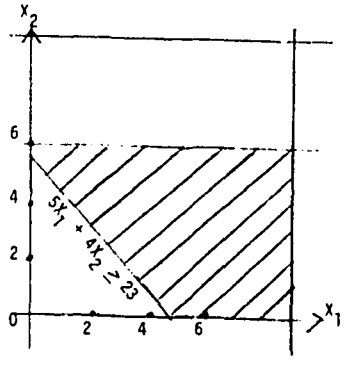
Figure 3.2



Graph of $4X_1 + 5X_2 \geq 24$

Next we graph equation (3) and do the same thing. If X_1 equals 0, then the smallest value X_2 could have would be just a bit less than 6 (5.75). If X_2 equals 0, then the smallest value that X_1 could have would be a little less than 5 (4.6). The shaded area in which the solution must occur, according to equation (3), is above the line $X_1 = 4.6$ and $X_2 = 5.75$.

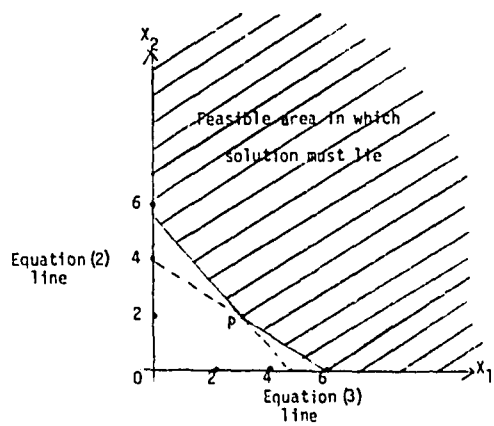
Figure 3.3



Graph of $5X_1 + 4X_2 \geq 23$

We can now put equations (2) and (3) on the same graph in Figure 3.4, and see where the two sets of lines intersect. The two equation lines will mark out an area in which the solution of the problem must lie. This is shown by the shaded area. The solution can lie anywhere in this shaded area. In Figure 3.4 there is a corner point marked at *P*. This is the lowest point, or minimum, that still falls within the shaded, or feasible, area, and the solution of the problem lies at this point.[a] We can read this solution from the graph. It shows that X_1 equals 3 and X_2 equals 2 at the lowest point, or corner of the feasible area.

Figure 3.4



Lowest point (minimum) is corner at P (3,2).

[a]There is a mathematical proof that the minimum or maximum must always fall at a corner point of the feasible region, but this will not be dealt with here.

Figure 3.5 shows how the objective function moves toward the minimal point in the feasible area during the solution of a linear program problem which uses the simplex algorithm. If we look at the top line in Figure 3.5, it shows that if X_1 is maximum at 10 ($X_2 = 0$), or X_2 is maximum at 8 ($X_1 = 0$), the objective function would have a value of \$320. What happens in the simplex algorithm is that the objective function line is moved down and parallel until it reaches the lowest corner point in the feasible region. This is *P*, where X_1 equals 3 and X_2 equals 2. When we put these values into the objective function we get:

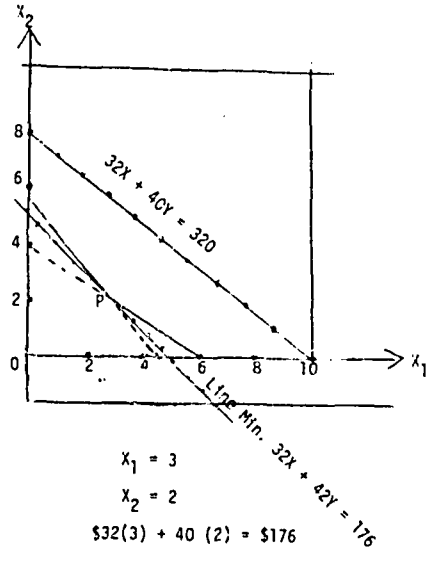
$$32(3) + 40(2) = \$176$$

This is the minimal weekly machine cost to serve both programs in the center. It will result from using 3 machines of Type X_1, and 2 of Type X_2. In following the simple problem, the reader may won-

der why the director would go through this routine to get the answer he did, since this situation would by no means require a linear programming approach, but that is the point about simplified problems: they help illustrate the general methodology and not the practical application.

Figure 3.5 then shows how the objective function line moves down and parallel until it reaches the corner point P, which gives the minimal solution to the problem. The minimal solution is at $X_1 = 3$ and $X_2 = 2$, and this gives a minimal weekly payroll of $176 to meet the instructional requirements at both centers.

Figure 3.5



2.3 *The Linear Algebra of the Simplex Solution*

The simplex algorithm, when applied in linear programming:

- Solves a set of simultaneous equations to yield a feasible solution. (Actually there may be, as the graph showed, many different feasible solutions, in the sense of different lines that lie within the feasible zone and satisfy the contraint equations.)
- Solves the set of equations so as to yield a point that is minimum or maximum in the feasible region. The objective function runs through that point, which was the corner point P.

Actually, for a simple set of two equations in two unknowns there is nothing new about the solution methodology. The inequalities

can be converted to equations and the equation set solved by one of the standard methods of solving simultaneous linear equations. The method of elimination is familiar from rudimentary algebra. In the example, we have selected the simple two-variable, two-equation case precisely because it is easy to solve and understand the method of solution. Few, if any, problems that planners meet will have this simplicity, a point that was made before. Most planning problems will have hundreds of variables and equations. The solutions cannot be graphed conveniently because, when we have to use more than two axes, it is difficult to depict and understand the analysis. Such equation sets are said to be solved in n-space, and that is hard to envisage. These large problems are solved by computers, using pre-written and documented programs or computer codes. The planner must first cast his problem into the right form, which means to describe the system using the type of equations (or inequations) which we have seen in the previous chapter and section. Most equations in a planning model are statements of goals, or constraints, in the system. We will study the form of these equations further later in this chapter. Once the system is described in equations of appropriate form, the only remaining problem is to select a computer code, prepare the submission for the computer according to the requirements of the computer code, and run the model to a solution. Large sets of equations are solved by matrix inversion. There is no way to watch a large model being solved in the computer, but the method that underlies most of thse solutions of sets of equations is familiar to most people who know some linear algebra. The method will be illustrated in the Appendix by going through a simple exercise using elimination to solve a set of linear simultaneous equations.

3.0 *The Planner at Work with Models*

In his work, the planner does not have to solve small sets of equations because most real problems don't come that way. Nor does he have to solve large sets of equations, because they can't be solved, in practical terms, using the long-hand methods illustrated. The large problems are solved by computers, using about the same essential methods, but applying the algorithm in a way that makes it impossible to follow the steps in the calculation with the human mind or eye. It is precisely because large problems cannot be followed as the computer solves them, that small and unrealistic problems are used to illustrate the algorithm. The previous section on the graphical method, and Appendix 3.1 on algebraic methods are useful for those who wish to understand what the computer does. The next sections explain what the planner does.

3.1 *Task One: Developing a Comprehensive Planning Model: Stating the Goals*

The first step in developing a comprehensive planning model is to state the planning goals as clearly and systematically as possible. In the Chilean case these were stated:

1. Costs (capital and current) of running the system over the plan period are to be minimized.
2. Economic goals are to be attained. Specifically:

- Manpower goals stated in the form of requirements for educated and trained workers are to be attained. These targets were forecast outside the model.
- The system is to be operated over time staying within budget limits. These are also forecast outside the model.

3. Educational technology (quality level) goals are to be attained. Certain standards of quality are to be maintained while staying within resource limits.

- Classroom facilities are to be used up to the limit of classroom space, using appropriate input norms of classroom space per student enrolled.
- Teachers are to be used up to the limits of the number of teachers already trained, plus the number who can be trained. The system will operate according to system input norms of teachers per student enrolled (teacher/pupil ratio). This means simply that if the teacher/pupil ratio is 1/30 and there are 3000 teachers in the system, the total enrollment is limited to 90,000 if that average is maintained.
- The total of resources available to the system will equal the unit cost of inputs multiplied by the numbers enrolled in the educational programs at various levels of the system. This means simply that if the per student cost is $300 (where the sign '$' stands for whatever monetary unit is used), and there are 90,000 students in the system, then the total current, or operating, cost will be $2.7 million.
- Flow through the system will be the maximum attainable, given the educational quality measured by inputs. To increase these flows will require an increase in inputs. In the Chilean model there was a variable y, which represented the additional amount of enrollment that could be accommodated in the system if there were additional resources available. To increase y required increasing the resources available and allocated to the system, and thereby increasing the costs of running the system.

4. Social goals are that most of the age group will be admitted to school and retained in school for a significant basic education. In the Chilean model the equations were set up so that the percentage of the age group admitted to school each year of the plan period had to be larger than the percentage of the previous year.

3.2 *Task Two: Stating the Goals Systematically in the Form of Systems Relationships or Equations*

Not all of these goal statements from the comprehensive model will be shown, but the equations which correspond to the major goals stated in Task One will be given as examples. The first will be the objective function statement. Note that these are only general statements, each of which may yield many detailed equations. This will be shown in an example in Task Three. (Note also that we have changed symbols from those used in Table 2.1 of the previous chapter. The choice of symbols is purely arbitrary.) The major equations are:

Objective function

Minimize: $C = \Sigma c_t$ (1)
Minimize: the sum of educational costs (Σc_t) over each year (t) of the plan,

where:

C = costs (capital and current) over the plan period;
Σ = sum over the plan period;
c_t = total costs each year of plan.

Constraint equations

(a) Economic goals
Manpower: $F_t Z_t + W_t \geq L_{t+1}$ (2)

where:

Z_t = the number of students enrolled in a given level and type of school in a given year;
F_t = the fraction flowing into the work force;
W_t = the number of workers trained on the job,
L_{t+1} = the manpower requirements for workers with this level and type of education.

(b) Economic goals
Budget/Constraint equation $c_t \leq \hat{c}_t$ (3)

c_t = the total costs in any one year, cannot exceed ($\leq$) the total of budget resources available which is symbolized by $\hat{c}_t$.

(c) Facilities (classroom space) constraint
$s_t Z_t \leq \hat{S}_t$, (4)

where:

s_t = the number of square meters of classroom space per student;
Z_t = the number of students enrolled in a given educational level in a given year of the plan period;
$\hat{S}_t$ = the total number of square meters of classroom space available in the level at the beginning of the period.

The constraint simple states that the school system cannot use more classroom space than is available. (Note that S_t is an input coefficient. These will be explained in (f) below.

(d) Teacher constraints

$$m_t Z_t \leq \hat{T}_t \qquad (5)$$

This is the same kind of equation as the previous one.

where:

m_t = teacher/student ratio, or input of teachers per student;

Z_t = the number of students enrolled in a given level in a given year;

$\hat{T}_t$ = the total number of trained teachers available.

The total number of teachers available in the system will limit the number of students (Z_t). The model solves for Z_t (enrollments) so as to minimize costs (1st goal) and stay within constraints of equations (4) and (5).

(e) Social goals

Demographic (constraint) $X_j \geq p'P$, where (6)

X_j, the number of children who enter school at a given level, must equal or exceed ($\geq$) a proportion p' of the population P in the age group that corresponds to that grade. P is the population in the age group, p' is the proportion of the age group to enter school. This proportion is fixed as a social goal.

(f) $a_t Z_t + r_t N_t + d_t T_t = c_t$ (7)

Total annual cost c_t equals capital and current costs.

where:

a_t = the average cost per student per year of education;

Z_t = the number of students enrolled in the level in a given year;

r_t = the cost per square meter of classroom space built for level and year;

N_t = number of square meters of classrooms built for level and year;

d_t = cost per teacher trained for level and year;

T_t = number of teachers trained for level and year;

c_t = total costs in any one year t.

Equation (7) shows that when unit costs are multiplied by the number of units, the total equals the annual cost of operating the system. This simply means that if the cost per student (a_t) is multiplied by the number of students enrolled (Z_t), the result is the cost of operating the system for a year. Equation (7) also shows the costs of some inputs necessary to maintain and expand the system over the plan years. In this case

only classroom space and teachers are shown in equation (7), although other inputs were specified when the model was applied in Chile.

Equation (7), like most other equations shown here, represents a set of many equations, because in the model a new equation must be written for each educational level and time period.

One important thing to note in understanding the model is that the unit cost and input equations are linked to the flows in the system. Enrollment flows cannot be increased without increasing unit costs to improve system performance and inputs:

$$a' Y_t = c_t - a_t Z_t, \text{ where} \quad (8)$$

a' = unit cost (per student) of increasing student flows in system;
Y_t = number of students who represent increased enrollment flows;
c_t = total annual costs for running system in year t;
a_t = normal unit cost (per student) per year of education;
Z_t = number of students enrolled in given level in a given year.

3.3 *Task Three: Writing the Equation Descriptions of the System*

The comprehensive model used equations and variables to describe the essential features of the Chilean Education System. Here we cannot spell out all these detailed equations, but in this section we will offer:

- a set of steps, or suggestions, on how to develop systems goals and equations for a planning model.
- detailed equations for one of the general equations, equation (4), described in the preceding section.

Most education system planning models will require statements of this general form:

(1) The economic goals of the system.

- That the education and training system will meet manpower requirement targets.
- That the education and training system will operate at minimal cost (capital and current).
- That the education and training system will operate within budget constraints, or limits. (Estimates of these limits will be derived from estimates of resources and revenues.)

(2) The social goals of the system will usually include statements:

- That entrance and enrollment targets for the basic level of education will cover all or most of the age group specified under law.
- That the proportion admitted will not decrease during the plan period.
- That certain social or ethnic groups will be admitted to the

system as a priority target; or that female children or rural children will be admitted in larger numbers. These kinds of goals were not incorporated into the Chilean model, but they could easily have been written into the social goal equations.

(3) The resource limits of the system are usually given in the form of constraint equations which state that the system will operate within limits of available resources and inputs. Constraints must be written on all major educational inputs:

- administrators, supervisors and teachers (of various types)
- physical facilities (classroom space, labs, shops, etc.)
- equipment
- instructional material
- other

(4) Enrollment flows in the system must be linked in two ways:

i) Enrollment flow through the educational levels must be linked externally to manpower requirements, and to the social requirements which are specified as goals.

ii) Flow through the system must also be linked *internally*. This means that enrollment flows must be linked to resource constraints through input coefficients. Note that this is the most important part of the entire model design. This is the dynamic heart of the systems planning models. The two links i) and ii) must then be linked to each other. The flow through the schools to participation in the workforce is linked to resource limits by means of technology or input coefficients and, in turn, linked to costs and resources. Flow is governed by the amount and quality of inputs. For example, promotion will be increased if more teachers, classrooms, and other educational inputs are available to the system. This is where the educational planner links teaching/learning to systems management and planning. This link between flow through the system and educational inputs is expressed in technological or input coefficients which state the relationship in very aggregate and average terms. In developing the model, these relationships would be investigated by research studies of inputs and effects of education. Models for studying input/output relationships and for analyzing educational effects were covered in the Appendix of Chapter 2.

Flow through the system is linked to inputs, which in turn are linked to costs. Costs are linked to resource and budget estimates. These links are shown in the goal of minimizing costs, staying within budget limits, and staying within resource constraints.

Once the system can be described in statements of goals and relationships, the statements can be written into systems of equations (or inequalities). Equations must cover:

- all the different educational programs and levels that are relevant for planning purposes;
- all the time periods (in units of one year) the term of the plan will cover.

The equations for the different levels and types of education and training can be linked across time periods. The results will be a model of the size and type described in Schiefelbein and Davis (1974).

Data are then gathered, analyzed, and put into the equations. The major kinds of data include:

- Manpower requirements targets, from manpower forecasts;
- Demographic targets from population forecasts;
- Budget and cost data;
- Education flow data, and workforce entry and participation rates;
- Educational technology data, i.e. input coefficients;
- Educational resources and inputs from inventories and construction and purchase plans.

4.0 *Detailed Equations for the Model*

In Table 2.1 of the previous chapter, the comprehensive model was described in the form of 15 general equations. In the preceding sections of this chapter, these general equations were described in greater detail, and the links between them were discussed. Before the general equations can be put into the computer-coded model, and the results run, two things must be done:

First, the general equations mut be rewritten in the form of many detailed equations which describe the system (various education levels and types of programs). Equations must also link the description of the system over the time period covered by the model. The comprehensive planning model, when it was applied in Chile, was run over an eleven-year plan period.

Secondly, the kind of data listed in the previous section must be put into the detailed equations. The data may be educational, economic, social, or demographic, but the data must do the following:

- Describe the initial conditions of the system, i.e. the way the system is at the start of the plan period;
- Guide the way the system will (or can) change over the plan period. Changes are controlled by two main factors, targets and rates. The targets specify where the system must be at the end of the plan period, and the rates control how the system will develop to reach the targets.

As an example of how detailed equations are written and data are incorporated, we will expand general equation (4) which dealt with the

limits of classroom space available.

The original equation statement was:

$$sZ_t \leq \hat{S}_{t'} \tag{4}$$

where:

sZ_t is the number of square meters of classroom space per student;

Z_t is the number of students enrolled in a given educational level in a given year of the plan period;

$\hat{S}_{t'}$ is the total number of square meters of classroom space available in the level at the beginning of the period. The equation states the obvious that the amount of classroom space used cannot exceed the amount available. But classroom space can be built.

As this constraint is written into the model, it is changed slightly to:

$$sZ_t - N_t = \hat{S}_{t'} \tag{4'}$$

or in the alternative form:

$$sZ_t = \hat{S}_{t'} + N, \tag{4''}$$

where N is the number of square meters of new classroom space built during the period.

The equation now states that the classroom space used during the period cannot exceed the amount that was available at the beginning of the period ($S_{t'}$) plus the amount build during the period (N_t).

When equation (4) or its variations are put into the programming model there must be a separate equation written for each level of the educational system and for each period of the plan. If the model is designed to distinguish three different levels of education and three different periods of time, the one general equation will appear as nine equations in the model. Note: All the equations in the previous section are general statements, and when they are written out for the model they are vastly expanded in number. In the case of the Chile model, the 15 general equations which describe the model were expanded into 196 detailed equations which were put into the model with data for computation. The reason for this is that special equations have to be written for each educational level and each time period over which the planning model is run (Schiefelbein and Davis 1974: pp. 86-115).

For the first period and the three levels the equations would be:

Period One ($i = 1$)

$2.5\ Z_{11} - N_{11} = 3{,}850$	primary school level space ($j = 1$)
$5.0\ Z_{12} - N_{12} = 2{,}020$	secondary school level space ($j = 2$)
$10.0\ Z_{13} - N_{13} = 500$	post-secondary level space ($j = 3$)

where:

2.5 is the number of standard m^2 of classroom space per student at primary level; Z_{11} = enrollment in period 1 and level 1;

5.0 is the number of m^2 of classroom space per student at secondary level;

10.0 is the number of standard m^2 of classroom space per student at post-secondary level;

N is the number of standard m^2 of new classroom space that must be built for the various levels during the period;

The number on the right-hand side of the equation is the amount (in thousands) m^2 of classroom space available at the beginning of the plan period.

Period Two ($i = 2$)

$2.5\ Z_{21} - N_{21} = 3{,}850$	period two, primary space ($j = 1$)
$5.0\ Z_{22} - N_{22} = 2{,}020$	period two, secondary space ($j = 2$)
$10.0\ Z_{23} - N_{23} = 500$	period two, post-secondary space ($j = 3$)

Period Three (i = 3)

$2.5\ Z_{31} - N_{31} = 3{,}850$	period three, primary space ($j = 1$)
$5.0\ Z_{32} - N_{32} = 2{,}020$	period three, secondary space ($j = 2$)
$10.0\ Z_{33} - N_{33} = 500$	period three, post-secondary space ($j = 3$)

Hence, nine equations are written for three levels and three periods. Note that the same values appear at the right of the equations for all three periods, since there will be the same amount of space available to start in the entire plan period. But note also that the same per student classroom space ratios are used throughout. Also, there is one average per student classroom space ratio for each level of school. These equations show the rigidity of the programming model. These ratios can be varied within each school level (for example, to show different space norms for primary schools in different regions of the country) and changed over the plan years, but this will increase the number of variables and equations in the model, which is already fairly large.

5.0 *Task Four: Preparing the Comprehensive Model for Computer Run*

When all equations for the system have been written and numerical values supplied, the model can be computer-coded according to one of the standard linear programming codes and run. Each one of these codes has a large amount of documentation which usually covers three major items:

- a general description of the problem situation in which the computer code is used, and a few general characteristics of the code;
- a user's manual which specifies how jobs are submitted to the computer to use this code or set of programs;
- program listing for main programs and sub-routines, if any. All of these things may be combined into one users manual, but the point is that there will be different characteristics (requirements and advantages and disadvantages) for each code, or program.

Most programs are machine-dependent, which means that one of the determinants of which code will be used is the computer available for running the program. A second determinant will be familiarity with the program, either on the part of the planner or on the part of a computer specialist who will be aiding him. (Some planners are specialists in computers, but usually these two specializations are different. Sometimes a planner requires no help because he has used one code several times and is familiar with it.) A third reason for a choice of a code is that some codes will do some things that others won't—e.g. handle larger programs, compute more efficiently or inexpensively, allow for more flexible options, or yield output in the form of more extensive or more readily interpretable reports.

We offer no detailed description of computer codes here, but simply list the main ones with which we have worked in planning problems similar to the Chilean comprehensive model. Selecting a code and preparing a model for running on a computer requires a substantial effort, and there is no easy set of steps which will allow the user to escape the work required to enter the system. The computer program used to run the Chile comprehensive model was the MFOR. This was the most useful code available at the time the model was last run some years ago, but it will not appear in the list of codes that are currently used. Even these so-called current codes may be dated. Among the current codes being used are:

Software	*Machine*
1. MPS (x) Mathematical Programming System Extension (This was just coming into use with the IBM 360 at the end of the time when the Chile model was being developed. MPS was used to some extent to re-run some parts of the model.)	IBM current models
2. GE Tempo	Burroughs
3. Ophelia	CDC Control Data Corporation
4. LP Linear Programming Package	PDP 10
5. Umpire ELONA	UNIVAC
6. SIMPLX (SIMPDX)	UNIVAC 1110

Most computer codes print out a staggering amount of information as a result of running a large model. In some cases this printed output is more than the nonspecialist can understand, or the working planner

can use. Many codes and programs print out special reports or highlights reports. In mathematical programming results, the planner is generally interested in three things.

First, the planner looks at the final index, or objective function result. In the Chilean example, this would be the minimal cost of running the system. In other models it might be the maximum number of graduates of given levels of schooling produced for the workforce; or the attainment, or nonattainment, of social goals expressed as a fraction of the school-age children enrolled. The quadratic model developed in Chile as an extension of the linear model attempted to minimize the discrepancy from an index of learning quality (Schiefelbein and Davis 1974).

Secondly, the planner is concerned with the so-called activity levels of the system. In the Chilean model these would be the enrollments (Z variable) that flow through the system, and the graduates of the system. It is always of interest to the planner to have the projected enrollments by grades and by years and the number joining the workforce. In the comprehensive and compound models, these results would be the maximum numbers of enrollments attainable, given the goals and constraints of the system. Hence, the projected enrollment reported as the result of a model run is of more value than a simple enrollment projection based on demographic projections and enrollment flow parameters.

Finally, the planner looks at the values that appear on the right-hand side of the program. The planner will notice any large changes in these values on the right-hand side of equations, and positive and negative values on the constraints or targets. These changes and negative values show the places where the system constraints are binding, indicating potential system bottlenecks. It also indicates places where the limits could be relaxed, and this would change the outcomes of the plan. The right-hand side values also can be interpreted in *shadow price* terms. We will not attempt to explore this concept of shadow price here except to say it is the resource cost that should prevail if resources were used optimally in the system. The shadow price results in the Chilean model were used to indicate where substantial cost savings could be realized by increasing system output and resource limits (Schiefelbein and Davis 1974: 84-85, 116-135).

References for Computer Programming Codes

There is a program given for the model run by C. Lee in the following reference: Lee, C. *A Goal Programming Model for Analyzing Educational Input Policy with Applications for Korea.* Doctoral Thesis, Florida State University, Talahassee, Florida, 1975. (Available through University Microfilms, Ann Arbor, Michigan.)

Two computer codes, each with descriptions of algorithms, data requirements, and a brief user's guide are offered as appendices in Ignizio, James P. *Goal Programming and Extensions*, Lexington,

Mass: Heath, 1976. The two codes are:

— "The Linear Goal Programming Code" (Limited to 10 variables, 10 priority levels and 20 objectives, but can be expanded in size with redimensioning).

— "The Modified Pattern Search Algorithm for Nonlinear Goal Programming" (Limited to 25 decision variables and 25 objectives, and can be expanded with redimensioning).

Appendix 3.1

In the text, we illustrated the simplex algorithm graphically. Here we will show the part of the algorithm which solves the equations to determine the feasible region for the solution. Equations (2) and (3), which bounded the feasible area in the graphical exercise in the text, can be solved in basic algebra by elimination.

In Table A3.1 we show two approaches to the solution of the equation set (equations 2 and 3) from the example. In the left-hand columns of Table A3.1 we have the familiar method learned in secondary-school algebra of substitution and elimination. We first multiply equation (2) by -5. Then equation (3) is multiplied by $+4$. We then add to eliminate variable X_1. We now have $-14X_2 = -28$. In the final step in our solution for X, we divide by -14, and the solution is $X_2 = 2$. We now do the same to solve for X_1. We multiply by $+4$ and -6, and add. The result is $-14X_1 = -42$. The solution is $X_1 = 3$.

The solution in the right-hand section of Table A3.1 is obtained by inverting the matrix A. The solution is done as it would be done as part of the simplex algorthm, or in standard methods for solving sets of simultaneous linear equations. The solution is obtained by inverting the matrix A of the coefficients of X_1 and X_2 in equations (2) and (3). The system of equations is symbolized as $A\ X = b$,

where: A is a matrix of coefficients of the variables in the equations.

In our set this matrix of coefficients would be: $\begin{bmatrix} 4 & 6 \\ 5 & 4 \end{bmatrix}$

X is a column vector of the variables X_1, X_2 $\begin{bmatrix} X_1 \\ X_2 \end{bmatrix}$

b is a column vector of the equation values $\begin{bmatrix} 24 \\ 23 \end{bmatrix}$

When we set up the problem for solution by inverting the matrix we add in one more factor, the identity matrix which is symbolized I. Here we actually write the expression $AIX = b$ in Table A3.1. The identity matrix I is a matrix with 1 in the main diagonal and 0 in all other entries. It is shown in this example as: $I = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$ Mathematically, to

multiply a matrix by identity matrix I simply gives back the original matrix. In this problem we use the identity matrix as a register device to show what happens to X_1 and X_2 as we invert the matrix. We begin the problem in the right-hand part of Table A3.1 in this way:

A		I		X	b
4	6	1	0	X_1	24
5	4	0	1	X_2	23

Inverting the matrix in the simple set of equations shown in Table A3.1 can be done exactly as in the steps of the elimination method shown in the left-hand column of Table A3.1. The result is the solution $X = A^{-1}b$.

In solving equations (2) and (3) in Table A3.1, we go from $X = AIB$ to $X = IA^{-1}b$. The final stage $IA^{-1}b$ is the solution of the set of equations in which the matrix A is inverted to the matrix A^{-1}. The matrix A must be square and nonsingular, i.e. have an inverse. An inverse matrix is one which, when multiplied by A, will give I, or the identity matrix. Hence we invert matrices of the coefficients of the equations so that we can solve the equations. This is indicated when we transform AIb into $IA^{-1}b$. The identity matrix I shows that the coefficient of each variable is 1, and b shows the value of the variable. When the coefficient of the variable is 1, i.e., the equation is solved for that variable. In the simple problem in Table A3.1 it is carried out just as in the elimination method shown in the left-hand side. We include the identity matrix I in order to show how the inverse is obtained.

The inverse of

$$\overset{A}{\begin{bmatrix} 4 & 6 \\ 5 & 4 \end{bmatrix}} \quad \text{is} \quad \overset{A^{-1}}{\begin{bmatrix} \frac{-4}{14} & \frac{+6}{14} \\ \frac{+5}{14} & \frac{-4}{14} \end{bmatrix}}$$

because if we multiply A by A^{-1} we will get I, the identity matrix $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$ again.

The identity matrix symbolizes the solution of the equation set. When the coefficient of each variable is 1, the equation is solved.

Table A3.1

Solution of Problem Equations by Elimination and Inverting the Matrix

$AX = b$

$AIX = b$

		A		I		X	b
$4X_1 + 6X_2 = 24$	(2)	4	6	1	0	X_1	24
$5X_1 + 4X_2 = 23$	(3)	5	4	0	1	X_2	23
Multiply Equation (2) by -5	$-20X_1 - 30X_2 = -120$	-20	-30	-5	0		-120
Multiply Equation (3) by +4	$20X_1 + 16X_2 = 92$	20	16	0	4		92
Add Equations	$0 - 14X_2 = -28$	0	-14	-5	4		-28
Divide by -14	$X_2 = 2$	0	1	$+\frac{5}{14}$	$-\frac{4}{14}$		2
				$X_2 = 2$			
Multiply Equation (2) by +4	$16X_1 + 24X_2 = 96$	16	24	4	0		96
Multiply Equation (3) by -6	$-30X_1 - 24X_2 = -138$	-30	-24	0	6		-138
Add Equations	$-14X_1 = -42$	-14	0	+4	-6		-42
Divide by -14	$X_1 = 3$	1	0	$-\frac{4}{14}$	$+\frac{6}{14}$		3
				$X_1 = 3$			

I		A^{-1}		b
1	0	$-\frac{4}{14}$	$\frac{6}{14}$	2
0	1	$+\frac{5}{14}$	$-\frac{4}{15}$	3

Part Two: *Setting Targets – Projection Methodologies*

Foreword

Part Two offers three chapters designed as instructional units on population projection, enrollment projection and enrollment statistics, and a fourth chapter on trend analysis and curve-fitting. The first unit on demographic analysis and population projection could fill a complete textbook. Hence, the introductory materials of the unit are supported by bibliographies and reference lists for further reading, technical appendices for follow-up, and documentation on computer-coded models designed to run the projections previously discussed in the instructional units.

Educational planners must chart the near-term future. Forecasts of this near future are most commonly based on projection methods. Population projections are the basis of all forms of social planning. Population projection methods are covered in the instructional unit of Chapter 4, and because these projections are based on the components of fertility, mortality, and migration, the unit introduces topics in systematic demography. A broad field cannot be covered in one unit. Chapter 4 also provides guidance for further reading.

The unit in Chapter 5 deals with enrollment projection methods. The basic model is discussed, and there is a further description of the computer-coded models which are used for enrollment projections. The use of enrollment projections in educational policy analysis and planning is also briefly illustrated, although these policy issues were more thoroughly covered in the thematic material of Volume I.

Chapter 6 opens with a discussion of the difficulties encountered in using educational statistics to compute flow rates in enrollment projection models. The main part of the chapter offers instruction on the computation of enrollment flow rates, using methods which attempt to get around the problems of missing or inadequate educational statistics.

Chapter 7 deals with curve-fitting as it is applied to trend analysis for extrapolation and projection. Curve-fitting can be applied in population and enrollment projections, the two projection methods dealt with in Part Two. Curve-fitting is also used in manpower analysis and projection, which will be dealt with in Part Three.

CHAPTER 4

An Instructional Unit on Population Projection Methods

1.0.1 *Objectives of this unit*

The objectives of this unit are:

— To establish the importance of *population censuses* and *population projections* by providing background information on their purposes and usefulness. Main emphasis will be placed on *population projections.*

— To provide instruction on the methods of population projection. A brief section will be offered on quick methods of projecting total population, but the centerpiece of the methodology is cohort survival projection based on analysis of the demographic components of fertility (births), mortality, (deaths) and migration. These three components account for population change. The three terms will be defined and illustrated.

— To provide some additional information on the demographic analysis which supports population projection methods. The objective is to introduce the topic, provide a brief background, and then guide the learner to additional reading.

— To limit instruction on projection methodology and demographic analysis to those aspects of the topic which are of prime interest to social planners, and specifically educational planners.

These objectives describe all that this unit purports to cover. In the broad field of demography and census methods many relevant topics in the foundations of demographic analysis will only be briefly introduced in this unit. Census methods and the appraisal of censal data are only briefly mentioned. A special reference bibliography at the end of the unit suggests extensive additional study of materials developed by the two prime sources, the United Nations and the United States Bureau of the Census. These references deal with such topics as the assessment of accuracy and the improvement

of precision in census data, specialized topics such as smoothing operations and adjustments to age and sex structures in population, and specialized methods for incomplete data. These are not topics of general interest to planners and nonspecialists in demography, but in any given situation the planner may have to be familiar with specialized techniques. Since no single book covers the field, many different references must be consulted as the need arises. An experienced planner would suggest that many of these manuals should be ordered as part of the professional tool-kit of a social planner.

Improved demographic analysis depends on the yield of research in economics, sociology, demography, and social psychology. Clearly, these fields are not covered here. Volume III in this series deals with survey and research methods for social planning. Demographic analysis may also be based on analysis of registry data and vital statistics. These topics are only introduced, and further reading is suggested.

1.0.2 *The content covered in this unit*

This unit begins with a brief note on the widespread use of population censuses and population projections in the nations of the world. The point is then made that because planners deal with the future, population projections are a central concern of social and educational planners. A population projection is defined as an estimate of a future population which is based on a current population estimate and a consistent set of assumptions about how it will change. A *projection* is distinguished from a *forecast*, and from a *prediction*, and later from a simple extrapolation based on past trends. The use of population projections in educational planning is dicussed, and the basic formula for a population forecast is presented. The components are briefly described as part of the projection methodology. Later, each component will be dealt with in some detail as a demographic problem. The cohort survival methodology is then painstakingly illustrated using demographic data of a developing country. This format for projection is important for it will underlie the enrollment projection in Chapter 5. Life tables for specific countries and model life tables are used extensively in population projections, and the design of life tables is discussed.

1.0.3 *Learning outcomes from this unit*

This unit is designed to provide instructional background to a workshop in which a computer-based projection of a population is carried out. It is expected that:

— Learners will be able to discuss the selection of fertility and mortality assumptions, and use these assumptions to project a national population. Learners will apply a standard computer program which only requires that they select certain demographic options at the keyboard.

— Learners will understand how to get information on which to base mortality, fertility, migration, and population estimates in developing countries. By using this information, they will know the mechanics of carrying out a cohort-survival projection based on demographic components.

1.0.4 *Basic definitions of the methodology*

In a cohort-survival projection based on demographic components, a cohort is a population group defined by date-of-birth, or age (7-year-old girls, or males born in 1980). The demographic components include fertility, mortality, and migration. We will come back often to these concepts.

1.1 *Population Censuses and Projections in World-Wide Use*

Most countries of the world have conducted a census to estimate their current population, and most have run population projections to derive estimates, or forecasts, of the population for future years. A world map prepared by the International Statistical Programs Center of the U.S. Bureau of Census (1975) indicates that in 1975, only 19 countries in the world had never conducted a census, and of these countries, 13 had scheduled a census for the following year, leaving only 6 countries without a census or without plans to conduct one. Our tally of country population projections is not so exact or complete, because in many countries, even in those lacking a basic census, some crude or partial attempt has been made to estimate present and future populations. It is difficult to judge how adequate the estimate must be before it can be called a systematic projection. Based on our own standards, more than half of the countries of the world have had systematic projections run. The popularity of censuses and projections is no sure grounds for establishing the importance and necessity of the activity, but it does indicate that a majority of world nations have judged the activity necessary enough to support such work at a high relative cost in effort and money; and nations do use the results as a basis for planning and development.

1.2 *The Purpose and Use of Population Projections for Planning*

Here we are concerned with the use of population projections in planning. Population censuses have a usefulness that extends beyond planning, but population projections, because they attempt to trace the future course of a major force influencing national development, are primarily addressed to prevision and planning. Of all the major influences that will shape a national future and therefore be of concern to planners, population is central and basic. Hence, the size of the population, the dynamics of population change, the age and sex structure of the population, and the distribution and density of population are

basic planning data. The status of the population, as revealed in a census, and the future changes in the population, as portrayed in a projection, provide the underpinning of any national plan. The population numbers also provide the base for critical ratios that serve as planning indicators: population-to-land ratios to indicate density; per-capita product and income; workforce participation rates; and literacy and educational attainment levels. Population numbers provide the base for indicators of economic, social, cultural, and political status; for assessment of national status, for comparisons of regions within countries, and for intercountry comparisons; for evaluating past-to-present changes and progress, or lack of it; for analyzing and monitoring current developments; and for forecasting and planning for the future.

At the base of economic, social, cultural, and political forecasts are demographic, or population, projections, and for this reason, planners generally must understand the basis of population projections. Population growth not only provides the central trend and dynamic to other changes, it has also received the most attention, application, and theoretical and methodological development. There are other applications of population forecasting that serve educational planning needs, and we shall be examining these in greater detail.

1.3 *Projections, Forecasts, and Predictions: Definitions*

In discussing population projections as a part of the methodology of dealing with the future, it is useful to distinguish between population *projections*, population *forecasts*, and population *predictions*. The three terms are often used interchangeably, but there is a difference. Projections usually offer a set of alternate population estimates based on different sets of assumptions, rather than a single estimate. The U.S. Bureau of the Census, in its current population report, Number 704 of Series P-25, "Projections of the Population of the United States: 1977 to 2050" (July 1977), explains the reason for the distinction:

> Population projections are 'Correct' by definition (except for computation errors) because they indicate the population that would result if the base date population is correct and if the underlying assumptions (guiding the projections) should turn out to be correct... If future population could be determined with negligible error, then only one projection would be necessary.

This single projection would then be a *prediction*. But errors are not negligible, nor can the range of error be statistically determined, because underlying factors influencing the population trends are imperfectly understood. Hence projections are offered in a set. Projections accompanied by an indication of accuracy are *forecasts*.

To summarize; a set of alternative estimates that rest on alternate assumptions about how a current population will change is a *projection*. If a projection is accompanied by an indication of accuracy, it is a *forecast*. If a single projection series is offered as *the* forecast, it is a

prediction. The Census Bureau labels its work as projections rather than forecasts or predictions to emphasize the difficulty of projecting populations accurately. The quality of a population forecast depends on the accuracy and precision of the base-year population estimate and on the validity and consistency of the assumptions. There is no short set of criteria for judging the accuracy of the base-year population estimate because the population estimate is the standard against which most other social data are judged. The references (U.S. Bureau of Census and UN) deal with methods for assessing accuracy. The same criteria are used for judging the validity of the projection assumptions. These are:

- Internal consistency in the data, especially as revealed in the sex and age structures of the population. Demographers have adjustment techniques which are described in the reference manuals, and will not be dealt with in detail here.
- External checks against total populations and age and sex structures in other countries, or against regional models. There is regularity in large numbers and averages, and this holds true to some extent for populations.
- Checks against history and past trends within the country. Birth and death rates do not usually shoot up or down rapidly. Discontinuities must be explained.
- Checks against known external events (wars, famines, migration waves) or against other economic, social and cultural data.

Even the most rigorous methods of forecasting has limitations, and population projection is no exception to that rule. The accuracy of the results in component-based, cohort-survival methods depends on the soundness of the underlying demographic analysis, which in turn depends on social research. Nevertheless, population projections have demonstrated their value for planners. Their application is widespread, as indicated, and they are often used in plans. For shorter forecasting periods the results have been validated fairly well with time. In educational planning we are concerned with a few general and important applications of population projection.

1.4 *Specific Applications of Population Projection in Educational Planning*

Population projections directly serve educational planning:

— In providing forecasts of school-age children: These forecasts can be used to assess the extent of coverage of educational programs for varying age groups, including adults. Projections provide the basis of future forecasts of demographic or social demand on the resources of the education system. Stated more simply, this means that the projections indicate how many children the schools must educate if universal education, or some reduced portion of coverage, is planned.

— Derived from the same projections, the forecasts indicate the number of children who will be coming into the entrance age for school, and presumably entering the first grade of the system. Here the projection provides the entering enrollments for an enrollment flow, or forecasting, model. These projections are sometimes called supply projections.

— From the basic projections the planner can derive, using educational norms and service ratios, the amount and type of school facilities required, the numbers of teachers and supporting staff required, and, on the basis of these, estimates of expenditures and resources required.

— Population projections also serve as the basis for manpower planning from which the so-called *economic demand for education* is derived. The population estimates along with workforce participation rates can be used to check estimates of workforce and employment growth. The population projections also may underlie large econometric models that are used to forecast economic growth, and from economic growth the corresponding growth in employment.

A projection of the total population lies at the base of most general planning which guides educational planning. In some cases the population is projected first and the workforce derived from it by assumed or projected participation rates; or the product or income may be derived from the population, with certain assumptions about per head contribution. In the basic method of manpower requirements forecasting (Part Three), the workforce is reduced by applying death and retirement rates and subtracting the numbers who will die or retire. The economically active population is determined by population size and rates of participation in the workforce. Planners need not be expert demographers, but familiarity with survey and census operations and demographic analysis underlying projections will enable the planner to work with censal and vital data and understand—as in the case of any national statistics—the strong and weak points in the estimates.

2.0 *Background to Population Projection: The Demographic Components*

The basic schema for a population projection is a simple one:

$$\text{Base Year Population} + \text{Births} - \text{Deaths} \pm \text{Migration} = \text{Projected Population} \quad (1)$$

The accuracy of a population projection then depends on (a) the accuracy of the base-year population estimate, based usually on a current census or the census carried forward to current date (the base year of the projection); (b) the estimates of births for future years, usually based on rates of *fertility*; (c) the estimates of deaths or survivors, based on rates of *mortality*; and (d) the net effect of *migration*. In most standard methods of population projection, *fertility*, *mortality* and *migration* are called the *components* of the projection.

We have previously stated that only general criteria can be used to guide an assessment of the accuracy of the base-year population estimate or the assumed changes in the components. There are no true statistical tests for component estimates. The changes are assumed. The base-year population can be adjusted and census results checked for inaccuracies, but again there is little statistical basis for independent validation. Planners may have to accept and use the population projections available without examination of the demographic analysis that underlies the components and the assumptions guiding their projection; but it is helpful to understand the basic methods of projection and some of the underlying demographic analyses on which they are based. There are also occasions when planners themselves may have to do projections, or check and modify the work of others.

In addition to the standard components methods there are quick methods for obtaining general estimates of the total population. These are mainly *extrapolation* methods based on analysis of past trends.

2.1 *Population Size and Growth and Quick Methods of Projection*

Planners may only be interested in the present and future size of the total population and not its detailed characteristics. They may be interested only in gross changes in the population as reflected in the natural rate of increase based on the excess of births over deaths. Size and growth can be dealt with in quick projection routines that are based on trend analysis, curve-fitting, and extrapolation. (See Chapter 7 on curve-fitting methods.)

2.2 *Short and Quick Methods: Extrapolations*

A short and quick projection of the population can be made by extrapolation based on arithmetical or geometric rates of increase that are either assumed or based on analysis of past growth trends. In the arithmetical case, if the total population increased by 100,000 over a 10-year period in the past, an average annual increase of 10,000 is projected. If the population base were 1,000,000, in 20 years the new total will be 1,200,000.

$$p_n = p_x + ct, \tag{2}$$

where p_n equals the projected population, p_x equals the base year population, t equals the number of years, and c equals the annual growth constant of 10,000.

$$1{,}200{,}000 = 1{,}000{,}000 + (10{,}000)(20)$$

The standard compound interest formula is also used for determining the population increase as in equation (3):

$$p_n = p_0 (1 + r)^t \tag{3}$$

Here, p_0 is the population at the beginning of the period, t is the time in years which the forecast or updating covers, r is the annual rate of natural increase, and p_n is the total population projected.

If the base-year population were 12 million, and the natural rate of increase, estimated on the basis of past growth, were 4 percent annually, then a 10 year projection would give:

$$p_n = p_0 (1 + r)^t$$
$$p_n = 12 (1.04)^{10} = 17.8 \text{ million}$$

The rate of natural increase could be calculated on the basis of two past censuses, p_1 and p_2, with equation (4).

$$(1 + r) = \sqrt[t]{\frac{p_2}{p_1}} \qquad (4)$$

If the current population were 12 million, as in the previous example, and the population in the census 10 years previously were 8.1 million, then equation (4) would have yielded a cumulative annual increase of 4 percent that was used in the previous example:

$$(1.04) = \sqrt[10]{\frac{12 \text{ m}}{8.1 \text{ m}}}$$

Analysts do not have to do the arithmetic to calculate the results with equations (3) or (4). These can be looked up in compound interest tables, as for example, the Stanford Research Institute tables listed in the reference bibliography.

Other curve forms may be fitted to data points to provide a basis for the projection. The quadratic curve form and the modified exponential are shown in Appendix 4.1. The general topic of curve-fitting, which is an important technique in demography as well as in economic forecasting, is dealt with in Chapter 7. Curve-fitting provides the growth form and the growth rate.

Projections can be made almost as rapidly, and more accurately, by analysis of the three components which influence future populations, mortality, fertility, and migration. Analysis of mortality yields survival rates. Survival rates are multiplied by the population in each age group to carry it forward to the next age group in the next time period (of one year or five years). Life tables for the individual country, or model tables which serve for groups of countries, provide the survival rates for each age group. A life table shows the mortality conditions of a population—that is, the proportion surviving from one age group to the next, for age groups from 0 to whatever upper age-limit is chosen, e.g., 65+, 85+ . . . The make up of a life table will be examined in later sections.

3.0 *Component-based Methods of Population Projection*

Component methods of population projection permit the analyst and

planner to deal with important structural features of the population that may be as significant as the size and natural growth of the population. For the educational planner dealing with the school-age population and the number or proportion of children reaching normal entrance age for school, a projection that portrays the age structure of the population is essential. This also applies to economic projections of the workforce (economically active population), because participation rates and death and retirement rates differ by age and sex. Components-based projections are only slightly more demanding of time and effort than the cruder methods for projecting total population, and in most developing countries the basic demographic data for components projection are either available for the country, or there are fertility or mortality data in the country which permit the analyst to relate the specific country to a set of model tables based on world demographic conditions.

Component-based projections in developing countries are essentially similar to the projections carried out by the U.S. Bureau of Census. The U. S. Census methods are slightly more elaborate, however, because the data are usually more ample and accurate, and the analysis somewhat more sophisticated. Here we will use a developing country situation to illustrate the components method, and discuss the elaborations of the U.S. Census Bureau projections afterward.

3.1 *Components Based Projection: A Developing Country Example*

Recall the basic formula for a population estimate shown in equation (1):

$$\text{Base Year Population} + \text{Births} - \text{Deaths} \pm \text{Migration} = \text{Projected Population}$$

The planner, before starting a national projection, will first check the existing and available data. If there is an existing projection, he will evaluate its adequacy, using the four general criteria in section 1.3. If there is no projection, he will then assess the availability of information for doing a projection. Minimal information required for a components-based projection would include:

- reasonably current census data, with population classified by sex and age;
- life tables for male, female, and total population, or mortality data so that abridged tables can be constructed, or model life tables used;
- fertility data which can be used to estimate age-specific fertility rates and hence project future-year births;
- migration data.

Migration is often insignificant in projections of the populations of national areas. In developing countries, migration data may be poor,

but the net numbers are usually insignificant. In the United States a constant migration (recently 400,000 a year) is added into the projection.

When the populations of subareas of the country must be projected, internal migration rates may be highly significant, and projections are quite difficult to bring off with accuracy in smaller regions and provinces. In general, assumptions are made that death and fertility ratios of the subarea population to the total population will prevail into the projectd period. Migration may be estimated as a residual between two past censuses, after population changes from births and deaths have been taken into account. National population projections will be discussed here. Appendix 4.2 outlines the methods for area projections.

3.2.0 *A national projection, using model life tables*

The model life table in exhibit 4.1 shows sets of survival ratios for 24 levels, which go from high mortality (low survival) to low mortality (high survival). All countries fall along this high-to-low mortality continuum, which means a country's mortality will approximately fit one of the 24 levels of the model table. Hence the table can be used for projections.

The survival ratios (p) start at birth and run to age-group 80+. For each of the 24 mortality levels in the table there is a complete and distinctive set of age-specific survival ratios (p) provided for all ages. At level 0, life expectancy at birth ($^0e_0$) is 20 years, and at level 115 of the table, the life expectancy at birth is 73.9 years. Coale and Demeny's work, *Regional Model Life Tables and Stable Populations* (Princeton University Press, 1966) provides more recent and general area life tables for use in developing countries. Coale and Demeny offer four sets of tables (North, South, East, and West) and instruction on how to select the set of tables that fits the mortality conditions of the specific country. To use a table the analyst must select the appropriate level or survival column.

To enter the table at the appropriate level, a demographer must have an estimate of the mortality conditions in the country for which he wishes to make the projection. Once he has this, the projection is reasonably automatic, assuming that fertility rates and base-year pouplation are available. *Estimating the mortality and fertility components is not an easy or automatic process*, but discussion of the methods will be deferred in order to run briefly through the projection method in its basic form.

3.2.1 *The base-year data and the components*

A projection requires a base-year population classified into age and sex groups, a basis for the mortality component of the projection, a basis for the fertility component of the projection, and a basis for the

migration component. Usually these components are treated separately, analyzed separately, and sometimes projected separately, and then combined to yield the projection sets, but in Table 4.1 we have combined the components in order to present the basis of the methodology in one place.

Table 4.1

Basic Data and Components

Base Year Population (1975)

Age-Group	Male	Female
0-4	475,291	459,374
5-9	402,120	392,669
10-14	314,449	340,742
15-19	302,190	315,684
⋮	⋮	⋮
85-89	2,382	4,030
90+	1,093	1,718

External Migration

none

Mortality Component

Having studied the vital data and constructed an abridged life table, we conclude that our survival ratios will move according to the U.N. Model Life Tables:

1975-80	1980-85	1985-90
Level 80	Level 85	Level 90
($^0e_0$ = 60.4)		

Fertility Component

The rates of Hypothesis II (a), are used

Birth Ratio for Sexes

Male = .5089 Female = .4911

The base-year data in this case are the population, male and female, by five-year age groups for the year 1975. The term of the projection is 15 years. The population will be projected to 1990 in five-year steps, 1975-80, 1980-85, and 1985-1990.

Basic projections are generally run in five-year steps. This convention will be followed in this example: from 1975 to 1980; from 1980 to 1985; and from 1985 to 1990. The base-year population is grouped into age cohorts of five years—for example, the ages 0-4, 5-9, 10-14. . . The mortality rates (survival rates) are also in five-year age groupings. Hence multiplying the five-year age group population by the five-year survival rate moves the population in a five-year age group ahead for five years. This is demonstrated in Table 4.3. Note that the population in the 5-9-year-old group is moved into the 10-14 age group between the years 1980 and 1985. If the planner wants the population in single years instead of five-year age groups, the five-year age group can be broken down into single-year ages by using Sprague Multipliers. This will be demonstrated after we have run through the main steps of the basic projection.

3.2.2 *The mortality component*

The mortality component here is based on a study of the vital data, starting with crude death rates and constructing an abridged life table

Exhibit 4.1

Table V.

Survival Ratios (P_3) of Model Life Tables
*Mortality level (or time-reference in years)**

Sex and age (x) in years	Level 0 (e_0 = 20)	Level 5 (e_0 = 22.5)	Level 10 (e_0 = 25)	Level 15 (e_0 = 27.5)	Level 20 (e_0 = 30)	Level 25 (e_0 = 32.5)	Level 30 (e_0 = 35)	Level 35 (e_0 = 37.5)	Level 40 (e_0 = 40)	Level 45 (e_0 = 42.5)	Level 50 (e_0 = 45)	Level 55 (e_0 = [illegible])
Males												
(Births)	(0.6092)	(0.6328)	(0.6622)	(0.6851)	(0.7058)	(0.7248)	([illegible])	([illegible])	([illegible])	(0.7950)	(0.8107)	(0.8256)
0-4	0.7666	0.7951	0.8200	0.8405	0.8577	0.8711	0.8868	0.8995	0.9098	0.9198	0.9287	0.9369
5-9	0.9267	0.9151	0.9436	0.9501	0.9556	0.9605	0.9651	0.9691	0.9725	0.9757	0.9785	0.9811
10-14	0.9181	0.9144	0.9498	0.9547	0.9590	0.9629	0.9666	0.9700	0.9729	0.9758	0.9783	0.9806
15-19	0.9234	0.9291	0.9346	0.9399	0.9444	0.9487	0.9532	0.9574	0.9612	0.9649	0.9681	0.9712
20-24	0.9073	0.9141	0.9232	0.9271	0.9326	0.9379	0.9434	0.9484	0.9530	0.9571	0.9615	0.9651
25-29	0.8906	0.8979	0.9058	0.9171	0.9245	0.9311	0.9381	0.9440	0.9494	0.9545	0.9592	0.9634
30-34	0.8575	0.8805	0.8925	0.9036	0.9130	0.9218	0.9301	0.9373	0.9437	0.9496	0.9551	0.9599
35-39	0.8457	0.8541	0.8692	0.8836	0.8957	0.9068	0.9170	0.9258	0.9336	0.9404	0.9473	0.9529
40-44	0.7976	0.8199	0.8397	0.8572	0.8722	0.8857	0.8980	0.9085	0.9180	0.9267	0.9342	0.9408
45-49	0.7603	0.7850	0.8072	0.8271	0.8440	0.8594	0.8734	0.8854	0.8963	0.9067	0.9150	0.9226
50-54	0.7219	0.7469	0.7698	0.7907	0.8086	0.8251	0.8406	0.8512	0.8664	0.8776	0.8877	0.8965
55-59	0.6776	0.7017	0.7255	0.7443	0.7626	0.7798	0.7968	0.8111	0.8249	0.8375	0.8484	0.8587
60-64	0.6221	0.6429	0.6631	0.6811	0.7011	0.7182	0.7355	0.7514	0.7650	0.7778	0.7924	0.8037
65-69	0.5395	0.5582	0.5772	0.5961	0.6139	0.6312	0.6492	0.6640	0.6820	0.6972	0.7116	0.7246
70-74	0.4301	0.4478	0.4660	0.4847	0.5023	0.5202	0.5356	0.5561	0.5742	0.5896	0.6054	0.6199
75-79	0.3054	0.3207	0.3381	0.3553	0.3724	0.3900	0.4084	0.4258	0.4430	0.4595	0.4757	0.4896
(80+)	(0.1095)	(0.1260)	(0.1443)	(0.1672)	(0.1850)	(0.2023)	(0.2195)	(0.2355)	(0.2502)	(0.2646)	([illegible])	([illegible])
Females												
(Births)	(0.6290)	(0.6558)	(0.6801)	(0.7024)	(0.7242)	(0.7447)	(0.7627)	(0.7802)	(0.7969)	([illegible])	([illegible])	(0.8443)
0-4	0.7637	0.7912	0.8179	0.8387	0.8570	0.8732	0.8873	0.8996	0.9105	0.9209	0.9100	0.9184
5-9	0.9232	0.9309	0.9392	0.9462	0.9524	0.9579	0.9627	0.9670	0.9707	0.9742	0.9773	0.9801
10-14	0.9301	0.9370	0.9432	0.9487	0.9539	0.9586	0.9624	0.9666	0.9701	0.9734	0.9764	0.9792
15-19	0.9146	0.9209	0.9271	0.9330	0.9390	0.9446	0.9495	0.9541	0.9587	0.9631	0.9671	0.9709
20-24	0.8965	0.9041	0.9115	0.9186	0.9259	0.9327	0.9387	0.9442	0.9500	0.9555	0.9606	0.9651
25-29	0.8779	0.8884	0.8981	0.9076	0.9165	0.9249	0.9322	0.9388	0.9456	0.9520	0.9577	0.9628
30-34	0.8581	0.8720	0.8849	0.8967	0.9077	0.9178	0.9265	0.9342	0.9419	0.9490	0.9550	0.9604
35-39	0.8390	0.8563	0.8717	0.8861	0.8989	0.9106	0.9204	0.9289	0.9372	0.9448	0.9513	0.9570
40-44	0.8203	0.8400	0.8576	0.8734	0.8875	0.9003	0.9110	0.9202	0.9290	0.9369	0.9439	0.9500
45-49	0.7965	0.8175	0.8364	0.8533	0.8686	0.8825	0.8942	0.9043	0.9140	0.9229	0.9304	0.9373
50-54	[illegible]	0.7872	0.8064	0.8241	0.8407	0.8560	0.8685	0.8800	0.8910	0.9012	0.9098	0.9178
55-59	[illegible]	0.7417	0.7626	0.7805	0.7981	0.8145	0.8285	0.8411	0.8534	0.8655	0.8761	0.8859
60-64	[illegible]	0.6411	0.6993	0.7171	0.7355	0.7530	0.7682	0.7822	0.7967	0.8104	0.8230	0.8348
65-69	[illegible]	0.5752	0.6125	0.6300	0.6487	0.6668	0.6830	0.6983	0.7145	0.7299	0.7443	0.7578
70-74	0.4636	0.4799	0.4970	0.5143	0.5330	0.5519	0.5689	0.5853	0.6029	0.6197	0.6358	0.6311
75-79	0.3275	0.3431	0.3600	0.3772	0.3959	0.4156	0.4331	0.4500	0.4687	0.4867	0.5040	0.5206
(80+)	(0.1320)	(0.1508)	(0.1694)	(0.1878)	(0.2066)	(0.2251)	(0.2409)	(0.2556)	(0.2708)	(0.2850)	(0.2979)	(0.3099)

Sex and age (x) in years	Level 60 (e_0 = [illegible])	Level 65 (e_0 = 52.5)	Level 70 (e_0 = 55)	Level 75 (e_0 = 57.5)	Level 80 (e_0 = [illegible])	Level 85 (e_0 = [illegible])	Level 90 (e_0 = [illegible])	Level 95 (e_0 = 68.2)	Level 100 (e_0 = 70.2)	Level 105 (e_0 = 71.7)	Level 110 (e_0 = 73.0)	Level 115 (e_0 = [illegible])	Sex and age (x) in years
Males													**Males**
(Births)	(0.8406)	(0.8557)	(0.8703)	([illegible])	([illegible])	([illegible])	(0.9338)	(0.9560)	(0.9678)	(0.9744)	(0.9788)	([illegible])	(Births)
0-4	0.9443	0.9518	0.9554	0.9614	[illegible]	0.9763	0.9818	0.9867	0.9904	0.9936	0.9954	0.9956	0-4
5-9	0.9834	0.9856	[illegible]	[illegible]	[illegible]	[illegible]	0.9937	0.9949	0.9953	0.9974	0.9982	0.9986	5-9
10-14	0.9827	0.9848	0.9867	[illegible]	[illegible]	0.9914	0.9928	0.9941	0.9955	0.9964	0.9977	0.9982	10-14
15-19	0.9741	0.9772	0.9794	0.9826	0.9848	0.9871	0.9893	0.9913	0.9935	0.9953	0.9965	0.9974	15-19
20-24	0.9694	0.9725	0.9759	0.9799	0.9819	0.9847	0.9873	0.9898	0.9924	0.9944	0.9957	0.9966	20-24
25-29	0.9673	0.9712	0.9745	0.9771	0.9811	0.9840	0.9866	0.9892	0.9916	0.9935	0.9948	0.9956	25-29
30-34	0.9644	0.9686	0.9725	0.9766	0.9792	0.9822	0.9849	0.9874	0.9897	0.9917	0.9930	0.9937	30-34
35-39	0.9559	0.9619	0.9671	0.9712	0.9746	0.9779	0.9805	0.9835	0.9866	0.9891	0.9897	0.9907	35-39
40-44	0.9467	0.9523	0.9575	0.9614	0.9655	0.9696	0.9728	0.9759	0.9781	0.9812	0.9835	0.9851	40-44
45-49	0.9293	0.9359	0.9419	0.9469	0.9516	0.9558	0.9596	[illegible]	0.9661	0.9696	0.9727	0.9754	45-49
50-54	0.9035	0.9121	0.9189	0.9250	0.9306	0.9356	0.9400	0.9431	0.9481	0.9521	0.9558	[illegible]	50-54
55-59	0.8678	0.8767	0.8847	0.8919	0.8985	0.9044	0.9098	0.9148	0.9198	0.9249	0.9296	[illegible]	55-59
60-64	0.8161	0.8244	0.8335	0.8421	0.8502	0.8573	0.8619	0.8702	0.8765	0.8830	[illegible]	[illegible]	60-64
65-69	0.7367	0.7487	0.7594	0.7693	0.7796	0.7881	0.7965	0.8042	0.8119	0.8197	0.8269	0.8335	65-69
70-74	0.6334	0.6469	0.6594	0.6708	0.6816	0.6917	0.7012	0.7102	0.7192	0.7283	0.7372	0.7454	70-74
75-79	0.5049	0.5193	0.5325	0.5449	0.5564	0.5675	0.5779	0.5878	0.5976	0.6072	0.6176	0.6250	75-79
(80+)	([illegible])	(0.3091)	(0.3185)	(0.3272)	([illegible])	(0.3426)	(0.3493)	(0.3556)	(0.3611)	(0.3668)	(0.3723)	(0.3775)	(80+)
Females													**Females**
(Births)	(0.8594)	(0.8719)	(0.8882)	(0.9016)	(0.9204)	(0.9380)	(0.9552)	(0.9660)	(0.9744)	(0.9501)	(0.9818)	(0.9864)	(Births)
0-4	0.9463	0.9537	0.9607	0.9669	0.9731	0.9791	0.9844	0.9892	0.9923	[illegible]	0.9963	0.9973	0-4
5-9	0.9818	0.9852	0.9874	0.9895	0.9914	0.9932	0.9948	0.9962	0.9972	0.9981	0.9986	0.9990	5-9
10-14	0.9819	0.9843	0.9865	0.9886	0.9906	0.9925	0.9941	0.9956	0.9967	0.9976	0.9982	0.9987	10-14
15-19	0.9745	0.9774	0.9800	0.9818	0.9865	0.9891	0.9914	0.9935	0.9952	0.9962	0.9974	0.9980	15-19
20-24	0.9694	0.9735	0.9771	0.9807	0.9839	0.9869	0.9896	0.9920	0.9940	0.9956	0.9966	0.9973	20-24
25-29	0.9674	0.9718	0.9756	0.9792	0.9826	0.9855	0.9884	0.9909	0.9929	0.9945	0.9956	0.9963	25-29
30-34	0.9654	0.9700	0.9738	0.9777	0.9811	0.9842	0.9868	0.9893	0.9913	0.9929	0.9941	0.9948	30-34
35-39	0.9622	0.9669	0.9710	0.9744	0.9783	0.9814	0.9841	0.9866	0.9886	0.9903	0.9915	0.9923	35-39
40-44	0.9556	0.9606	0.9650	0.9691	0.9727	0.9759	0.9788	0.9814	0.9835	0.9853	0.9868	0.9879	40-44
45-49	0.9437	0.9493	0.9543	0.9592	0.9631	0.9668	0.9700	0.9731	0.9754	0.9775	0.9792	0.9806	45-49
50-54	0.9252	0.9318	0.9377	0.9433	0.9482	0.9529	0.9570	0.9609	0.9637	0.9661	0.9680	0.9695	50-54
55-59	0.8949	0.9030	0.9104	0.9175	0.9238	0.9299	0.9351	0.9402	0.9437	0.9466	0.9491	0.9510	55-59
60-64	0.8459	0.8559	0.8655	0.8745	0.8825	0.8903	0.8971	0.9036	0.9083	0.9122	0.9161	0.9196	60-64
65-69	0.7710	0.7832	0.7945	0.8052	0.8152	0.8259	0.8345	0.8423	0.8490	0.8549	0.8609	0.8668	65-69
70-74	0.6562	0.6704	0.6940	0.7071	0.7197	0.7316	0.7422	0.7525	0.7602	0.7677	0.7764	0.7852	70-74
75-79	0.5369	0.5523	0.5672	0.5819	0.5955	0.6088	0.6207	0.6323	0.6410	0.6491	0.6592	0.6697	75-79
(80+)	(0.3211)	(0.3313)	(0.3406)	(0.3495)	(0.3575)	(0.3652)	(0.3719)	(0.3781)	(0.3828)	(0.3869)	(0.3913)	(0.3957)	(80+)

* Equivalent values of e_0 shown in parentheses refer to expectation of life at birth, for both sexes, in years.

for the country. (This step will be explained later, after a run-through of the projection methodology in Table 4.3). Analysis of the death rates and mortality data indicates the level at which to enter the U.N. Model Life Tables, which will serve as a basis for projecting the mortality component. Using expectation of life at birth ($^0e_0$) of about 60 years, it appears that the country is at about level 80 of the U.N. Life Tables. Analysis of past trends in mortality, and knowledge of present status and future programs in health and nutrition, suggest that mortality levels will be dropping over the years of the forecast. For this reason, the mortality projection moves up five levels for each five years of the projection, going from level 80 to level 85 to level 90. (Note that the numbers of the levels 80, 85, etc., do not refer to years of the projection, but are simply numbers used to label the levels of the table.)

3.2.3 *The fertility component*

Table 4.2 outlines a set of assumed, or hypothesized, fertility rates that will be used in the projection. Different fertility rates and changes are assumed, and these will yield alternative sets or series of projections. In the U.S. Census projections there are three major series according to different assumptions about fertility. In developing countries there can be five or six different projections, although one of them may be identified as the most reasonable. The alternative sets or series of projections are developed on the basis of assumed changes in the components of fertility and mortality, and these components are projected separately and then combined to yield alternate projections. Table 4.2 shows alternative hypotheses of age-specific fertility rates.

Table 4.2

Hypothesized Fertility, 1970–1980 (rates per 1,000 women) according to Hypotheses I (a) and II a

	Hypothesis I (a) Unchanging Fertility			
Woman's age	1970	1975	1980	1985
15-19		84.4		
20-24		223.3		
25-29		260.4		
30-34		198.7		
35-39		139.0		
40-44		64.9		
45-49		15.8		

	Hypothesis II (a) Declining Fertility			
Woman's age	1970	1975	1980	1985
15-19	84.2	81.3	78.4	75.7
20-24	223.3	214.3	206.7	199.4
25-29	260.4	251.3	242.2	233.6
30-34	198.7	191.5	184.9	178.3
35-39	139.0	134.0	129.2	124.6
40-44	64.9	62.6	60.4	53.3
45-49	15.8	15.2	14.7	14.1

In Hypothesis I (a) the same age-specific fertility rates are assumed to prevail over the period 1970 to 1985. In Hypothesis II (a) the rates are declining over the period 1970 to 1985.

3.2.4 *The migration component*

In this country example there is no external migration. Hence, no migration component will influence the projection results, they will be influenced only by varying assumptions about mortality and fertility.

3.3 *Illustration of the Projection Methodology*

Once fertility and mortality are estimated, the projection method is simple, as Table 4.3 illustrates. The table shows only a partial projection of the female population from the base-year 1975 to the year 1985. The projection would be completed by following exactly the same procedure for the male population, and the period of the forecast would be extended to the full 15 years by adding two more columns and projecting the 1985 population to 1990. Good basic data in the form of an accurate census or base-year population and good mortality and fertility data would permit the projection to be extended for any number of years that the planner requires, but in most developing countries projections that extend beyond 10 or 15 years are of doubtful worth.

The p^1 and p^2 columns in Table 4.3 are survival rates taken from the UN Model Life Tables at the appropriate level according to mortality assumptions. These survival rates—i.e., the proportion of the age group that survives to the next age group five years ahead—are multiplied by the base population.

Table 4.3

Partial Projection Table, Females (1975-1985)

Age-group	Base population (1975)	p^1	Pop. 1980	p^2	Pop. 1985
0-4	459,374	0.9731		0.9791	
5-9	392,669	0.9914	447,017	0.9932	
10-14	340,742	0.9906	389,292	0.9925	443,977
15-19	315,684	0.9865	337,539	0.9891	386,372
20-24	311,429	0.9939	311,422	.	.
25-29	289,619	0.9826	306,415	.	.
.	.	.	.	.	.

p^1 Survival rates from Level 80 of Model Life Tables for females

p^2 Survival rates from Level 85 of Model Life Tables for females
The assumption is that mortality improves

Note: The appropriate table for survival ratios is Table V found on pages 80-81 of Methods for Population Projections by Sex and Age, United Nations, 1956.

The group that is 0-4 in the base year, multiplied by the survival ratio (459,374 × .9731), equals 447,017, the number that will be 5-9 in 1980. This can then be multiplied by .9932 to give 443,977, the number 10-14 in 1985 (see Table 4.3). All of the numbers below and to the left in the table can be filled in for all ages and future years. To obtain the numbers above—e.g., the group that will be 0-4 in 1980—we must use the fertility components to estimate births. For this we will need the women in childbearing ages (15-49) and the age-specific fertility ratios of Table 4.2. We will, for illustrative purpose, cover only the births between 1975-80, i.e., the group that will be 0-4 in 1980. Again, we will work only with females, but to include males requires only two more columns and the same routine. Note also that we would have had to fill in projection Table 4.3 completely in order to get the women in childbearing ages in 1980.

Table 4.4

Births and Survivors 1975-80

Age-group	Average of women in group 1975-80[a]	5-year fertility[b]	Births	Female[c]	Surviving[d]	Male	Surviving	Total
					(0.9208)			
15-19	326,612	.4065	132,768	65,202	60,038			
20-24	300,298	1.0715	321,769	158,021	145,506			
25-29	263,735	1.2565	331,383	162,742	149,853			
30-34	223,715	.9575	214,207	118,457	109,075			
35-39	199,583	.6700	133,721	65,670	60,469	(Total, male-female born		
40-44	175,226	.3130	54,846	26,935	24,802	and survived goes into		
45-49	145,662	.0760	11,070	5,436	5,006	0-4, 1980)		

[a] This is the average of the number of women in the age group in 1975 and the number that would be projected for 1980 if the first table had been completely filled out. There will be slight discrepancies because the calculations were not carried out and an approximation was used.

[b] This results from multiplying the rates in Table 4.2 by 5 (to obtain five-year rate), e.g., .0813 x 5 = .4065...

[c] Total births multiplied by .4911 to obtain female births

[d] Births multiplied by birth survival rate taken from level 80 of U.N. Model Life Tables.

Male survivors would be computed the same way, and male and females added to give the number in the 0-4 age group in 1980. The same operation would be carried on to obtain the 0-4 group in 1985, 1990. . .

The projection methodology is repetitive, and we need not spin out all the numbers in this example. The age groups are survived into the next higher age group five years ahead, and all the groups can be filled in at once, except the 0-4 group, which must be calculated from births by women in ages 15-49. If the projection goes beyond 15 years (beyond the year 1990 in the example), the survivors of the female births in the

first five years (Table 4.4) will be the women in the childbearing group 15-19.

The example shows only one projection series based on one fertility assumption. In the example, we had two alternate hypotheses about fertility: first, that it would remain constant over the forecast (unlikely); and second, that it would change as shown in Table 4.2. In the worked example we used the second hypothesis, taking the age-specific rates from Table 4.2, Hypothesis II. (The rate for one year is .0813. It is multiplied by 5 to give .4065).

3.3.1 *Distributing five-year age-group populations into single years*

The projection yields a population grouped in five-year age groups. Educational planners may often require single year projections. Appendix 4.3 shows how Sprague Multipliers are used to distribute five-year age groups into single years.

4.0 *The Components of Fertility and Mortality When applied in the Projection*

The major components of mortality and fertility require skilled demographic and sociological analysis before they can be set out as they were in Table 4.2. Demographic and social analysis will yield varying hypotheses on the way the fertility rates will move in the years ahead.

In Table 4.2, Hypothesis I(a) assumes that they will remain the same over the 15-year period. Hypothesis II(a) may be based on analysis of past trends, which show a decline over a period of years. Or, the rates in II(a) may be set on the basis of assumptions about the way concomitants of lower fertility will affect births in future years. Shifts from rural to urban living, from agricultural to industrial employment, from less to more education, and the spreading of information and assistance on means of population control, all tend to lower fertility. The demographer takes these factors into account in his analysis. Generally, as countries develop economically and socially, the rates tend to fall slightly. Mortality rates also tend to go to lower levels with development and the introduction of disease control and improved medical services.

Demographic analysis also yields alternate assumptions about the way mortality rates will go in future years. Again, shifts from rural to urban, improved nutrition, sanitation and social services, and increased medical attention will tend to lower morbidity and mortality rates. On this basis, the demographer reduces mortality or increases survival rates. This is work for the skilled demographer with experience of the country and its data, and only the superficial features of it are examined here. In closing this section on the mechanics of a standard component projection (actually components were not separately pro-

jected and checked, but the basics of the method were followed), it is important to return to the basic concept of a projection, discussed earlier. Projections yield alternate sets of estimates according to assumed fertility and mortality. In the example, only two projections would be run, but in most situations mortality would have varied, and hence more projections series would be run. Most fertility and mortality rates are assumed, but their validity depends on the demographic analysis which backs the assumptions.

4.1 *Constructing Abridged Life Tables and Using Model Life Tables*

If the life tales are not available, they can be constructed if mortality data can be obtained. In many developing countries such data are available from death registries or health statistics. First, age-specific death rates are calculated:

$$m_x = \frac{d_i}{p_i} K, \tag{5}$$

where d_i is the number of deaths during the year in the ith age group, and p_i is the midyear population of the same age group; K is usually 1000. Equation (5) yields m_x, the age-specific death rate.

Infant death rate is almost always computed separately:

$$_1m_0 = \frac{d_0}{B} \tag{6}$$

where d_0 is the number of deaths below age 1 registered during the year, B is live births in the same year, and $_1m_0$ is the infant death rate.

Once the age-specific death rates (the m's) are computed for all age groups, they can be converted to the probability of dying within any age interval symbolized by q. These q's are the basic column values around which the rest of the life table columns are built. (Demographers fit the data points represented by the m's to a smooth curve of exponential form. For any given m value, a q value, or probability of dying within the age interval, can be read off. The curve function for the fit is discussed in standard demographic manuals as, for example, in Jaffe's *Handbook 1951*). The computations of the life-table columns are deferred to Appendix 4.4.

The other columns of the life table can be readily worked up, beginning with the imaginary cohort of $l_x = 100{,}000$, multiplying by the probability of dying $_nq_x$ and then subtracting. This yields the column d_x which in turn yields $_nL_x$, T_x and e. Exhibit 4.2 details life-table columns.

Using life expectancy at birth, symbolized by ($^0e_0$) the analyst can enter Model Life Table V (abridged in Exhibit 4.1) and run projections as shown previously in section 3.

If single years are required and the population is projected in five-year groupings, the Sprague Multipliers are applied (Appendix 4.3).

Exhibit 4.2

Life Table for the Total Population: Massachusetts, 1969-71

AGE IN YEARS	PROPORTION DYING	OF 100,000 BORN ALIVE		STATIONARY POPULATION		AVERAGE REMAINING LIFETIME
PERIOD OF LIFE BETWEEN TWO EXACT AGES STATED	PROPORTION OF PERSONS ALIVE AT BEGINNING OF YEAR OF AGE DYING DURING YEAR	NUMBER LIVING AT BEGINNING OF YEAR OF AGE	NUMBER DYING DURING YEAR OF AGE	IN YEAR OF AGE	IN THIS YEAR OF AGE AND ALL SUBSEQUENT YEARS	AVERAGE NUMBER OF YEARS OF LIFE REMAINING AT BEGINNING OF YEAR OF AGE
(1)	(2)	(3)	(4)	(5)	(6)	(7)
x to x+1	q_x	l_x	d_x	L_x	T_x	$\mathring{e}_x$
0-1	0.01725	100,000	1,725	[illegible]	7,102,897	71.03
1-2	.00085	98,275	84	98,233	7,004,416	72.09
2-3	.00072	98,191	71	98,155	6,906,183	71.19
3-4	.00053	98,120	52	98,095	6,808,028	70.20
4-5	.00049	98,068	48	98,044	6,709,933	69.24
5-6	.00041	98,020	40	98,000	6,611,889	68.27
6-7	.00038	97,980	37	97,961	6,513,889	67.30
7-8	.00035	97,943	34	97,926	6,415,928	66.32
8-9	.00031	97,909	31	97,894	6,318,002	65.35
9-10	.00027	97,878	26	97,865	6,300,108	64.37
10-11	.00024	97,852	24	97,839	6,202,243	63.39
11-12	.00023	97,828	23	97,817	6,104,404	62.40
12-13	.00027	97,805	26	97,792	6,006,587	61.41
13-14	.00035	97,779	35	97,762	5,908,796	60.43
14-15	.00048	97,744	47	97,720	5,811,034	59.45
15-16	.00063	97,697	61	97,667	5,713,314	58.48
16-17	.00077	97,636	75	97,599	5,615,647	57.52
17-18	.00088	97,561	86	97,518	5,518,048	56.56
18-19	.00095	97,475	93	97,429	5,420,530	55.61
19-20	.00098	97,382	95	97,334	5,323,101	54.66
20-21	.00100	97,287	97	97,239	5,225,767	53.71
21-22	.00103	97,190	100	97,140	5,128,528	52.77
22-23	.00104	97,090	102	97,039	5,031,388	51.82
23-24	.00104	96,988	100	96,938	4,934,349	50.88
24-25	.00103	96,888	100	96,838	4,837,411	49.93
25-26	.00100	96,788	97	96,739	4,740,573	48.98
26-27	.00096	96,691	96	96,643	4,643,834	48.03
27-28	.00097	96,597	94	96,549	4,547,191	47.07
28-29	.00101	96,503	97	96,455	4,450,643	46.12
29-30	.00107	96,406	104	96,354	4,354,188	45.17
30-31	.00117	96,302	112	96,246	4,257,831	44.21
31-32	.00128	96,190	124	96,128	4,161,585	43.26
32-33	.00138	96,066	133	95,999	4,065,457	42.32
33-34	.00146	95,933	139	95,864	3,969,458	41.38
34-35	.00152	95,794	146	95,721	3,873,594	40.44
35-36	.00157	95,648	150	95,573	3,777,873	39.50
36-37	.00167	95,498	159	95,418	3,682,300	38.56
37-38	.00186	95,339	176	95,251	3,586,882	37.62
38-39	.00211	95,163	201	95,062	3,491,631	36.69
39-40	.00244	94,962	232	94,846	3,396,567	35.77
40-41	.00281	94,730	266	94,597	3,301,723	34.85
41-42	.00319	94,464	298	94,316	3,207,126	33.94
42-43	.00346	94,166	326	94,003	3,112,810	33.04
43-44	.00371	93,840	350	93,665	3,018,807	32.17
44-45	.00399	93,490	373	93,303	2,925,142	31.29
45-46	.00429	93,117	396	92,920	2,831,839	30.41
46-47	.00456	92,721	423	92,509	2,738,919	29.54
47-48	.00496	92,298	457	92,070	2,646,410	28.67
48-49	.00547	91,841	503	91,589	2,554,340	27.81
49-50	.00609	91,338	556	91,080	2,462,751	26.96
50-51	.00677	90,782	615	90,474	2,371,691	26.13
51-52	.00748	90,167	675	89,830	2,281,217	25.30
52-53	.00824	89,492	737	89,124	2,191,387	24.49
53-54	.00904	88,755	802	88,354	2,102,263	23.69
54-55	.00988	87,953	869	87,519	2,013,909	22.90

Source: National Center for Health Statistics. U.S. Decennial Life Tables for 1969-70, Vol. II, No. 22, "Massachusetts State Life Tables: 1969-71."

5.0 *A Summary Note on the Terminology of the Mortality Component*

Some of the concepts and terminology central to an understanding of the mortality component have been introduced in the text, and further study of life-table terminology in Exhibit 4.2 is recommended. The crude death rate is the basic statistic of the mortality component, and it is used to build the life table. Crude death rates come from registry data and vital statistics holdings, supplemented by special surveys, corrections, and adjustments which will not be dealt with in

this unit of material. Migration and fertility data can be used to check changes in census results for the effects of mortality. Data on one component can be used to adjust another component. Other social data—health statistics, for example—can be used to guide adjustments. There are also model distributions and tables that can be used to adjust population estimates and the component rates in any given national area. The reading selections are recommended as a start in covering these specialized topics.

The analyst builds the life table around the crude death rate (m_x) statistics. From this, as we have seen, the probability of dying within a given age interval (q_x) is estimated. The complement of the probability of dying is the probability of surviving. This is the central statistic used in the population projection methodology that was illustrated. The common symbol for the survival probability is p_x, sometimes written in upper-case letters as P_X. When the probability of surviving is multiplied by the number of people in one age interval, the number surviving to the next age interval is obtained.

In the life table, the column symbolized as l_x is the number surviving to the exact age marked by the interval. (Intervals may be marked by single-year or five-year groupings.) The column symbolized as L_x is the number surviving to the midpoint of age interval. (L_x may also be the arithmetical average computed between any two successive l_x values). The T_x is the total years lived after an exact age interval by the stationary population in a life table (100,000). It is found by cumulating L_x up from the last age group in the life table. If T_x is divided by l_x, the result is symbolized as ${}^{x}e_0$. This represents the expectation of years of life from the age specified. Most commonly this expectation is computed from birth and it is symbolized as ${}^{0}e_0$, *life expectancy at birth.* No glossary really serves to make the mastery of these concepts' terms and symbols easy. The reader simply must study the values as they are associated in the life table. It requires more than one reading to learn the symbols and concepts.

5.1 *A Summary Note on the Terminology of the Fertility Component: Rates and Their Uses*

The concepts and terminology of demography are sometimes special and sometimes confusing, and this manual has provided only a brief introduction. A short list of readings for expanding this limited coverage is suggested in the reference bibliography. It might be useful to review some basic terminology for the component of fertility.

The major fertility measures are:

— *Crude Birth Rate:* This is the *basic* fertility indicator and, as titled, the crudest. (It corresponds to the Crude Death Rate. This death rate, subtracted from the birthrate, yields the Rate of Natural Increase of the Population.) The number of births is divided by the total midyear population, and because it is expressed per thousand, the ratio

is multiplied by 1000:

$$\text{C.B.R.} = \frac{B}{P} \cdot 1000$$

— *The General Fertility Rate:* This is the number of births divided by the number of women of childbearing age. (This may be taken to be 14-49, or it may also be 15-45). It is symbolized as:

$$\text{G.F.R.} = \frac{B}{F} \cdot 1000,$$

where F = females of childbearing age.

— *Age-Specific Fertility Rates:* These are rates for women in either five-year or single-year age groups. This is symbolized as:

$$\text{A.S.F.R.} = \frac{{}_nB_x}{{}_nF_x} \cdot 1000,$$

where x to n indicates the specific age range covered.

— *Total Fertility Rate:* This is the sum of each age-specific rate over the fertile age groups, and is symbolized by placing a summation sign in front of the age-specific rate symbol and indicating the summation range:

$$\text{T.F.R.} = \sum_{15}^{45} \frac{{}_nB_x}{{}_nF_x}$$

It sums each age-specific rate to a total rate for the childbearing years.

— *Central Brith Rates:* These are based on births adjusted for under-registration and the number of females adjusted for under-counting.

— *Completed Cohort Fertility:* This is the sum of fertility rates accumulated across age groups for a given cohort of women; that is, women born in same year. This is sometimes referred to as "the average number of births per woman." As calculated, it is cohort-specific and applies to women born in a given year.

6.0 *A Brief Note on Adjustment of Census Results and Base Year Populations*

In developing countries, census results have inaccuracies which require correction. This is a constant task of the national census and statistics office and not one that most planners and analysts deal with in practice. The first estimates are usually for national totals and are based on a sample. Later, population totals may be modified to account for failures in the enumeration or coding. The data can be miscounted, miscoded or mistabulated. The original data can be misstated, and often there are systematic biases in the reporting which can be adjusted. These

specialized topics are discussed in the United Nations manuals of the reference bibliography. Similar problems occur in the United States Census and population reporting, and the Census Bureau applies standard adjustment methods. These are discussed in Appendix 4.5.

Common methods for correcting and adjusting census and population estimates may include:

— Correcting vital data for misreporting and underreporting based on sex bias. Children may be reported as males when they are females, or unreported if they are females. These discrepancies show up in distortions in the sex and age structure of the population. In most areas these problems are probably declining; training and motivation of enumerators cuts down the problem at the source.

— General correcting and smoothing of numbers in population distributions because of digit preference: Reports may be biased toward even numbers in ages, or toward the fives or tens within the decades of age groups. Model adjustment tests and tables can be applied. to smooth out anomalies in the distributions, for example much larger numbers at 10 than at 9 and 11.

— Correcting and smoothing of age groups, particularly the 0-4 group: Ages may be systematically raised or lowered at different ends of the age continuum. The major bases for correction are to adjust toward model demographic structures and to use averages and interpolation to smooth out discontinuities in the data.

These specialized topics cannot be dealt with here, and it is fairly useless to read about them in general terms. The manuals should be consulted when there is a problem at hand, but the methods are pretty much those applied in managing all large data collections.

7.0 *Planning for Subnational Areas*

Planners in developing countries may have to deal with subnational areas, i.e., regions, zones, states, or departments. The plan may be limited in coverage to less than an entire nation. Or, the nation may be a collection of regions or states that have very different characteristics relevant to development (rural-urban, climatic, ethnic, economic, political), which require separate analysis before they can be combined in any meaningful way into a national plan. Presumably the school organization, curriculum, teacher force, and physical facilities will be planned to accord with these differences. The ethnic difference may necessitate a different language of instruction; the rural environment may require different emphasis in curriculum content; the climatic conditions may suggest that different physical facilities are appropriate; and differences in wealth may limit the quality level of the program.

Different regions within the same country may be at entirely different stages of economic, cultural, and social development, and plans will have to take this into account. To use a simple typology, regions within a country may be at Level I (underdeveloped), Level II (partially developed), and even Level III (semi-advanced). Averages at the national

level may have very little meaning (Harbison and Myers 1964).

The schemata and models which are applied at the national level require modifications to make them suitable for subnational applications. Going from the national to the regional level complicates and simplifies the planner's task. Generally, subnational surveys and censuses are easier to take and cheaper to run, and permit more depth and elaboration. But regional projections are more difficult, because data on inter-regional migration are unavailable. The regions are *open*, and the populations are shifting.

The necessary past data on which assumptions about future trends may be based are generally difficult to obtain for subnational areas. Internal migration, which underlies population and workforce projections, is a fair example. The components for national projections are births, deaths, and migration. External migration is not usually very accurately registered in developing countries, but neither is it a very important component in national population change. Quite the contrary may be true with respect to population changes between regions or areas within the country. Internal migration rates are critical in the projection of populations for subnational areas.

Large population shifts do occur within developing countries. In fact, flow from rural areas to urban centers characterizes internal migration in developing countries at a certain stage of growth. Assessing this migration and incorporating it into regional projections is a demanding task. But it is a necessary one, above all in areas which are undergoing very rapid economic and social change. For a region where economic growth is under way, a detailed study of migrants is fundamental. The application of national population models is useless. To make an accurate estimate of migration in a rapidly changing area may require a house-to-house census run at frequent intervals over a long time span. Sometimes employment records and job applications to the major industries in the area will indicate in-migration.

Rather than elaborate the methods used, the tables in Appendix 4.2 taken from Stanbery (1960), sketch out the essentials of the method. The Stanbery formulas and schemata are run using the State of California as a subnational area of the United States. Better data are available there than would be available in the states or departments of developing countries, but the methods are essentially the same. Given the existence of reasonably adequate subnational data, the essentials of the method are as follows:

- The basic assumptions underlying both national and subnational projections are established.
- The population of the national area by major age groups is projected for future years.
- The size and the rate of migration into and out of the subnational area are derived from past trends, according to the formats in Appendix 4.2.

- Net migration (excess of in-migrants or out-migrants) is established.
- The population of the subarea is projected, taking into account natural increase (excess of births over deaths), net migration, and the survival of in-migrants.
- Other characteristics of the population, e.g., labor force participation rates for age groups, can be derived from the basic population in the subnational area and participation rates in the total country workforce. School-age populations can also be determined. These economic, social, and educational statistics, called *symptomatic data* in census and projection terminology, can also be used to derive estimates of the total population in the subnational area. The U.S. Bureau of Census has used school enrollment gains to indicate general population gains in an area for which there is no recent migration information. Because enrollment ratios to general population are known and may not be changing except for population increase, the gains in enrollment when expanded by the enrollment/population ratio can be used to estimate the area population.

In local areas, housing starts, building permits, and employment changes also provide useful symptomatic data for indicating population changes.

From the basic data above, all of the usual statistics and projections for education and human resource development can be established. In developing countries, subnational populations are very often estimated on the basis of sample surveys or local special purpose censuses.

8.1 *Population Estimation in Local Areas and School Mapping*

For the purposes of school location planning, more specific techniques must be applied in the local areas. The basis is usually a census of school-age and preschool-age children. Irons and Kern (1953) used a land-utilization study technique which is a variant of the methods described in section 7.0. This short-cut system used in urban areas entails a survey and enumeration of existing residences. To this is added the number of probable future homes, which is based on the number of suitable vacant lots. The average number of children per dwelling is determined in the survey, and this is multiplied by the number of dwellings estimated. Estimates can be modified according to the zoning for commercial and industrial establishments. The load can be reduced according to the existing and planned enrollments in private schools. This method will not serve in rural areas, or in the swarming "temporary" neighborhoods that cluster on the outskirts of large cities in many developing countries. There are few methods that make it easy to deal with the data problems caused by sparse populations in isolated and inaccessible areas. Costs of information are sometimes simply beyond the resources of the country, and may not be worth it in

the return of information. Dealing with nomadic people in such areas compounds the difficulty. Rural areas and isolated people are gradually being covered by census and by special surveys undertaken in the developing countries.

Selected Bibliography
Additional Reading and Reference Tools and Resources For Population Projection and Demographic Analysis

The books, manuals and articles listed are for three purposes:

i) Some are references cited in this unit on poulation projection methods

ii) Some are suggested further readings in demographic analysis and population projection

iii) Some are reference tools and sources of statistics and methods for demographic analysis and population projections.

1. *Cited in text and suggested additional reading:*

De Jouvenal, B. *The Art of Conjecture.* New York: Basic Books, 1966

Duncan, Otis, Dudley. "Social Forecasting—The State of the Art." *The Public Interest* 17 (Fall, 1969).

Dunn, Edgar, S. *Economic and Social Development.* Baltimore: Johns Hopkins Press, 1971

Heer, David. "Economic Development and the Fertility Transition." In D.V. Glass and R. Revelle, eds. *Population and Social Change.* London: Edward Arnold, 1972

—— *Readings on Population.* Englewood Cliffs, New Jersey: Prentice Hall, 1968

Helmer, Olaf. *Social Technology.* New York: Basic Books, 1966

Irons, Gerald E. and Kern, Willis P. *A Survey of Population, School Enrollment and School Building Program in Willoughby-Eastlake School District.* Lake County, Ohio: Willoughby-Eastlake School District, 1953

Keyfitz, Nathan. "On Future Population," *Journal of the American Statistical Association.* Vol. 67, No. 338, 1972

National Academy of Sciences. *Rapid Population Growth.* Baltimore: Johns Hopkins Press, 1971

Ridker, Ronald G. ed, *Population and Development: The Search for Selected Interventions.* Baltimore: Johns Hopkins Press, 1976. See especially, Ronald G. Ridker, "Perspectives on Population Policy and Research," Chap 1; Robert Repetto, "Direct Economic Costs and the Value of Children," Chap 3; Dennis De Tray, "Population Growth and Educational Policies," Chap 6; Donald B. Holsinger, and John D. Karsarda, "Education and Human Fertility: Sociological Perspectives," Chap 5.

Schultz, T. Paul. "Interrelationships Between Mortality and Fertility." In Ronald G. Ridker, ed, *Population and Development.* Baltimore: Johns Hopkins Press, 1976

2. *Methodological tools and source data for demographic analysis and population projections:*

Barclay, George W. *Techniques of Population Analysis*. New York: John Wiley, 1958. (Old but still useful)

Bogue, Donald. *Demographic Techniques of Fertility Analysis*. Chicago: Community and Family Study Center, FP Manual No. 2, 1971. (Useful manual has been updated in published book form)

Coale, A.J., and Demeny, P. *Regional Model Life Tables and Stable Populations*. Princeton, Princeton University Press, 1966. (These tables and the UN Model, Life Tables, shown in text are basic tables.)

Coale, A.J., and Demeny, P. *Regional Model Life Tables and Stable Populations*, Princeton, Princeton University Press, 1966. (These tables and the UN model tables in the text are basic tools.)

Jaffe, A.J., *Handbook of Statistical Methods for Demographers*. Bureau of the Census, Washington, D.C.: US Government Printing Office, 1951. (Old but still useful)

Keyfitz, Nathan, and Flieger, Wilhelm. *World Population*. Chicago: University of Chicago Press, 1968. (Valuable reference on demography and population, with data and indicators becoming dated, but methodological and analytic material still useful.)

——, *Applied Mathematical Demography*. New York: John Wiley, 1977 (New and Useful).

National Center for Health Statistics, Hyattsville, Maryland provides several valuable demographic statistics and statistical series: *Monthly Vital Statistics Report, Life Tables* (for US for various periods), *Fertility Tables for Birth Cohorts* (various periods)

Population Council, Frederick C. Shorter with David Pasta. *Computational Methods for Population Projections: With Particular Reference to Development Planning*. New York: The Population Council, 1974. Note: This manual is accompanied by a program tape, and basic demographic data can be read in, and projections carried out for five-year age groups (FIVFIV) and in turn translated into single year groups (SINSIN).

Shryock, Henry S., and Seigel, Jacob S. et al. *The Methods and Materials of Demography*. 2 Vols., 3rd printing (rev). Washington, D.C., U.S. Government Printing Office, 1975. (Very Complete Reference).

TEMPO, General Electric. *Demos: Demographic Economic Models of Society: A Computerized Learning System*. Santa Barbara, Ca: Center for Advanced Studies, 1974

U.S. Bureau of Census. *Population Estimates and Projections: Projections of the Population of the United States to 2050*. Washington: U.S. Government Printing Office (Various numbers of P-25 Series

which is updated periodically). See No. 601, issued October 1975, no. 704, issued July 1977

United Nations. Issues various manuals with useful applications, under various series: Series A, *Manuals on Methods of Estimating Population: Manual I: Methods of Estimating Total Population for Current Dates,* No. 10, 1952, *Manual II: Methods of Appraisal of Quality of Basic Data for Population Estimates,* no. 23, 1955, Manual III: *Methods for Population Projections by Sex and Age.* (This has model lite tables) No. 25, 1956; Manual IV: *Methods of Estimating Basic Demographic Measures from Incomplete Data,* no. 42, 1967. Also: *Reports on Population Studies,* e.g. No. 22, *"Age and Sex Patterns of Mortality: Model Life Tables for Under-Developed Countries,"* 1955. Also: *Series F, Handbook of Population Census Methods:* Volumes I to III. (These are old but indispensable tools for planners.)

Interest Tables, Growth Tables

1. Stanford Research Institute. *Growth Factors...Compound Interest Tables.* Menlo Park, Cal: SRI, 1963 and later updates.
2. World Bank. *Compounding and Discounting Tables for Project Evaluation.* Washington, D.C.: World Bank (with Johns Hopkins Press), 1973.

APPENDIX 4.1

A Note of Growth Trends

In the first quick projection method illustrated in this chapter we assumed arithmetical growth for the population. In the second example, the one illustrated in equations (3) and (4), we are assuming an exponential growth. Equation (3) was the standard compound interest formula, and this is an alternative expression of an exponential growth curve. When the equation is applied to money invested, it will show the principal (sum invested) increasing over time in an exponential form. (The exponential curve form is illustrated and explained in Chapter 7). The form of the increase (rising smoothly) is exponential, and the amount of increase is determined by the rate of interest and the number of years over which it is compounded. We will see in this section that there are other growth forms beside the linear and the exponential.

We will examine the other growth curves, the quadratic and the modified exponential, and work through a simple arithmetical exercise with equation (5). A number of other growth curves will be shown in Chapter 7.

A quadratic Example

$$p_n = a + bx + cx^2 \tag{5}$$

Results of three past censuses are required for a second-degree polynomial:

$$\begin{aligned}
&1960 \text{ population} = 1{,}000{,}000 = a + 0.b. + 0.c. \quad (x = 0)\\
&1970 \text{ population} = 1{,}100{,}000 = a + 10.b + 100c \quad (x = 10)\\
&1980 \text{ population} = 1{,}500{,}000 = a + 20.b + 400c \quad (x = 20)
\end{aligned}$$

$a = 1{,}000{,}000$:

$$\begin{aligned}
10b + 100c &= 100{,}000\\
20b + 400c &= 500{,}000\\
c &= 1500\\
b &= -5000
\end{aligned}$$

To estimate 1990, where $x = 30$:

$$1{,}000{,}000 + (30)(-5{,}000) + (900)(1{,}500) = 2{,}200{,}000.$$

The parabola, or higher-degree curve, or any curve fit, has warranty only to the extent that the past census data actually fit the trend. When decennial censuses are used, the fit is generally not based on more than three or four data points. Three is the minimum number of points for a quadratic fit. When projections are made beyond a few years, the

population may be badly overestimated or underestimated by extrapolation methods.

More elaborate growth curves (Pearl-Reed, Gompertz, or Yule) can be fitted to multiple-census results so that future totals can be extrapolated. Curve-fitting is discussed more fully in Chapter 7.

APPENDIX 4.2

Stanbery Formula for Projection of the Civilian Population of an Area of A Country by Decades

Let A = Civilian population of area at beginning of decade
Let X = Civilian population of area at end of decade
Then X = A + (total in-migration − total out-migration + natural increase during decade)
Let B = Arithmetical mean of civilian populations of country at beginning and end of decade
Let R_1 = Projected rate of total migration of civilians into area during decade per mean civilian population of country excluding civilian populatin of area
Let R_2 = Projected rate of total out-migration of civilians from area during decade per mean civilian population of area (arithmetical mean of civilian population of area at beginning and end of decade)
Let N = Projected average annual crude rate of natural increase per 1000 mean civilian population of area during decade multiplied by 10 (years)

$$\text{Then total in-migration} = R_1 \left[B - \left(\frac{A + X}{2}\right)\right]$$

$$\text{Out-migration} = R_2 \left(\frac{A + X}{2}\right)$$

$$\text{Natural increase} = N \left(\frac{A + X}{2}\right)$$

Hence:

$$X = \frac{R_1 B + A \quad 1 - \left[\left(\frac{R_1 + R_2 - N}{2}\right)\right]}{1 + \left(\frac{R_1 + R_2 - N}{2}\right)}$$

COMPUTATION OF POPULATION PROJECTIONS

EXAMPLE OF COMPUTATION OF POPULATION PROJECTIONS IN TABLE C-5 BY FORMULA IN TABLE E

Series B Projection, July 1, 1960-July 1, 1970

R_1 = 0.045675 = 1950-1960 rate of 0.0435 + assumed increase of 5%

R_2 = 0.273525 = 1950-1960 rate of 0.2605 + assumed increase of 5%

$R_1 + R_2$ = 0.3192

$N = 0.143$ (from Table C-4)

$$\frac{R_1 + R_2 - N}{2} = \frac{0.1762}{2} = 0.0881$$

$$1 - \left(\frac{R_1 + R_2 - N}{2}\right) = 0.9119 \qquad 1 + \left(\frac{R_1 + R_2 - N}{2}\right) = 1.0881$$

$B = 192{,}250{,}000$

$BR_1 = 0.045675 \times 192{,}250{,}000 = 8{,}781{,}019$

Civilian population of California, July 1, 1960 = A = 15,530,000

$$A\left[1 - \left(\frac{R_1 + R_2 - N}{2}\right)\right] = 15{,}530{,}000 \times 0.9119 = 14{,}161{,}807$$

$$R_1B + A\left[1 - \left(\frac{R_1 + R_2 - N}{2}\right)\right] = 22{,}942{,}826$$

Civilian population of California, July 1, 1970 = $X = \frac{22{,}942{,}826}{1.0881} = 21{,}085{,}000$

Assumed military population = 300,000

Total population of California, July 1, 1970 = 21,385,000

= Series B projection U.S. census report

SOURCE: Stanbery, Van Beuren, *Some New Techniques for Area Population Projections*, Los Angeles: Haynes Foundation, 1960, p. 97

APPENDIX 4.3

Distributing Five-Year Age Groupings Into Single Years

The educational planner usually works with a population projected in single years rather than the five-year groups used by most demographers, 0-4, 5-9, 10-14. . . It is a straightforward matter to break five-year groups into single years using Sprague Multipliers. These multiplier panels take a five-year age-group population estimate and apportion the five-year total into 5 single-year populations. The panels and the method are described in United Nations Manual III, *Methods for Population Projection by Sex and Age.* In many cases computer-coded programs for population projection have options for both five-year and single-year groupings. For example, the computerized models prepared by Shorter and Pasta (1974) for the Population Council offer a program option for five-year age groups called FIVFIV and an option for single years called SINSIN.

Here, we will illustrate the use of multiplier panels with a simple exercise. We begin with the partial population projection illustrated in Table 4.3 of the text, which shows that the 1980 projected population in the age group 15-19 is 337,000. (Note that in the table we have kept numbers to the units place in order that readers can follow the arithmetic. In actual projections the numbers have no such precision and would generally be rounded off to the nearest thousands. We will keep all the digits in this exercise.) An educational planner would want the population broken into single-year age-groups, especially in the age-group 15-19, which would include entrants into secondary school and post-secondary level programs. Hence, in this exercise we will apportion the 337,000 females in age-group 15-19 into five single-year groups.

Table A4.3.1 shows the Sprague multiplier panels, which are explained in the accompanying text. The purpose of the panels is to apportion five-year age-group totals into single-year age-group totals. The upper-case N's along the top of the multiplier panel represent the five-year age-group totals from the projection. The lower case n's along the rows represent the single years.

In this exercise we are going to break the total of the 15-19 age group into the single years, 15, 16, 17, 18, and 19. This means that we put the 15-19 total as N_3 in the middle of the panel, the 10-14 age group as N_2 to the left, the 20-24 age group as N_4 to the right, etc. For the age-group 15-19, we use the mid-panel proportions shown in Table A4.3.1, which is taken from *United Nations, Methods for Population Projections by Age and Sex.* (ST/SDA/Series A, Population Studies, No. 25)

To obtain the single-year total of 71,070 shown in the right-hand column of Table A4.3.2, we multiply the proportions of the n_1 line by the five-year age-group totals (N's) above: (−.0128) × (447017) + (.0848) × (389292) + (.1504) × (337539) + (−.0240) × (311,422) + (.0016) × (306415), and the total is 71,070. The n_2 line is done the same way.

Table A4.3.1

The Sprague Multipliers

	N_1	N_2	N_3	N_4	N_5
			FIRST END-PANEL		
n_1	+0.3616	−0.2768	+0.1488	−0.0336	—
n_2	+0.2640	−0.0960	+0.0400	−0.0080	—
n_3	+0.1840	+0.0400	−0.0320	+0.0080	—
n_4	+0.1200	+0.1360	−0.0720	+0.0160	—
n_5	+0.0704	+0.1968	−0.0848	+0.0176	—
			FIRST NEXT-TO-END PANEL		
n_1	+0.0336	+0.2272	−0.0752	+0.0144	—
n_2	+0.0080	+0.2320	−0.0480	+0.0080	—
n_3	−0.0080	+0.2160	−0.0080	+0.0000	—
n_4	−0.0160	+0.1840	+0.0400	−0.0080	—
n_5	−0.0176	+0.1408	+0.0912	−0.0144	—
			MID-PANEL		
n_1	−0.0128	+0.0848	+0.1504	−0.0240	+0.0016
n_2	−0.0016	+0.0144	+0.2224	−0.0416	+0.0064
n_3	+0.0064	−0.0336	+0.2544	−0.0336	+0.0064
n_4	+0.0064	−0.0416	+0.2224	+0.0144	−0.0016
n_5	+0.0016	−0.0240	+0.1504	+0.0848	−0.0128
			LAST NEXT-TO-END PANEL		
n_1	−0.0144	+0.0912	+0.1408	−0.0176	—
n_2	−0.0080	+0.0400	+0.1840	−0.0160	—
n_3	+0.0000	−0.0080	+0.2160	−0.0080	—
n_4	+0.0080	−0.0480	+0.2320	+0.0080	—
n_5	+0.0144	−0.0752	+0.2272	+0.0336	—
			LAST END-PANEL		
n_1	+0.0176	−0.0848	+0.1968	+0.0704	—
n_2	+0.0160	−0.0720	+0.1360	+0.1200	—
n_3	+0.0080	−0.0320	+0.0400	+0.1840	—
n_4	−0.0080	+0.0400	−0.0960	+0.2640	—
n_5	−0.0336	+0.1488	−0.2768	+0.3616	—

Source: United Nations, Methods for Population Projections by Age and Sex. ST/SOA/ Series A, Population Studies, No. 25

Table A4.3.2

Using Sprague Multipliers to Apportion the 15-19 Population Into Single Years

	N_1	N_2	N_3	N_4	N_5	
	5-9	10-14	15-19	20-14	25-29	
	447,017[a]	389,292	337,539	311,422	306,415	Single Years
n_1	- .0128	.0848	.1504	- .0240	.0016	15 = 71,070
n_2	- .0016	.0144	.2224	- .0416	.0064	16 = 68,966
n_3	.0064	- .0336	.2544	- .0336	.0064	17 = 67,148
n_4	.0064	- .0416	.2224	.0144	- .0016	18 = 65,730
n_5	.0016	- .0240	.1504	.0848	- .0128	19 = 64,625
						337,539

[a]Population totals are from Table 4.3 in text.

APPENDIX 4.4

Table A4.4.1

Some Functions of an Abridged Life

Age in years (x)	Age-specific death rate ($1{,}000\ m_x$)	Life-table death rate ($1{,}000\ q_x$)	Survivors to exact age (l_x)	Survivors in age group (L_x)	Survival ratio (P_x) ($P_0 = 0.9350$)	T_x	Expectancy ^0e_x
0	71.1	63.0	100,000	467,715	0.9862	(not shown)	62.1
1-4	3.1	12.0	93,700				65.2
5-9	1.4	7.0	92,576	461,260	0.9937	--	62.0
10-14	1.1	5.5	91,928	458,375	0.9933	--	57.4
15-19	1.6	8.0	91,422	455,282	0.9901	--	52.7
20-24	2.4	11.9	90,691	450,755	0.9879	--	
25-29	2.5	12.4	89,611	445,278	0.9859	--	
30-34	3.2	15.9	88,500	438,982	0.9822	--	
35-39	4.0	19.8	87,093	431,155	0.9751	--	
40-44	5.7	28.1	85,369	420,818	0.9626	--	
45-49	9.6	47.0	82,970	405,100	0.9490	--	
50-54	11.3	55.1	79,070	384,458	0.9284	--	
55-59	18.0	89.1	74,713	356,922	0.8918	--	
60-64	27.5	129.1	68,056	318,415	0.8412	--	
65-69	42.5	192.9	59,270	267,768	0.7676	--	
70-74	65.2	281.1	47,837	205,545	0.6649	--	
75-79	103.4	410.0	34,381	136,662	0.5224	--	
80-84	173.4	592.2	20,284	71,900	0.3875	--	
85 and over	260.9	1,000.0	8,272	31,406			

Source: United Nations, Methods for Population Projections by Age and Sex. ST/SDA/ Series A. Population Studies, No. 25

Explanation of life table columns and how computed

1. The first column x indicates the age group.
2. The second column ($1000\ m_x$) is the age-specific death rate.
3. The third column is the probability of dying before reaching upper limit of age group. (See explanation above)
4. The fourth column l_x is the number of survivors to exact age. It begins with 100,000 and is reduced by the number dying in each age group.
5. The fifth column L_x is survivors within the age group (average number of years lived). It can be computed (except for the first age group) by averaging successive 1 values.
6. The column ^xP_x shows the proportion in age group surviving to next age group, and is obtained by dividing successive L_x values.
7. The T_x column would be obtained by cumulating up from the lowest L_x through each successive age interval.
8. The last column ^0e_x is the number of years (expected) of life remaining at the beginning of the year of age. From 0 it is commonly called life expectation at birth. It is obtained by dividing the T_x value by l_x value.

We can use values from Table A4.4.1 to illustrate how the q values (probability of dying in a given age interval) are generated from the m values (age-specific death rates), using the curve-fitting equation (1) below. Once the q values are obtained, the rest of the columns of a life table can be computed.

We will use the age group 55-59, underlined in Table A4.4.1, as an example, but the same procedure of converting from age-specific death rate to a probability of dying in the age interval would hold for all age-groups.

$$_nq_x = \text{probability of dying within } n \text{ years after age } x$$

$$_nq_x = 1\text{-}e^{-n\ {}_nm_x\ -an^3\ {}_nm_x^2},$$

where $a = 0.008$

$n = 5$

$_nm_x = 18.6/1000$

$= .0186$

Thus, $1000q_x =$

$$1000\ \left[1\text{-}e^{-5(.0186)-(.008)\ (5)^3(.0186)^2}\right]$$

$$= 1000\ \left[1\text{-}e^{-.0933}\right]$$

$$= 1000(.0891) = 89.1$$

APPENDIX 4.5

U.S. Census and Projection Methodologies

The fundamental projection basis was shown in equation (1) in the text. U.S. Census Bureau Methods are simply more elaborate variants of that basic schema:

$$\text{Base Year Population} + \text{Births} - \text{Deaths} \pm \text{Migration} = \text{Projected Population} \quad (1)$$

Alternative projection sets or series will result from alternate assumptions on fertility, mortality, and migration. In the United States currently, alternate assumptions on the fertility component (only) lead to three projections. Each of the three projections is called a "series". Specifically, there are three series: Series II, a central projection which assumes medium fertility rates; Series I, which assumes higher fertility; and Series III, which assumes lower fertility. The mortality assumptions are the same in all three series and are based on one life table and one set of survival ratios. Hence, only fertility affects the outcome in each series. Thus, Series I, with the highest fertility, yields the highest population estimate, followed by Series II and then Series III.

Projections in developing countries usually are based on different assumptions about both mortality and fertility. United States projections use the same migration component in all three series. National projections in developing countries either exclude or use only one migration estimate.

The most recent population projection for the United States is found in *Current Population Reports*, Series p-15, No. 704 (July 1977). In this report there are annual total populations projected to the year 2050, and projections by age, sex, and race to the year 2000. As a curiosity that someone might wish to validate in future years, when the time has run its course, these are:

Total Population Projected to Year 2000	
Series I	283 million
Series II	260 million
Series III	246 million

The accuracy of these projections depends, as the basic schema indicates, on the accuracy of assumptions about fertility, mortality, migration, and the accuracy of the base year population estimate. Series II is considered the most likely projection, but planners have their choice and can challenge the assumptions. In the writer's opinion, Series II is the most likely estimate over a longer time period, but currently births are rising but fluctuating.

The Base-Year Population Estimate

One variant on the basic cohort components method of projection is introduced by the U.S. Census Bureau because of recognized inaccuracy in the base-year population estimate. Despite the quality of the U.S. Census and the vital statistics that are used to bring census totals forward to the base year of a population projection, projections must be adjusted for population under-counting by age, sex, and race. This methodology for adjustments is called the *inflation-deflation* variant on the cohort component projection method. (For details on the general methodology, see U.S. Bureau of Census, references.)

Migration

An assumed net immigration of 400,000 a year, distributed by age and sex, is added into all United States projection series alike. It is felt that this constant understates the net migration considerably because of failure to include any estimates of the illegal immigrants, thought to number in the millions. It is also suggested that these illegal immigrants, unknown in number and with different fertility patterns, affect the most recent birth numbers, although it is unlikely they distort the national fertility estimates markedly. It should be noted, however, that migration is a fairly weak component in the U.S. Census projections, and the only defense that can be claimed is that, given the very large population of the country, the migration component probably does not affect population dynamics and projections very much.

Fertility

Fertility, which is the basis for the differences in the series projections, is most difficult to estimate and project, and receives the greatest attention in the demographic analysis that supports the census projections. Census Bureau projections are based on three different assumptions about cohort fertility. The middle variant is the basis of Series II, with a higher variant in Series I and a lower in Series III. These assumptions are based on "ultimate completed cohort fertility". The ultimate completed cohort fertility rate may be thought of as the average number of births over a lifetime for women in a given cohort, i.e., born in a given year, and found in a given age group in some future year. Two basic approaches were used in setting these rates. The first looks to the long term and is not based on past trends in fertility. It assumes that population growth will cease at some point in the future, and studies when this will occur, at what level, and by what path it will be reached. In the projections for Series II, it is assumed that the ultimate cohort fertility rate will reach the replacement level of 2.1 children per woman for women presently in the young childbearing ages. It also assumes that fertility rates will move smoothly toward the assumed ultimate level (U.S. Census, 1977).

With the cohort fertility rate set for Series II, the rates are set higher for Series I and lower for Series III. Hence the rates were set at 2.1 for Series II, 2.7 for Series I, and 1.7 for Series III.

A second approach to setting the fertility assumptions rests on

expected births which are reported by women in recent surveys. This again is based only on an assumption that fertility is moving toward replacement level for the younger married women.

To compute projected births for future years requires that age-specific birth rates be estimated for each age in the childbearing range, from 14 to 49. According to the Census Bureau this requires:

- Interpolating linearly between estimated age-specific birth rates computed for 1973 and ultimate age-specific birth rates. (These ultimate age specific birth rates came from the ultimate cohort fertility pattern and timing pattern.) The interpolation produces age-specific birth rates projected for each year and each cohort over the period of the forecast.
- The interpolated rates are then adjusted according to the completed cohort fertility rates set in the assumptions.
- There are further adjustments and checks, but the final step consists in applying the age-specific birth rates to the projected population of women in childbearing ages, about as shown in the previous numerical example which appeared in Table 4.4 in the text.

Hence the U.S. Bureau of Census follows the same basic procedure, but with elaborated and improved techniques for estimating the components.

CHAPTER 5

Enrollment Projections for Educational Planning: An Instructional Unit

1.0 *The Instructional Objectives of This Unit on Enrollment Projections*

This unit is designed to provide:

— Background information on the use and usefulness of enrollment projection for educational planning.

— An outline of the situations in which enrollment projections are used in planning, with emphasis on projections at national or systems-wide level.

— A description of the mathematical model which underlies enrollment flow projections.

— An explanation of the flow rates of promotion, repetition, and dropout which determine enrollment flows through a graded school system. These three rates are the parameters which govern system flow and output.

— An illustration, using a numerical example, of an enrollment flow projection.

— An introduction to an instructional exercise on enrollment flow projections using school system data.

— Background information on computer-coded models for enrollment projections.

— A general background for understanding how flow models and more comprehensive manpower requirements and educational flow models can be used for tracing policy and program implications.

The expected learning outcomes are:

— Learners will demonstrate general knowledge of how enrollment projections are used in planning.

— Learners will specify the situations in which enrollment forecasts are required, and detail the information which is required to perform the projections.

— Learners will be able to present and explain the mathematical structure of enrollment flow models.

— Using the model and some example data, learners will be able to project enrollment flows through a one- or two-year plan cycle.

— Learners will understand the mathematical structure of flow models used in the computer exercises which would follow this unit in a usual sequence of instruction. (See Appendix 5.1 at the end of this unit.)

— Learners will also obtain a basic understanding of how enrollment flow models can be used to trace policy and program implications for the educational system; learners will also be able to illustrate this understanding by giving examples of policy change possibilities.

— Learners will also understand how enrollment flow models fit into larger, compound models, in which manpower requirements and educational supply projections are linked.

1.1 *Background Note on Enrollment Projection in Educational Planning*

Enrollment projection is a standard task in educational planning, Projections are made at the national level for the centralized school systems common in most developing countries. Enrollment projections may also be run for subnational areas, regions or provinces, or school districts. Projections are also run for local communities, town, or cities; and enrollment projections may be made for single institutions, particularly for large secondary schools or universities. The basic methodology is the same for enrollment projections at any level, from single institution to national system, although the data and the problems of analysis will differ slightly.

The most straightforward task is projecting enrollments for a national system, because the system is closed, meaning that there is no migration, or it is negligible. Or, if there is migration, then sounder statistics are available at the national level. Generally, the larger the unit the better the data. An enrollment projection is usually preceded by a demographic projection of the numbers of children who reach the legal age to enter the system. Once the number of entrants into the system is forecast, they are moved through the system according to the flow rates that prevail in the system. The flow is determined by the promotion, repetition, and dropout (includes death/migration) rates. These are called the flow rates of the system. A national level projection based on flow rates will be illustrated in this unit.

The model and methodology are essentially the same for subnational projections, except that the projections are complicated by the need for accurate migration statistics. Internal migration statistics are not readily available in either developing or developed countries; and when the migration statistics are available they are not easy to assess for accuracy or precision. Sometimes a special research study is necessary to estimate the area migration characteristics. Migration into or out of a village, town, or city district will determine future numbers of children available to enter the various grades and levels of the system. Migration is influenced by the geographical and physical characteristics of the area, the economic and social opportunities, or lack of them, and any of a number of social, cultural, economic, and political influences that may be operating at a given time and in a given place. Estimating these factors and their influence is a problem for sociological research and demographic analysis. Once the estimates are obtained, the essentials of the method are the same as in national projections. Migrants may, however, enter the school system in grades above the first, and the model must be modified to accommodate these inflows or outflows at all levels.

In projecting enrollments for single institutions it is difficult to establish the *catchment area*, or entrants pool, that feeds the system. Universities, and sometimes large secondary schools, may draw from populations residing in large, ill-defined areas. Often a special research study of the catchment or sending area, and the entrants pool, must be run. Once this pool is established, the model follows the general form outlined in this paper.

1.2 *Introduction: Enrollment Projection for Planning*

Enrollment projections are central to educational planning because the future development of the system will depend on the numbers and kinds of students entering the various grades and levels and programs in the system. On the basis of future enrollment projections, program coverage and input requirements can be determined; and on the basis of this, costs and future budgets can be estimated. In manpower planning, enrollment projections are the basis of the supply estimates, and these are compared with requirements or demand estimates, in order to calculate deficits and surpluses of given classes of educated and trained workers. In education or manpower planning, the central dynamic of the system is based on future changes in enrollments and graduates. Planners at some stage in their work prepare enrollment projections, either for an entire school system, a special region of the country, or a single institution.

2.0 *Educational Systems Models and Enrollment Flow Models*

The flow of enrollments through a graded school system can be described by simple models. The ideas behind the models are also easy to understand. The procedures for moving enrollments through the grades of a system are simple and general. The models and procedures can be applied in a wide variety of planning situations. It is worth making a small effort to understand the logic of the method because it underlies almost all systematic models and computer routines for projecting enrollments through the levels and grades of a system. Because the method is so general and permits wide application in planning practice, it is also worthwhile understanding the general mathematical expressions of the model. (The mathematical explanations are deferred to Appendix 5.1).

2.1 *A Graphic Model of a School System*

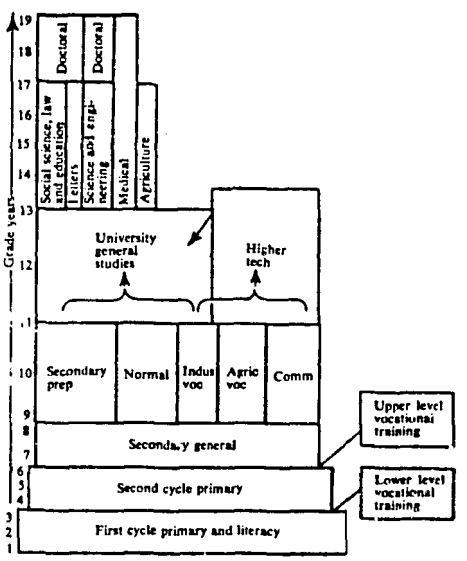
Before looking at the mathematical expression of the model we will begin with a more familiar model of reality, a graphic scheme of an education and training system. This scheme is shown in Figure 5.1, which is a modified version of an actual system. (An alternative way of depicting an educational system is shown in Exhibit 5.1 at the end of this unit).

Most planners have seen systems schemes similar to the one shown in Figure 5.1. Such schemes are useful for planners and administrators. Figure 5.1 attempts to show the complete system of educational programs from

elementary school through university level. The scheme begins with grade 1 of elementary school and goes through to the very highest-level programs, some of which may be offered outside the nation itself.

Figure 5.1

A Conventional Graph of an Educational System



Other similar schemes might show different arrangements and different features of the educational program. (Exhibit 5.1 emphasizes the dynamics of flow through the system. All the elementary grades have been grouped in one stage, and the intermediate grades have been grouped as J.H.S., Junior High School. The level of detail in a graphic systems model depends on the purpose of the planner or administrator.)

3.0 *Description of an Enrollment Flow Model and a Simple Example of the Arithmetic.*

In the enrollment flow model of the following exercise we will limit attention to the elementary school level, grades 1 to 6. The same procedure is followed for tracing enrollment flows through all grades, levels, and programs of the system. The form of this model is completely general, and it is found as part of many educational planning models. Among planners, this form is referred to as an Enrollment Flow Model, a term that will be used in this discussion.

The number finishing grade 6, the highest grade of the elementary school level, is determined by:

a. The number entering the first stage of the system, and in this case it will be limited to the number enrolling in grade 1 for the first time.

b. The number promoted from grade 1 to grade 2 and from grade 2 to grade 3 and on to grade 6, the final grade in the elementary level. (The same applies for flows from level to level, as, for example, the number who go from grade 6 of elementary to grade 7 of intermediate, and then to general secondary school. The flow can then be traced by the proportion who go from the final stage of schooling into the work force. This rate is sometimes called a workforce entry rate.

c. The number who repeat the grade.

d. The number who drop out of the system at a given grade level.

The number who are *promoted,* who *repeat,* and who *dropout* can be converted to a proportion, or a rate, by dividing by the original number enrolled. If the original enrollment was 100, and 90 were promoted, 6 repeated and 4 dropped out, the promotion rate would be .90, the repetition rate would be .06, and the dropout rate .04. These rates will be symbolized as p (promotion), r (repetition), and d (dropout). The rates always add to one, because they are proportions that cover all possibilities. Hence: $p + r + d = 1$. In the example given: $.90 + .06 + .04 = 1$.

Once the idea of flow rates, or transition proportions, is understood it is easy to summarize the procedure briefly and understand the way even larger systems models work. The same procedure is used over and over again. The computer simply multiplies enrollment by promotion rates to take the enrollments through the grades of the elementary level to graduation, and then multiplies the number of graduates by rates for continuing on to other school levels or for entry into the workforce. Before presenting the general, or mathematical, form, of the flow model it is worth emphasizing a fundamental assumption. *It is assumed that the rates are stable over time, at least over the period of the forecast. Or it is assumed that the rates can be changed as a result of policy and program interventions. These assumed or target rates then become stable enough to project enrollments.* Hence, rates may be thought of either as historically determined, or as targets which are set. In developing countries, rates are not stable, but change over time. This puts a time limit on the validity of projections.

In this instructional unit we will not discuss the methods for estimating the rates in the first place. In countries where educational statistics are based on machine tabulation of individual promotion records, the estimates are usually readily available, valid and reliable. In these same countries where there is social promotion (near-automatic promotion of all enrolled), the promotion rate may be almost 1. Dropout and repetition rates may be low, but there is always some dropout or repetition.

The challenge for analysts comes in those countries where statistics are not based on individual records tabulated by machine, but instead are based on analysis of aggregate data. Only groups of students are followed through the grades by years, and the flow rates are estimated. The methods for making these estimates are covered in the next instructional unit.

3.1 *Mathematical Form of the Flow Model*

To estimate enrollments by grades for the following year, we multiply the enrollment by grades in the present year by promotion, repetition, and dropout rates, and add in the new enrollments coming into the grades during the year. This statement can be symbolized in compact algebraic notation:

$$z_{t+1} = A_t z_t + a_{t+1}$$

Enrollments by grades in the following year $t + 1$ = A (p, r and d rates) multipled by z(enrol), + a(entrants)

The procedure is clearer if we examine the way it is arranged for the computer. Note that the ordering of terms is changed slightly for the computer operation in Figure 5.2.

Figure 5.2

The Basic Flow Model for the Computer

$$\underbrace{\begin{bmatrix} r_{1t} & 0 & 0 & 0 & 0 & 0 & 0 \\ p_{1t} & r_{2t} & 0 & 0 & 0 & 0 & 0 \\ 0 & p_{2t} & r_{3t} & 0 & 0 & 0 & 0 \\ 0 & 0 & p_{3t} & r_{4t} & 0 & 0 & 0 \\ 0 & 0 & 0 & p_{4t} & r_{5t} & 0 & 0 \\ 0 & 0 & 0 & 0 & p_{5t} & r_{6t} & 0 \\ d_{1t} & d_{2t} & d_{3t} & d_{4t} & d_{5t} & d_{6t} & 1.0 \end{bmatrix}}_{A_t} \cdot \underbrace{\begin{bmatrix} z_{1t} \\ z_{2t} \\ z_{3t} \\ z_{4t} \\ z_{5t} \\ z_{6t} \\ z_{dt} \end{bmatrix}}_{z_t} + \underbrace{\begin{bmatrix} a_{1,t+1} \\ a_{2,t+1} \\ a_{3,t+1} \\ a_{4,t+1} \\ a_{5,t+1} \\ a_{6,t+1} \\ 0 \end{bmatrix}}_{a_{t+1}} = \underbrace{\begin{bmatrix} z_{1,t+1} \\ z_{2,t+1} \\ z_{3,t+1} \\ z_{4,t+1} \\ z_{5,t+1} \\ z_{6,t+1} \\ z_{d,t+1} \end{bmatrix}}_{z_{t+1}}$$

This says that when we multiply the enrollments in grades 1 to 6 in year t by the repetition (r), promotion (p), and dropout (d) rates, and add in new entrants, a_{t+1}, the result is the enrollments by grades in the following year, z_{t+1}. The arrangement may appear difficult to understand at first glance for those not accustomed to looking at mathematical expressions, but a simple numerical example, using actual country data, will make it clear. It is worth understanding the flow model because this is what the computer does hundreds of times in any model. The same model can be applied to all graded systems anywhere. Appendix 5.1 gives a brief review of matrix algebra and applies it to a simple example of enrollment projection.

3.2: *An Arithmetical Example*

Figure 5.3 shows the basic computer scheme illustrated with a simple arithmetical example which traces the flow of enrollments for students from the base year 1975-76 to the following year 1976-77 for the first six primary grades. A_t is the matrix of repetition, promotion, and dropout rates for the six grades of elementary schooling for this country. The repetition rates are .206, .150, etc., along the main diagonal. The promotion rates are .735, .840, to the left of the main diagonal. The dropout rates are along the bottom row, .06, .01, etc. For simplicity in this worked example we have excluded from considera-

tion the dropout rates in the bottom row, and the final column of zeros in the matrix A_t. This means we are dealing only with the six rows and six columns within the inner lines of A_t, or, in other words, A_t is a 6-row and 6-column matrix. (Section E of Appendix 5.1 explains why this is done).

The numbers shown in z_t are the enrollments in grades 1 to 6 in the year 1975-76. The number shown in a_{t+1} is the entering enrollment to grade 1 in 1975-76. (Note that this arrangement shows new enrollments entering only at grade 1, but in some situations new entrants in 1975-76 could come in at any grade). The result z_{t+1} is the enrollments in grades 1 to 6.

Figure 5.3

Example of Enrollment Flows, Using the Computer Model

$$\underbrace{\begin{bmatrix} .206 & 0 & 0 & 0 & 0 & 0 & 0 \\ .735 & .150 & 0 & 0 & 0 & 0 & 0 \\ 0 & .840 & .160 & 0 & 0 & 0 & 0 \\ 0 & 0 & .830 & .260 & 0 & 0 & 0 \\ 0 & 0 & 0 & .700 & .170 & 0 & 0 \\ 0 & 0 & 0 & 0 & .800 & .100 & 0 \\ .06 & .01 & .01 & .04 & .03 & .02 & * \end{bmatrix}}_{A_t} \cdot \underbrace{\begin{bmatrix} 84206 \\ 66433 \\ 60335 \\ 61300 \\ 45750 \\ 36160 \end{bmatrix}}_{z_t} + \underbrace{\begin{bmatrix} 58551 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}}_{a_{t+1}} = \underbrace{\begin{bmatrix} 75897 \\ 71856 \\ 65460 \\ 66016 \\ 50688 \\ 40216 \end{bmatrix}}_{z_{t+1}}$$

Grade 1 = (.206)(84206) + 58551 = 75897

Grade 2 = (.735)(84206) + (.150)(66433) = 71856 + 0 = 71856

General Rule: Multiply each entry in the Matrix A_t row by each entry in the z_t *column* corresponding, and add in the a_{t+1} number.

At the bottom of Figure 5.3 is a simple worked example for grades 1 and 2. For grade 1 the repetition rate (.206) is multiplied by the first-grade enrollment (84,206) and the result added to the new entrants to grade 1 (58,551), giving a first-grade enrollment for the following year of 75,897. For grade 2 the promotion rate (.735) is multiplied by the first-grade enrollment (84,206), and this result is added to the repetition rate (.150) multiplied by the second-grade enrollment (66,433). The result is the second-grade enrollment in the following year (71,856). If new enrollments had been allowed at the second grade, these would have been added in, but the entry is 0 in this example. The same procedure is followed to yield the enrollments in the following grades: 3, 4, 5, and 6. If dropouts are being calculated, then each dropout rate in the bottom row is multiplied by each enrollment in the column z_t. For example, the dropout for the first grade is (.06) × 84,206 = 5052.

4.0 *Suggested Exercise with Enrollment Flow Models*

It might be useful, as an exercise, to compute the enrollments for grades 1 to 6 for the following year, 1977-78. For this we already have the enrollments in grades 1 to 6 in the year 1976-77. The only new information/data we require is the number of new entrants to grade 1. We will assume this is 60,000. We will also assume that the promotion, repetition and dropout rates stay the same. (Note that it would be simple to introduce improved rates by simply changing the p, r, and d rates in the matrix A. See Appendix 5.1 for an illustrative exercise.)

4.1 *Additional Comment on the Flow Model*

Two additional points can be raised. First, the origin of new entrants to the system. We have assigned the number 60,000 for the exercise, but generally this number comes from projecting the population by age groups and estimating the fraction of the population in relevant age groups that will enter school. The model in the example shows entrants at grade 1 only. The largest fraction of an age group to enter grade 1 is from the 6-year-olds, the normal entry age to Elementary School in this country. About 60 percent of 6-year-olds enter school; 20 percent of the 7-year-olds enter, etc. Later we will discuss policies to attain almost 100 percent of the 6-year-olds as entrants to grade 1. The fraction of children seven years and older will drop in the first grade, as admission of 6-year-olds is regularized.

Second, the progress of those promoted from grade 6 to higher levels and grades in the system. In this example, about .88 are promoted from grade 6 and eventually graduate. A fraction of graduates go on to higher grades and at some point enter the workforce. These workforce entry and participation rates are discussed in the units dealing with projection of manpower supply in Part Three of this volume.

5.0 *Tracing Policy Planning and Program Implications from Flow Models: A General Comment*

It is helpful to understand the simple arithmetic behind flow models, but once this is understood the only interesting matter is in using the model to study the effects of policies, plans, and programs on the educational system. We have seen that the flow rates can be easily changed in the model. Changing them in the real world is not so easy. A compound manpower and educational planning model would estimate the requirements for educated and trained manpower in the workforce. Within this compound model, the enrollment flow model would estimate the supply of educated and trained people to meet the manpower requirements. This future supply will be largely determined by:

- Entrants into the system. In the example given for elementary school there are entrants only at grade 1.
- Flow through the grades of the system. These are determined by the promotion, repetition and dropout rates. Promotion rates move enrollments through the grades of the elementary school level to graduation from grade 6, or highest grade of the level. (Recall that promotion, repetition, and dropout rates are related to each other and add to 1.)
- Continuation rates to a higher level of the system. In the present case, an example would be continuation to grade 7, which is the secondary level. There also might be entrance into the workforce.

Chapter 7 of Volume I offered a discussion of the policy issues raised by the enrollment flow model component of a comprehensive planning model. Here we will briefly examine some of the policy issues raised by changes in enrollment flow rates.

5.1 *Policy Changes and Model Changes*

Using the enrollment flow model, planners and policy makers could change any of the numbers or rates listed, and then study the resulting changes in the numbers graduating from grade 6 of elementary school, the number continuing on to grade 7 in the intermediate level, or the number entering into the workforce. These changes could be related to policies and plans. For example, policies could be established to accommodate a larger percentage of six-year-olds into the first grade, and in later years this would increase the enrollment flow through and out of the elementary grades. The policies would have to be backed by programs, and the programs would require increased resources; for example, providing new schools in remote regions and training and assignment of more teachers. Putting increased numbers of entrants into the model does not change reality unless actual changes are made in programs and allocations to accomplish the increase, but the model does serve to show planners the resource, cost, and manpower supply consequences the changes would bring in future years.

Policies could also be developed to change flow rates. An obvious example is to adopt social promotion, or something similar to it, where promotion through the grades is made close to automatic. Programs would have to be developed to improve education and to accommodate more enrollments at higher grades. The model does not accomplish this; it merely shows planners what the consequences would be for higher grades in future years. Similarly, continuation rates to higher levels, as well as workforce entry rates, can be changed. This would increase the supply of higher-level manpower.

5.2 *Tracing Changes in the School System*

Using enrollment flow models, we will examine how changes will affect the system in future years. Table 5.1 shows projections for the elementary school grades of a country for 1984-85 when two different sets of promotion rates are used, the present rates and improved rates. Note that at the present rates the projected enrollments are actually greater in the first three grades; but with the improved rates, enrollments are larger in grades 4 to 6. One goal of educational planning is to increase the numbers of students who complete the last grade and graduate (always assuming that the education offered to the increased numbers is the same in quality or better). In this sense, the improved rates do reflect improved performance of the system.

It may seem surprising that the total enrollment in the elementary grades (1984-85) with improved rates is actually lower than with present rates. Though more students pass through the system with the improved rates, fewer stay in the schools through repetition. It is possible, though this run of the model does not show it, that even with the program requirements and budget allocations necessary to attain the improved rates, the total costs of running the elementary schools may be less. If this is so, then it represents a gain in efficiency; more output for less input. Different costs for maintaining old rates and improving to new rates can be estimated, and the total cost of improving the system flow over time can be projected and studied by plan-

Table 5.1

Enrollments in Elementary Grades in 1984–85 (Projections from 1975–76 with Present and Improved Rates)

Grades	With present rates*	With improved rates*
1	145571	130274
2	115295	113828
3	106983	106184
4	108828	108735
5	83543	86738
6	68665	78035
Total	628885	623794

*Source: Based on actual runs of a computer model applied to this school system. To simplify, actual data are not shown. Present rates are actual rates computed for system in 1975-76. Improved rates are based on projected improvements.

ners. This was illustrated by McGinn and Davis in Venezuela (1969) and by Schiefelbein and Davis in Chile (1974). The latter work illustrated the advantage of a comprehensive model which traces efficiency consequences through the whole system, because, though unit costs were lowered and efficiency improved in the primary school level, the sudden increase in numbers flowing through the system increased both total costs and unit costs at the next higher level in secondary schools.

It is possible to trace other implications of changed numbers and rates by using an enrollment flow model alone. Some of these effects will be obvious and others not so obvious—in fact, contrary to what might be expected. One seemingly contrary effect is indicated in Table 5.1, where enrollments in the first grade appear to fall under improved rates. Although this may seem at first to indicate that new entrants into the first grade may be falling, it does not mean that more children are being denied the opportunity to enter school. On the contrary, accompanying demographic projections indicated that over a period of ten years almost all six-year-olds could enter school. First-grade enrollment still came out smaller. This can happen because there is a lower repetition rate, and hence fewer children staying back in the first grade to increase the enrollments and, in one sense, waste resources.

Improved flow rates will not only yield larger enrollments in grades 7, 8, and 9 (intermediate level), but will also increase the numbers of graduates available to enter the workforce. If entry rates stay the same, or improve, larger numbers will enter the workforce with more education. However, we may again see an effect that appears counter to our expectations. It will require time for larger numbers of more highly educated people to enter the workforce. *In the short-term run of the model,* from 1975-76 to 1984, improved rates may actually lead to fewer youths entering the workforce, because more

people are being kept in school to reach higher levels of educational attainment. Here we have gone beyond the enrollment flow model. This introduces the policy and plan implications of compound models which were discussed in Chapter 7 of Volume I.

6.0 *A Closing Note on Compound Planning Models*

Planners, policy makers, and decision makers can better study and understand the system-wide effects of policies, plans, and programs if the educational flow model is incorporated into a larger or compound model. The larger systems model permits the planner to compare requirements for educated and trained manpower with projections of the supply of the education and training system. The advantage of the larger or compound models is that they can provide a general framework for studying effects throughout an educational system.

Policies and programs implemented in the elementary school grades will have consequences in the higher grades, as we have seen. In 1964, a large and rapidly developing country markedly improved its primary school system and doubled promotions and flow through the system to higher grades. Students poured into and through the intermediate and secondary school grades, and suddenly they were demanding entrance to the universities. There was no space in universities, which had already been expanding at a rapid rate. The last-ditch alternative, implemented without curriculum planning or resources, was to add another year onto the secondary level. This emergency measure was taken mainly to keep secondary graduates out of universities one more year. The educational benefits of that extra year remained dubious for a long time afterward.

The policy and program issues raised by using comprehensive or compound planning models have already been discussed in the previous volume. The compound model shown in Figure 1.3 of Chapter 1 of this volume had four major components, or blocks. Enrollment flow models are the basis of the third block of the compound model. Flow models are used to project the supply of the education/training system. In the compound model these supply projections are compared with the manpower requirements projected in block III. Enrollment flow models can be used for general policy analysis when they are incorporated into a larger systems model framework.

The compound model may be used to identify gaps between requirements for educated and trained manpower, as estimated in the manpower requirements block, and the supply of educated and trained people, as estimated in the education training block. The model serves to forecast requirements and supply over time, and to give planners and policy makers an estimate of short falls, or surpluses, in educated and trained manpower. By having these estimates beforehand, planners and decision makers have time to develop policies and programs to remedy estimated shortages or surpluses.

Planners can use the model to simulate trials of alternate ways of remedying the problems. If the supply of educated and trained people is insufficient to satisfy the manpower requirements, one alternative is to to reduce the

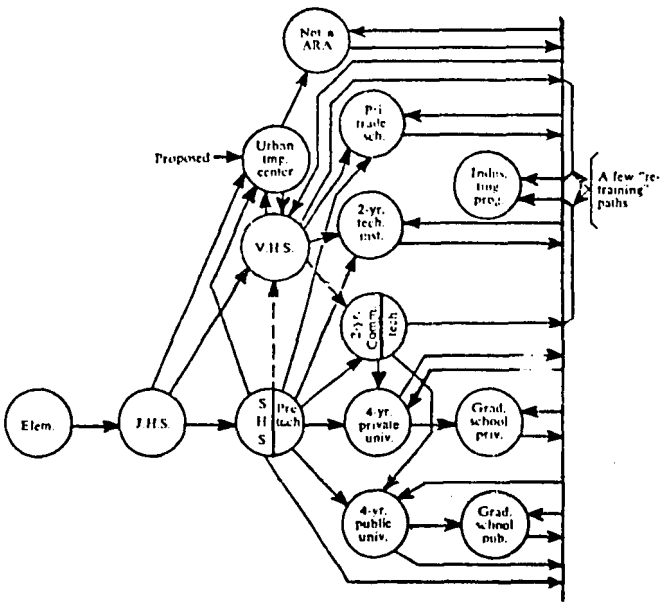
requirements. Manpower requirements are estimated on the basis of economic output projected (Chapter 8). Plan alternatives may be to reduce the output, scale down economic growth targets, modify the output mix, or change the technology. This will reduce manpower requirements both in quality and quantity. Consideration of this alternative is a task of economic planners in the country. Another alternative might be to recruit and allocate more expatriate manpower to fill critical gaps by sectors and occupations. A compound model might provide a system for tracing this alternative in another block of the model, but this will be discussed in other sections of these planning materials. A third alternative is to develop educational policies and programs to increase and improve the supply of educated and trained people. It is this third set of policy and program options that can be examined with an enrollment flow model.

6.1 *A Summary Comment*

Compound models provide the planner with a tool for relating economic growth policies and plans to manpower allocation policies and plans and, in turn, to educational policies and plans, which lay out alternative possibilities for changing education and training programs to match the supply requirements. See Exhibit 5.1. In other places in this book the policies which govern economic growth and manpower allocation will be discussed, but here the emphasis is on the education and training policies which affect supply of educated and trained manpower to meet manpower requirements.

Exhibit 5.1

An Alternative Scheme of Education and Training



APPENDIX 5.1

Supplementary Material on the Use of Matrices for Enrollment Projections

I. *Intent of This Appendix*

The purpose of the material in this appendix is to provide instruction supplemental to that in the text, on the use of matrix operations for enrollment projections. There will be three sections to the appendix:

- A simple one-year enrollment projection will be presented without the use of matrices, to provide a reference point for comparison in section 3 below.
- Matrix notation will be introduced and the operations of addition and multiplication illustrated with examples.
- The same examples, used in section 1 above, will be presented using matrices.

II. *A Simple One-Year Enrollment Projection*

Imagine that we are concerned with a three-grade school system at time t and that we wish to project what the enrollment will be at time $t + 1$. Suppose we have the information shown in the first four sections of Table A5.1: (a) enrollments by grade at time t; (b) enrollments broken down into

Table A5.1

The Components of a Simple One-Year Enrollment Projection

1		2			3			4	5				
Enrollment by grades		Promotions, repetitions dropouts			Rates			New entrants	Enrollments, time = t+1				
Grade	Enrollment, time = t	P	r	d	P	r	d	a	P	+	r	+	new
1	100	90	4	6	.90	.04	.06	95	0	+	4	+	95 = 99
2	80	76	2	2	.95	.025	.025	5	90	+	2	+	5 = 97
3	75	66	6	3	.88	.08	.04	2	76	+	6	+	2 = 84

those who *are promoted* to the next grade, those who *repeat* a given grade, and those who *drop out* from the system; (c) the information in (b) expressed as rates; and (d) estimates of the number of new entrants to each grade of the

system. The fifth section shows estimated enrollments at time $(t + 1)$ as the sum of those promoted from the previous grade, those who repeat the grade, and those who are new entrants to the system at that grade. It is possible to standardize this simple enrollment projection method so that a computer can do the necessary computation. In doing so, it is most convenient to use matrices.

III. *Matrix Notation and Definitions*

A. *Definition:* A *matrix* is just a rectangular array of numbers.

Examples: $\begin{bmatrix} 1 & 2 & 4 \\ 2 & 1 & 0 \end{bmatrix}$ or $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$

B. *Kinds of matrices:* A matrix is described by the number of rows and columns it has: an $n \times m$ matrix (read as "n by m") has n rows and m columns. Thus, the first matrix above is a 2×3 matrix, while the second is a 2×2.

C. *Definition:* A *vector* is a row or a *column* of numbers:

Examples: $(1 \quad 2 \quad 7 \quad 0)$ $\begin{bmatrix} 4 \\ -1 \\ 3 \end{bmatrix}$

D. *Addition of vectors:* Vectors can be added if they are the same kind, that is, if they are both row (or column) vectors with the same number of elements. In Example 1, each of the two column vectors has three elements. *Vectors are added by adding corresponding elements.*

Example 1: $\begin{bmatrix} 6 \\ 4 \\ 3 \end{bmatrix} + \begin{bmatrix} 1 \\ -1 \\ 0 \end{bmatrix} = \begin{bmatrix} 7 \\ 3 \\ 3 \end{bmatrix}$

E. *Multiplication of matrices or vectors:* Matrices or vectors may be multiplied if the number of columns of the left-hand matrix (or vector) equals the number of rows of the right-hand matrix. In Example 2 below, the left-hand matrix is 2×3 (3 columns) and the right-hand matrix is 3×2. Matrix multiplication follows a standard procedure:

— The top row of the left-hand matrix is used first.

— Each element of this row is multiplied by its corresponding element in the first column of the right-hand matrix, and the products are summed. This answer is written down as the element in the first row and column of the answer matrix.

— Still using the first row of the left-hand matrix, the same procedure is applied to the second column of the right-hand matrix and the answer written as the first element in the second column of the answer matrix. This step is repeated until the top row of the left-hand matrix has been multiplied by all columns in the right-hand matrix.

— The process is repeated using the second and subsequent rows of the left-hand matrix until all rows have been used.

The process is hard to describe in words but is simple in actual practice, as shown in Example 2:

Example 2:

$$\begin{bmatrix} 1 & 2 & 0 \\ 0 & 4 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 0 & 2 \\ 1 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 4 \\ 1 & 9 \end{bmatrix}$$

Each element of the answer matrix is given below:

$1 = 1(1) + 2(0) + 0(1)$
$4 = 1(0) + 2(2) + 0(1)$
$1 = 0(1) + 4(0) + 1(1)$
$9 = 0(0) + 4(2) + 1(1)$

IV. *Enrollment Projections Using Matrices and Vectors*

The basic format for enrollment projections using matrices is shown in Figure A5.1. A vector of enrollments by grade (at time t) is multiplied by a matrix of repetition and promotion rates. This yields a new vector which is then added to the vector of new entrants to yield a vector of projected enrollments. The basic steps in constructing the vectors and matrices are as follows:

Figure A5.1

The Basic Enrollment Projection With Matrix Notation

$$\begin{bmatrix} \text{Matrix of} \\ \text{promotion and} \\ \text{repetition rates} \end{bmatrix} \cdot \begin{pmatrix} \text{Vector} \\ \text{of present} \\ \text{enrollments,} \\ \text{time} = t \end{pmatrix} + \begin{pmatrix} \text{Vector} \\ \text{of new} \\ \text{entrants} \end{pmatrix} = \begin{pmatrix} \text{Vector of} \\ \text{enrollments} \\ \text{time} = t + 1 \end{pmatrix}$$

Vector of present enrollments: Create a column vector of present enrollments, grade 1 being the first element, grade 2 the second, etc.

Vector of new entrants: Construct a column vector of new entrants, where the first element refers to grade 1, the second to grade 2, etc.

Matrix of promotion and repetition rates: Construct a matrix with the same number of columns as the school system has grades, with column 1 referring to grade 1, column 2 to grade 2, etc. The steps are as follows:

i) The repetition rate for grade 1 goes in the (1,1) element (first row, first column). Directly below it in the (2,1) element the promotion rate for grade 1 (i.e., the first grade to second grade promotional rate is placed. For the time being, nothing is done with the dropout rate.

ii) The repetition rate for grade 2 is placed in the (2,2) element, and directly below it the promotion rate for moving from grade 2 to grade 3.

iii) This process of building up the matrix with repetition and promotion rates is continued until the last grade has been reached. For example, if we have a six-grade system, the repetition rates is in the (6,6) spot and the promotion rate in the (7,6) spot.

iv) After the matrix has been built up this way through the last grade, dropout rates are placed in a bottom row.

v) Finally, put zeros in all elements of the matrix not filled.

Again, the procedure is complicated to describe, but is quite simple in practice. The example i Figure A5.2 shows the simple enrollment projection performed above. Note that, for the projection, we use only as many rows of our promotion, repetition, and dropout matrix as there are grades in the system. For example, here we have a 3-grade system, so a 3 × 3 matrix is used for projection, above the line. The other rows are useful, however. The bottom row, when multiplied by present enrollments, shows dropouts of the system (41). The row above shows graduates (.88 × 75 = 66).

Figure A5.2

A Simple One-Year Enrollment Projection Using Matrices

$$\begin{pmatrix} .04 & 0 & 0 \\ .90 & .250 & 0 \\ 0 & .95 & .08 \\ 0 & 0.88 & .88 \\ .06 & .025 & .04 \end{pmatrix} \cdot \begin{pmatrix} 100 \\ 80 \\ 75 \end{pmatrix} + \begin{pmatrix} 95 \\ 5 \\ 2 \end{pmatrix} = \begin{matrix} \text{New} \\ \text{Enrollments} \\ \begin{pmatrix} \\ \\ \\ \end{pmatrix} \end{matrix}$$

$$\begin{pmatrix} 4 \\ 92 \\ 82 \end{pmatrix} + \begin{pmatrix} 95 \\ 5 \\ 2 \end{pmatrix} = \begin{pmatrix} 99 \\ 97 \\ 84 \end{pmatrix}$$

Dropouts:

Grade one = (.06)(100) = 6
Grade two = (.025)(80) = 2
Grade three = (.04)(75) = 3

Graduates = (.88)(75) = 66

APPENDIX 5.2

A Note on Computer Coded Models for Enrollment Forecasting

Elizabeth Truesdell and Mary Hyde

This section refers to the introductory guide of an interactive computerized model for simulation of the flows of students through a school system. (It was written to accompany a user's guide and program listing which detailed the computer-coded model for projecting enrollments in a school system. This program documentation was prepared as part of the USAID/Harvard Project in educational planning. Because of its size, the program could not be included here, but it has been sent out as part of the product documentation to the program libraries of some planning offices in developing countries). The model is a modified version of one developed by the World Bank which was a modified version of models developed in UNESCO, Harvard, Chile, and other planning centers and projects. The model consists of three submodels: the Enrollment Forecasting Model, the Educational Efficiency Model, and the Educational Targeting Model. Each submodel involves calculation of the flow of students through a school system, but each is designed for slightly different applications.Because the computer program is interactive, the user is asked specific questions by the model, and enters the data via a terminal in response to the specific questions.

The Enrollment Forecasting Model asks the user to supply initial enrollments, grade-specific promotion, repetition and dropout rates, new entrants over time at each level of the system, and the number of years for the projection. The computer then performs the necessary calculations to project the flow of students through the school system.

A complete description of the computer-coded model is available in a paper prepared by Elizabeth Truesdell and Mary Hyde for the USAID/Harvard Project (Elizabeth Truesdell and Mary Hyde, "Computer Coded Models for Enrollment Projection, Targetting and Efficiency Assessment (An Interactive System)", Cambridge, Mass: USAID/Harvard Project Paper 38, 1979. This paper discusses the underlying model, which is essentially the same as the one shown in this chapter, discusses the purpose, capacity and characteristics of the three submodels, and furnishes essential program documentation and directions for students to access an interactive version of the model which has sufficient flexibility, with some modifications, to be mounted on various machine systems. The length of the description and documentation (154 pages) makes it impossible to include the paper in this book, but it will be distributed on a limited basis as a part of the USAID/Harvard project.

CHAPTER 6

Methods of Estimating Enrollment Flow Rates: An Instructional Unit

Ernesto Schiefelbein and Russell G. Davis

(Maria Clara Grossi and Andrés Schiefelbein performed most of the tabulations on which this analysis is based).

1.0 *Objectives and Content of This Unit on Enrollment Flow Rates*

Let us review a chain of relationships between an educational plan and the data which support it. The adequacy of an educational plan may depend on the quality of the enrollment projections on which it is based. In turn these projections depend on the validity of the assumptions on which they are based and on the accuracy and precision of the statistics employed that derive from the data used to estimate them. The objectives of this instructional unit are:

— To acquaint readers with the sources and types of data used to estimate the enrollment flow rates applied in the enrollment projection models covered in the previous instructional unit. The main types of data are educational statistics on enrollment, promotion, repetition, and dropout. These statistics, as reported in the aggregate, often have weaknesses. Demographic data on student age, educational attendance, and attainment may be used to supplement and cross-check educational statistics. A critical data component is the so-called age-grade matrix, which cross-tabulates students by age and grade. This unit attempts to specify data requirements and sources of data for age-grade tables and enrollment projections.

— To acquaint readers with the weaknesses of educational statistics, and with methods for dealing with weak or unavailable data. In some educational planning situations, essential data are not available to make accurate estimates of enrollment flow rates. In other planning situations, inappropriate analysis methods are applied.

— To provide instruction on methods of estimating enrollment flow rates when essential educational data are defective.

— To provide instruction on methods of estimating enrollment flow rates when essential educational data are missing.

The content of the unit follows directly from the objectives. A brief introductory comment is offered on the importance of educational statistics for planning. The weaknesses in these statistics are discussed in general terms. Data from Paraguay are offered to illustrate the classic method of diagonal analysis of enrollments, and to demonstrate weaknesses in the data which

are indicated by under-estimates of repetition. A brief comment follows on why estimates were unreliable in Paraguay.

Demographic data are useful to check and correct educational statistics, which are often inaccurate. There is a special problem with official rates. Inaccurate repetition rates can destroy the validity of enrollment flow rates as a basis for enrollment projection and educational planning. The remainder of this unit examines five methods which can be used to estimate flow rates when data are missing or defective.

Brief statistical appendices are offered at the end of the text. These illustrate the kinds of data and analyses which support enrollment projections in a country where educational data are of the quality which is typical in developing countries. The data are mainly taken from recent research studies and planning operations in Paraguay, but supporting evidence is brought in from research studies and planning practice in other countries of Latin America. For those who find educational statistics and statistical analysis tedious or difficult, this is not a unit of light and pleasurable reading. Despite editorial efforts to cut down tables and formulas, a number of tables are necessary to illustrate methods of analyzing educational data. The section is not designed for general purpose reading, but as a methodological reference for those who have the task of analyzing educational data. If this is not a current problem, the reader might skip detailed study of the section. The basics of enrollment projection were covered in the previous chapter.

1.1 *Background Note on Educational Statistics*

The effectiveness of an educational planning model is destroyed if the statistics used in the calculations are not accurate. Research studies suggest that the basic statistics published by ministries of education in developing countries are often inaccurate (Schiefelbein 1975). Flow rates based on these statistics are used to analyze enrollment trends and project enrollments. The enrollment series for Paraguay (1964-1976) in Table 6.1 show continuous growth over the whole period. The enrollment of 344,637 in 1964 increases to 467,552 in 1976. Increases appeared mainly in the higher grades while the first grade remained almost stable. In some countries, stable first-grade enrollments mean that a decreasing proportion of the population is attending the educational system. In other countries, stable figures mean students are flowing through the system at a faster rate. This was illustrated in the previous chapter. To determine which condition prevails, series data on repeaters and new entrants must be available for analysis.

Educational data from Paraguay will be used first to evaluate the reliability of the data, and second to suggest methods to correct unreliable data under alternative sets of assumptions.

1.2 *Checking Available Educational Data for Estimating Flow Rates*

Data on enrollments by grades and repetition by grades can be arrayed and analyzed to project enrollment flows. These data are sufficient to compute all

three enrollment flow or transition rates. Figures on repeaters in Paraguay are presented in Table 6.2. When these figures are related to enrollment figures in Table 6.3, the weaknesses of official statistics are demonstrated. The most common method for estimating enrollment flows is the diagonal method illustrated in Table 6.3. This is the classic method applied when data are fairly bad and highly aggregated. Davis (1966) has discussed other methods used many years ago when data in developing countries were even more inadequate. Currently, most developing country data permits analysis of the kind illustrated in Table 6.3 and described in the following outline:

(1)	a. Students in 2nd grade in 1974 (Table 6.1)	100,324	
	b. Repeaters in 2nd grade in 1974 (Table 6.2)	20,366	
	$(a - b = c)$		
	c. *Promoted* from 1st grade in 1973 (computed)	79,958	
(2)	d. Students in 1st grade in 1973 (Table 6.1)		126,077
	e. Repeaters in 1st grade in 1974 (Table 6.2)	31,722	
	c. Promoted to 2nd grade in 1973 (computed above)	79,958	
	$(e + c = f)$		
	f. Repeaters plus promoted (computed)		111,680
	g. Drop-outs from 1st grade in 1973 (computed $d - f = g$)		14,397
(3)	h. Students in 1st grade in 1974 (Table 6.1)	124,709	
	e. Repeaters in 1st grade in 1974 (Table 6.2)	31,722	
	i. *Newcomers* in 1st grade in 1974 (computed $h - e = i$)	92,987	

The same procedure is repeated in the next year:

(1)	a′ Students in 2nd grade in 1975 (Table 6.1)	99,139	
	b′ Repeaters in 2nd grade in 1975 (Table 6.2)	18,703	
	c′ *Promoted* from 1st grade in 1974 (computed $a' - b' = c'$)	80,436	
(2)	d′ Students in 1st grade in 1974 (Table 6.1)		124,709
	e′ Repeaters in 1st grade in 1975 (Table 6.2)	28,752	
	c′ Promoted to 2nd grade in 1974 (computed above)	80,436	
	$(e' + c' = f')$		
	f′ Repeaters plus promoted (computed)		109,188
	g′ Drop-outs from 1st grade in 1974 (computed $d' - f' = g'$)		15,521

Table 6.1

Enrollments by Grades, 1964-1976 in Paraguay

Year	Totals	1st	2nd	3rd	4th	5th	6th
1964	344637	117344	81181	51805	41077	27828	19102
1965	356998	118822	84215	59867	43054	29727	21313
1966	365932	119531	84921	62729	44796	31438	22517
1967	378463	120810	88608	64441	47409	32968	24227
1968	399685	120544	94760	69050	51103	36859	27369
1969	408524	119784	94320	72769	53250	38819	29582
1970	424179	125052	96799	74661	56602	40725	30340
1971	436857	126034	99585	77467	58009	43397	32365
1972	440151	125983	98826	79252	59114	43878	33098
1973	451530	126077	100796	80675	62147	46789	35046
1974	454853	124709	100324	82160	63299	47874	36487
1975	452249	121736	99139	81889	63763	48283	37439
1976	467552	128537	100560	83343	65693	50249	39170

Source: Unpublished figures, Dirección de Planeamiento, MEC, Asuncion, 1977.

Table 6.2

Repeaters and Repetition Rates by Grades: 1964-1976

Year	Total	Grades											
		1st	%	2nd	%	3rd	%	4th	%	5th	%	6th	%
1964	48274	32652	28	18397	23	11051	19	6074	15	2894	10	1385	
1965	78165	34679	29	20360	24	11931	20	6673	15	3230	11	1292	
1966	82486	36216	30	21262	25	12773	20	7391	16	3393	11	1451	
1967	85920	36518	30	22581	25	13805	21	7526	16	3728	11	1762	
1968	67623	31765	26	18339	19	9524	14	4812	9	1994	5	1189	
1969	73251	32082	27	20506	22	11044	15	5794	11	2525	6	1300	
1970	74943	31501	25	21096	22	12183	16	6067	11	2803	7	1293	
1971	76449	32265	26	21024	21	12389	16	6320	11	2960	7	1491	
1972	77169	32021	25	20890	21	12583	16	6909	12	3288	7	1478	
1973	77642	32326	26	20742	21	12161	16	6659	11	3330	7	1424	
1974	76366	31722	25	20366	20	12856	16	6963	11	3183		1276	
1975	69378	28752	24	18703	19	11946	15	6103	10	2680		1186	
1976	68606	28220	22	18413	18	11814	14	6155	9	2754		1250	

Source: Unpublished figures, Dirección de Planeamiento, MEC, Asuncion, 1977.

Promoted and *dropout* are computed by simple subtraction. Table 6.3 shows the difference between the number of promoted students reported by the schools (presented in parenthesis) and the estimated number of promoted, computed as described above. In each one of the four years presented in Table 6.3 the computed figure is larger than the official figure presented in parenthesis. Why? One explanation may be that a few students skipped one year, but that would not be likely to happen four years in succession. The explanation must be that the *Repeaters* reported in second grade are underestimated.

1.3 *Evidence of Error Based on Population Data*

Newcomers (entrants) are computed as the difference between first-grade enrollments and repeaters in that grade. However, if the new enrollments are compared with the seven-year-old population (presented in parentheses each year below the number of new enrolled), some doubts may also arise. The Latin American Demographic Center (CELADE) estimates the seven-year-old population for 1975 as 79,378 children. The school reports 92,984 new entrants. The system is receiving 13,606 students more than the population reaching school entrance age. Similar differences are observed in each one of the five years studied. (In addition, national census figures in 1975 show that 5.9 percent of the population never attended school.)

In summary, each year many more students join the educational system than the number who reach the entrance age normally set for joining the system. Such a difference is possible for one or two years, when a massive campaign is launched to enroll new students from all ages. But it is impossible to maintain such differences for more than a decade. Furthermore, no campaign occurred in Paraguay in the 1970s.

It seems evident that some figures are wrong. It might be that the Census figures are underestimated; however, demographers agree that errors in Census data would be no larger than 10 percent at most. If this statement is true, there are only two alternatives: enrollments or repeaters must be the sources of error. This point is discussed in more detail in Appendix 6.1.

2.0 *The Need to Study Repetition Rates*

The analysis of educational and other data in Appendix 6.1 demonstrates that it is worthwhile to look for alternative methods to compute the enrollment flow rates of repetition, promotion, and dropout. This is particularly true for repetition rates, or flow parameters, which are fundamental in carrying out enrollment projections using the enrollment flow model discussed in the preceding instructional unit.

The usefulness of the enrollment projections depends fundamentally on the accuracy of the three rates, or parameters, which determine flow, i.e., promotion, repetition, and dropout. The three rates are generally expressed as proportions, and add to 1; and hence if one rate is poorly estimated the other two rates may be in error. In developing countries, the rate that is subject to

Table 6.3

Paraguay Official Figures on Student Flow 1972-1976 Classic Method of Diagonal Analysis

Year	New Enrollments	Grade 1	Dropouts	Promoted	Grade 2	
1972	94,578 (73,014)	126,599	13,603		98,826	
	Repeaters	32,326		80,054 (77,725)	20,742	Repeaters
1973	93,751 (75,077)	126,077	14,397		100,796	
	Repeaters	31,722		79,958 (78,770)	20,366	Repeaters
1974	92,987 (77,198)	124,709	15,521		100,324	
	Repeaters	28,752		80,436 (73,968)	18,703	Repeaters
1975	92,934 (79,378)	121,736	4,566		99,139	
	Repeaters	28,220		82,147 (78,950)	18,413	Repeaters
1976	100,317 (82,357)	128,537			100,560	

Source: Ministerio de Educación y Culto, "Características del flujo de matrícula escolar en la educación primaria del Paraguay, Serie Estudios acerca del funcionamiento del sistema de educación del Paraguay, N 3, Asuncion, November 1977. Tables I, II, III, Annex 2.

( ) = Official population figures

most error is the repetition rate. It is also the rate that has the most profound impact on the efficiency of a school system, because repeaters are kept year after year in the same class, absorbing scarce inputs and taking up scarce space. Hence, educational policies to improve systems efficiency, cost-efficiency, output of graduates, and to increase the coverage of the population requiring basic education, are dependent on improvement, in this case reduction, of repetition rates. Thus, for planning purposes it is important to base projections, as well as policies and programs for improvement of systems, on accurate estimates of repetition. Repetition rates are more often inaccurate than are the complementary rates of promotion and dropout.

In each country there are different sets of statistics and different holdings of data available for the estimation of repetition rates. Here we develop several models, or methods, for improving estimates of repetition, depending on the data available. The methods can best be illustrated with an actual example of data in Paraguay. We will discuss five methods of estimation, each tailored to the educational and demographic data available for planning.

3.0 *First Method: Data by Grades and Ages*

The first method is used when the analyst has two basic sets of statistics: (i) enrollment statistics in the form of an age-by-grade matrix or cross-tabulation; and (ii) demographic data showing the population in given age groups in given years. In Appendix 6.2 at the end of this chapter, there are two examples of the large tables in which children are cross-tabulated by age, grade, and sex for a series of six years from 1972 through 1977. We show the tables only for the first year (1972) and the final year of the series (1977). Using tables such as these, the summary Tables 6.4, 6.5 and 6.6 can be built to analyze enrollment flows.

Table 6.4

Paraguay Males: 7 Year Old Students in 1972 By Grades Attended in Each Following Year

Grade	7 yr. old 1972	8 yr. old 1973	9 yr. old 1974	10 yr. old 1975	11 yr. old 1976	12 yr. old 1977
1st	26,886	15,505	7,652	3,944	1,997	1,153
2nd	4,755	13,604	11,874	9,333	5,324	3,361
3rd	343	4,102	10,282	9,448	7,736	5,515
4th	2	275	3,707	7,732	7,678	6,641
5th	1	27	345	3,723	6,137	6,610
6th			78	309	3,172	5,091
Total	31,987	33,513	33,938	34,539	32,044	29,271

A cohort is a specific age group followed through time. Strictly speaking, the cohort is not followed, but rather the follow-up is *modeled* by assuming that those 7-year-olds in the system in 1972 are the 8-year-olds in 1973, and so on. Age-grade data do permit this modeling, or *simulated cohort.* Though each individual is not followed, the model of a cohort is sound at national level of aggregation.

In Table 6.4, starting with 31,987 7-year-olds in 1972, most of them in first grade, the simulated cohort reaches the maximum enrollment of 34,539 in 1975. Most students now age 10 are enrolled in grades 2, 3, and 4. There are some obvious faults in such a model. For example, there are 27 students in fifth grade in 1973, but there were only two in the fourth grade in 1972. If this were a real cohort rather than a simulated one, it would be impossible to have more in the fifth grade in one year than there were in the fourth grade the year before. On the other hand, it is quite possible that the 275 in fourth grade in 1973 were promoted from the 343 in the third grade in 1972.

Tables 6.5 and 6.6 are also built up from the tables in Appendix 6.2, where the number of children is cross-tabulated by age, grade, and sex for a six-year series from 1972 to 1977.Table 6.5 shows the 7-year-olds in 1974 distributed by grade; the 8-year-olds in 1975 distributed by grade; and the 9-year-olds in 1976 distributed by grade.

Table 6.5

Simulated Cohort Distributed by Grade from 1974 to 1976 (based on tables like those shown in Appendix 6.2, Males Only)

Age in Year	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Total
7 in 1974	27099	5703	355				33217
8 in 1975	14799	13594	4921	391			33075
9 in 1976	7171	12209	9403	4277	375	18	33453

Analytic Table 6.6 is built on the basis of the data in Table 6.5. This illustrates that analysts working on poor and incomplete data in developing countries, where there are no computerized accounting systems of enrollment, are forced to apply considerable ingenuity in the methods of analyzing whatever data are available.

To understand Table 6.6, begin with the total attendance column in 1975 (from Table 6.5). The 391 fourth-graders in 1975 are made up of 355 promoted from third grade in 1974 and 36 new entrants. In the same column, the 4,921 third-graders in 1975 are all promoted from second grade in 1974. Of the total 13,594 in grade 2, 842 are repeating that grade, and 12,752 must have been promoted from first grade in 1974 to reach the total of 13,594. Of the 14,799 in first grade, 14,347 were repeaters (as a maximum); so 452 newcomers must have entered first grade in 1975.

Table 6.6

Analysis of the Flow of the Seven-Year-Old Cohort in 1974 to the Grade Distributions in 1975 and 1976 (Males)

Grades	7 Years in 1974	8 Years in 1975				9 Years in 1976			
	Enrollment	Promoted	New entrants	Repeaters[a]	Total attendance	Promoted	New entrants[b]	Repeaters	Total attendance
1	27,099	--	452	14,347 (52.9%)	14,799	--	--	7,171 (48.5%)	7,171
2	5,763	12,752	--	842 (14.6%)	13,594	7,358	--	4,851 (35.7%)	12,209
3	355	4,921	--	--	4,921	8,743	--	660 (13.4%)	9,403
4	--	355	36	--	391	4,261	--	16	4,277
5	--	--	--	--	--	375	--	--	375
6	--	--	--	--	--	--	18	--	18
Totals	3 ,217[c]	18,028	488	15,189	33,075[c]	20,737	18	12,698	33,453[c]

[a]The repetition is calculated by subtracting the number promoted from the number enrolled the year before. (27,099 - 12,752 = 14,347). Rates are shown underneath in parenthesis.

[b]4887 pupils dropout or desert. Part of this dropout must happen in second grade. Also, new pupils enter.

[c]Total male population (of the 7 year old group in 1974) is 37,021, and the maximum enrollment rate is 89.7%.

Ministerio de Educacion y Culto, Direccion de Planeamiento. "Estudios del Funcionamiento del Sistema de Educacion del Paraguay. No. 1: Factores que Afectarian al Rendimiento Escolar en la Educacion Primaria del Paraguay." Asuncion, Paraguay: Agosto 1977; Tabla 17.

Repeating rates may be computed by age and grade in Table 6.6. For example, 14,347 students repeated first grade out of 27,099 students enrolled in that grade in 1974, i.e., 52.9 percent of the total number of students. The repetition rates estimated by this method for first grade are almost double the figures reported by school teachers. (Remember the teacher estimate is based on the teachers' asking students to raise their hands to signify that they are repeaters.) Hence the teachers report that the rate for males is 25 percent, whereas this method estimates a rate near 49 percent (see Table 6.7).

Rates for males and females are about the same with this method; they are a little bit larger for girls in the fourth grade. This pattern may be a result of incomplete rural schools. Teachers may suggest that good female students attend an additional year. Because there is no higher grade, these students have to remain in the highest grade available. They are not repeaters in any meaningful educational sense; nor are other students who leave the school, because there is no higher grade, really dropouts. Educational planners in developing countries have sometimes called the latter group "forceouts" rather than dropouts, in order to lay the blame where it is due—on the government, which has not provided facilities. Perhaps the so-called repeaters, who stay in school waiting for openings in higher facilities should be called "shut-ins." A field research study is the only way to determine the true status of children. Many show up in official statistics as dropouts and repeaters only because there is no school place for them.

Table 6.7

Repetition Rates by Grade Computed by Weighting Repetition Rates of Each Age Group (Males-1974)

Age (Years)	1st Grade 1974		2nd Grade 1974		3rd Grade 1974		4th Grade 1974	
	Attended	Repeater	Attended	Repeater	Attended	Repeater	Attended	Reneater
7	27099	14347	5763	842	355	--	--	--
8	15555	6802	14783	4985	4275	133	263	--
9	7652	3315	11874	4996	10282	2170	2707	20
10	4035	1981	8706	5248	9261	3852	7045	1648
11	1742	857	5459	2415	7573	2700	7424	1956
12	812	557	3426	1762	5874	2917	6382	2105
Totals	56895	27859	50011	20253	37620	11772	24821	5729
Repetition rate (males only)	48.96%		40.49%		31.29%		23.08%	
Reported official rate for both sexes	25%		20%		16%		11%	

Ministerio de Educacion y Culto, Direccion de Planeamiento. "Estudios del Funcionamiento del Sistema de Educacion del Paraguay, No. 1: Factores que Afectarian al Rendimiento Escolar en la Educacion Primaria del Paraguay." Asuncion, Paraguay: Agosto 1977; Tabla 13.

4.0 *Second Method: Where Analyst Has Data on Numbers Promoted and Repeating by Years*

In the countries where analysts have data on enrolled, passed and repeaters, a second method is possible. Table 6.8 presents data on students passing the grade in the years 1969 through 1976. Table 6.9 presents data on students repeating the same grades in the same years. In general, enrollments increase over the years for all grades in the schools of a developing country, in part because the population has been increasing, but also because the schools are taking in an increasing fraction of the children reaching entrance age. This increase can be seen in Table 6.1 and in Table 6.2, shown earlier. (Table 6.9 is based on Table 6.2). Though enrollments increase over time, repeaters decrease over time. Repetition also decreases in the higher grades of a system. Promotion follows the opposite trend. It is hoped that increased promotion and decreased repetition reflect improvement in the school system.

Having data available on *promoted* and *repeaters* enables the analyst to estimate the minimum level of enrollments by grades from second grade on. The formula to be used in computing promotion and repetition rates is:

$$E_{gt} = P_{g-1,t-1} + R_{gt}, \qquad (1)$$

where

E_{gt} = enrollment in grade g in year t (estimated minimum)

$P_{g-1,t-1}$ = number promoted from grade $g - 1$ in year $t - 1$ to grade g in year t.

R_{gt} = number of repeaters in grade g, year t.

Results are presented in Table 6.10. For example, enrollment in grade 2 in 1979 equals promoted from first grade in 1969 plus second-grade repeaters in 1970:

$$\begin{aligned} E_2,70 &= P_1,69 + R_2,70 \qquad (2) \\ &= 72{,}062 + 21{,}096 \\ &= 93{,}158 \end{aligned}$$

Enrollment figures thus estimated are compared with reported enrollments, and the results presented in Table 6.11.

When estimated enrollments are smaller than the official ones, the difference shows an underestimate of repeaters, because the number of promoted cannot be expanded. If estimated enrollment figures are larger than the official ones, it may be attributable to dropouts. Smaller, or underestimated, repetition is shown by negative numbers.

In Table 6.11, the last columns show the additional percentages needed to correct the underestimated rates of repetition for grades 2 and 3. They range between 1 and 3 percent in second grade and are almost negligible in third grade.

In this method, no correction can be made for repeaters in first grade, but if the analyst has additional demographic data, he can use a third method which will be described.

Table 6.8

Official Data on Students Passing (Successfully Completing) the Grade

Year	Grades						
	1	2	3	4	5	6	Total
1969	72062	62312	51910	39873	30146	24682	280985
1970	76267	65761	53485	42557	32076	25825	295971
1971	77480	68934	55191	43691	34188	27338	306822
1972	77725	67645	56978	44859	34470	28219	309896
1973	78770	69865	58531	47510	32204	30368	322188
1974	78968	70527	60226	48945	38837	31738	329241
1975	78950	70690	60921	49993	39808	33072	333434
1976	85168	73228	63989	52671	42238	35123	352429

Ministerio de Educacion y Culto, Direccion de Planeamiento. "Estudios del Funcionamiento del Sistema de Educacion del Paraguay. No. 1: Factores que Afectarian al Rendimiento Escolar en la Educacion Primaria del Paraguay." Asuncion, Paraguay: Agosto 1977; Tabla 18.

Table 6.9

Official Data on Students Repeating for Same Grades and Same Years

Year	Grades					
	1	2	3	4	5	6
1969	32082	20506	11044	5794	2525	1300
1970	31501	21096	12183	6067	2803	1293
1971	32265	21024	12389	6320	2960	1491
1972	32021	20890	12583	6909	3288	1478
1973	32326	20742	12161	66[illegible]	3330	1424
1974	31722	20366	12856	6963	3183	1276
1975	28752	18703	11946	6103	2680	1186
1976	28220	18413	11814	6155	2754	1250

Source: Unpublished figures, Direccion de Planeamiento, MEC, Asuncion, 1977.

Table 6.10

Computed Level of Attendance Based on Official Statistics on Passing and Repeaters

Years	Grades						
	1	2	3	4	5	6	Total
1970		93158[a]	74495	57977	42676	31439	
1971		97291	98150	59805	45517	33567	
1972		98370	81517	62100	46979	35666	
1973		98467	80806	63637	48189	35894	
1974		99076	82721	65494	50693	38480	
1975		97671	82473	66329	51633	40023	
1976		97363	82504	67076	52747	41058	

Table 6.11

Differences Between the Computed Level of Attendance and Official Statistics of Attendance

Years	Differences by grades						Percentage	
	1	2	3	4	5	6	Needed addition to rate of repetition	
							2nd	3rd
1970		-3641[a]	- 166	1375	1951	1099	3.76	0.22
1971		-2294	683	1796	2120	1202	2.30	
1972		-1013	1641	2367	2513	2038	1.02	
1973		-2329	131	1490	1400	848	2.31	
1974		-1248	561	2195	2319	1995	1.24	
1975		-1468	584	2566	3350	2584	1.48	
1976		-3197	- 839	1383	2498	1888	3.18	1.02

[a]Official enrollment 96,799 minus estimated 93,158 = -3,641.
Minus indicates repetition is underestimated.

5.0 *Third Method: Analysis of New Entrants by Ages, to Adjust Rates*

When population and enrollment figures by ages are available, a simple demographic accounting may provide an estimate of the amount of correction in the first-grade repetition rate. Figures for Paraguay in 1972-73 are presented in Table 6.12.

Table 6.12 (col. 6) shows that 18,430 eight-year-olds joined the school system in 1973. Yet there are only 9,264 members (col. 3) of that age group that have not previously joined the educational system in the past. Some-

Table 6.12

Comparison of Newcomers by Ages in 1973 With the Population That Had Never Joined the School System Until That Year (Third Method)

Age in 1973	1972 Population	Enrolled in 1972	1972 Population never entered educ. system	Enrolled in 1st grade 1973	Repeaters in 1st grade 1973	New-comers 1973	Negative differences	94.1% of 1972 pop. that once entered the system	Avail.pop. to enter the system	Negative differences
	(1)	(2)	(3)	(4)	(5)	(6)	(7)=(6)-(3)	(8)	(9)=(8)-2	(10)=(6)-(9)
6	77,892	-	77,892	14,760	1,284	13,476	--	73,296	73,296	
7	75,373	13,839	61,534	52,875	3,362	49,513	--	70,926	57,087	
8	73,185	63,921	9,264	28,841	10,411	18,430	9,166	68,867	4,946	13,484
9	71,117	63,698	7,419	14,332	6,627	7,705		66,921	3,223	4,482
10	69,138	63,365	5,873	7,556	4,247	3,309	--	65,050	1,794	1,515
11	67,215	60,813	6,402	3,673	3,299	374	--	63,249	2,436	
12	65,313	58,187	7,126	1,905	1,725	180	--	61,460	3,273	
13	63,513	51,413	12,100	890	887	3	--	59,766	8,353	
14	61,839	33,931	27,908	375	353	22	--	58,190	24,259	
15	60,221	20,148	40,073	142	131	11	--	56,668	36,520	
				125,349	32,326	92,023	9,452			19,481

Number of students enrolled in first grade in 1972:	125,983	125,983
Increment to be added to the repetition rate in 1972:	7.5%	15.5%
Repetition rate estimated from statistical forms 1972:	25.0%	25.0%
Minimum repetition rate for 1972:	32.5%	40.5%

thing similar happens to the nine-year-olds, where the 286 excess students over the available population are registered as newcomers in 1973. Both figures account for an increment of 7.5 percent in the first-grade repetition rate, increasing it up to 32.5 percent (col. 7).

The comparisons should really be carried out with the proportion of the population that attended school over their lifetime. Thus, in column (8) the percentages of those never attending the school are computed, and negative differences can be estimated and added. In this third method, the correction is raised to 15.5 percent, thereby obtaining a total first-grade repetition rate of 40.5 percent (col. 10).

6.0 *Fourth Method: Based on the Total Number of Newcomers by Ages*

To use method four the analyst must have (i) the seven-year-old population; (ii) total enrollments in first grade; (iii) enrollments by ages; and (iv) enrollment rates by ages. First-grade enrollments are equal to the sum of new entrants and repeaters. Therefore, if enrollments and newcomers are known, it is possible to compute first-grade repeaters and to relate them to first-grade enrollments of the previous year in order to compute the repetition rates.

New entrants may be estimated from the data on enrollments by age that are available in many countries. In Table 6.13, data for Paraguay are presented for the 1964-1976 period. Diagonal arrows in the table show us the evolution in the total number of children of a given age-group who are enrolled in the educational system. A careful analysis of the figures can yield an estimate of newcomers joining the school for the first time in each one of the years.

For example, it is possible to estimate newcomers by ages comparing:

— 8-year-old students in 1973	66,046
— 7-year-old students in 1972	63,921
— Number of students in the age group joining the school system (in any grade) in 1973	2,125

The previous figure represents a minimum number of students joining the school system, because a certain number of the 63,921 students enrolled in 1972 may have dropped out. Therefore, there may in fact be a larger number of newcomers in 1973. The analysis may be carried out in the following years:

— 9-year-old students in 1974	66,446
— 8-year-old students in 1973	66,046
— Newcomers of the age group in 1974	400

In 1975, the ten-year-old group totals only 66, 373, and so for the first time the age group registers a decrease. No newcomers may be estimated for this year. Further reductions are recorded for 1976 and the following years. We should remember, however, that in 1975 there might be a certain number of dropouts, and in that case there could be an increase in the number of

Table 6.13

Enrollments by Ages: 1964-1976

Year \ Age (years)	less than 7	7	8	9	10	11	12 and more	Total
1964	7,556	52,409	49,789	48,648	48,011	42,438	95,786	344,637
1965	8,127	52,527	51,516	49,948	49,984	44,203	100,693	356,998
1966	8,343	52,055	52,661	51,122	51,408	45,970	104,373	365,932
1967	9,313	53,329	52,984	53,430	53,196	47,472	108,736	378,453
1968	9,773	57,864	56,686	54,738	56,018	50,202	114,404	399,685
1969	11,762	56,690	60,369	57,413	56,090	51,525	114,675	408,524
1970	12,864	61,806	59,659	60,299	59,995	52,963	116,593	424,179
1971	12,737	63,389	64,353	60,061	62,969	56,308	117,040	436,857
1972	13,839	63,921	63,698	63,365	60,813	58,187	116,428	440,151
1973	14,029	66,368	66,046	64,781	65,659	56,686	117,961	451,530
1974	14,844	65,533	67,159	66,446	65,618	59,989	115,264	454,853
1975	15,567	66,260	63,367	66,672	66,373	59,617	112,393	452,249
1976	16,901	70,763	68,400	66,171	68,936	61,905	114,476	467,552

Source: Unpublished figures, Directorate of Planning, Ministry of Education, Asuncion, 1977.

newcomers. For example, if 1,000 students dropped out from the total enrollment in 1974, there would be a positive difference between 66,373 ten-year-olds in 1975 and 65,446 nine-year-olds in 1974, or 627 new students. As shown in Schema 6.1, it is possible to follow down the diagonal in Table 6.13, and to estimate the number joining by successive subtraction. We will begin with those under 7 years old in 1971.

Schema 6.1

Diagonal Analysis Beginning in 1971

Students joining in 1971	12,737
Students joining in 1972, 63,921 − 12,737 =	51,184
Students joining in 1973 66,406 − 63,421 =	2,125
Students joining in 1974 66,446 − 66,046 =	400
Minimum number of the age group that joined the school system (1974 enrollment)	66,446
Total number of children in the age group (census)	73,014
Maximum possible error equals 9 percent of total age group.	6,568

The maximum possible error is indicated by the difference between total population in the age group (Census) and the minimum number of that age group ever registered in a given school year (school statistics).

Table 6.14 summarizes the analysis shown in Schema 6.1 for all the diagonals of Table 6.13. All available information on enrollment by ages in Paraguay is summarized for the 1968-1975 period. The last column computes the "maximum possible error" as shown in Schema 6.1. For the 1968-1973 period, the maximum possible error would be 13.8 percent in 1975. The averaging for all years would be 8.8 percent.

Remember that the number of children *never* joining the educational system was reported as 5.9 percent in the Census data. Our estimate is 8.8 percent. The difference between the two is within error range at 2.9 percent.

Table 6.14 provides an estimate of newcomers for the entire 1972-1975 period. The conclusions drawn in the previous paragraph suggest that the figures for newcomers are reliable enough to be used as an alternative source of information.

For any given year it is interesting to study the difference between the *total number of newcomers of the age group* (addition of each row) and the *total number of newcomers in each year* (addition of each column). This difference reflects the opportunity for a given age group to join the system on a normal basis. When the number of newcomers is made up mainly of the number in the age group that would normally be joining the system, the difference is smaller. Hence, the difference indicates whether or not students enter school

Table 6.14

Number of Students of the Age-Group Born in Year t-7 Joining The School System in Each Year (thousands)

Seven-year-old population		Number of students joining the school system in each year									Total number of newcomers of the age-group	Maximum possible error
Year(t)	number in census	1967 or before	1968	1969	1970	1971	1972	1973	1974	1975		
1966		52984	1754	1352								
1967		53329	3357	727								
1968	66040	9313	48551	2505	—	2670					62,969	4.7
1969	67532		9773	46917	2969	402	752				60,813	9.9
1970	69057			11762	50044	2547	—	1306			65,659	4.9
1971	71008					50525	309	1083	837		65,618	7.6
1972	73014					12737	51184	2125	400	—	66,446	9.0
1973	75077					—	13839	52529	731	1777	68,936	8.2
1974	77158					—	—	14029	51504	—	67,615	12.4
1975	79378					—	—	—	14844	52416	38,400	13.8
1976						—	—	—	—	15567		
Total number newcomers of different age-groups in each year			63435	62538	68460	68881	66084	71072	68376	68760	526,456 537,606 Dif. = 2.1%	AV = 8.8

at the normal (legal) age. When a campaign is run to enroll students of younger ages, the total for the column (year) will be increased. The row will be increased only if the total proportion of the age group is increased. In general, the longer the period of time considered, the smaller the difference between the row and column totals. The explanation for this lies in the fact that, over a longer period, almost all students in the central and adjacent age groups will be included in the distribution. For the entire eight-year period presented in Table 6.14, the difference is 2.1 percent.

The total number of students of a given age group who eventually join the school system may be used as an alternative basis for estimating the total number of newcomers. The difference is small over time (Schiefelbein 1975). A correction that includes the difference of 2.1 percent can be used as a second alternative. These two alternatives are shown as columns 2 and 3 in Table 6.15.

In summary, newcomers may be estimated from demographic data plus enrollment ratios. This new source of data for estimating newcomers avoids some of the limitations in the first method, which estimated transition ratios by subtracting repetition, and computing a promotion rate based on the balance of enrollments. Repetition rates based on the fourth method, in which enrollment ratios are computed by age, are shown in Table 6.15. Two alternatives are given.

The repetition rates estimated in Table 6.15 are much higher than the rates reported in official ministry statistics. The second alternative is smaller because it includes the increasing fraction of younger students joining the school system.

6.1 *Seasonal Effects on Rates*

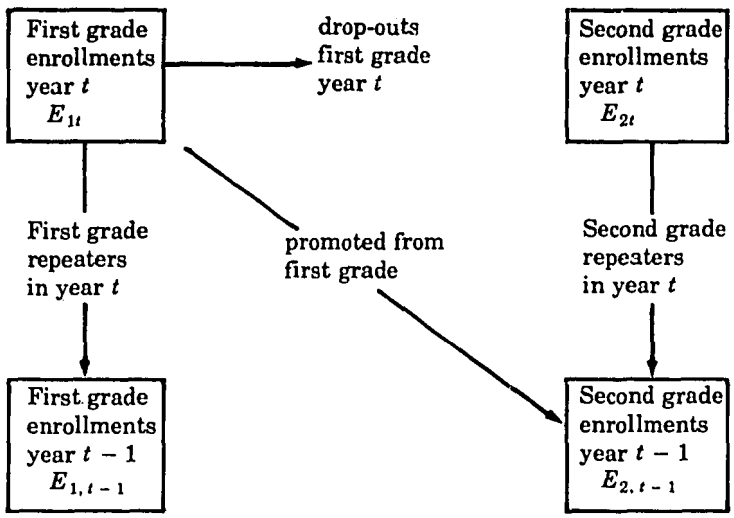
Flow rates may be affected by the time (month) in the school year that enrollment data are gathered. Data obtained in the beginning of the school year tend to be larger than those collected at the end of the school year, when some students have dropped out. Enrollments early in the school year may reflect social demand for education. Enrollments late in the year show the ability of the system to motivate students and to keep them in school. The difference may be poverty effect.

7.0 *Fifth Method: Using the More Reliable Second Grade Repetition Estimates as a Basis for Estimating Rates in First Grade*

First grade repetition rates are generally less reliable than second grade rates in Latin American schools (Schiefelbein 1975). This is true in Paraguay also. First, students must present a dated certificate of the previous grade. This cannot be asked in first grade. Second, most students are held back in first grade, according to teachers' reports. Lastly, promotion from first grade is controlled by reading tests.

In Paraguay, repetition is lower in the second grade than in the first (Table 6.8). A fifth method was used in the initial stages of this work as a rule-of-

thumb for rapid estimation of repetition levels. The computations are patterned on the classical diagonal analysis model used in most analysis of aggregate enrollments.



In analytic terms:

$$E_{2t} \times r_{2t} = R_{2t}$$

$$E_{2,t-1} - R_{2t} = P_{1t} \tag{4}$$

$$R_{1t} = E_{1t} - P_{1t} - D_{1t}$$

where,

E_{2t} = enrollment grade 2, year t

P_{1t} = promoted (number) from grade 1

r_{2t} = second-grade rate of repetition in year t

D_{1t} = dropouts from grade 1 in year t.

R_{1t} = repetition in grade 1

The computation of available data on repeaters in second grade, when placed in equation (4), gives the number of students promoted from first grade (Table 6.16). The only additional information required is the number of dropouts. There are various bases for improving the estimates of the number of dropouts. All of these are approximations.

For example, the age 10 enrollment, which is the maximum for any age group, can be subtracted from the age 11 enrollment, which reflects the first

drop from the maximum, and this can be taken as an indicator of the dropouts. Clearly, these are only approximation methods, and the increase in precision they bring may not be worth the trouble. The point is not that endless refinement is necessary but rather that the analyst can, when he studies the data in detail, find ways of improving them.

When it is worth the trouble, evidence about dropout rates can be used to refine alternative rates. Given the rather narrow range of the extremes, this refinement will not produce any great difference in the rates of repetition. The results are presented in Table 6.16.

Table 6.15

Estimated Rates of Repetition for First Grade (Fourth Method)

Items	Transition year 1972/1971 1)	First alternative 2)	Second[a] alternative 3)	Transition year 1975/1974 4)	First alternative 5)	Second alternative 6)
7 year old population	1972	73,185	73,185	1975	79,378	82,461
Enrollment rate (maximum)	1972	96%	98.1%	1975	94.5%	98.1%
First grade estimated number of newcomers	1972	70,258	71,794	1975	75,012	80,894
First grade enrollments	1972	125,983	125,983	1975	121,736	121,736
First grade estimated number of repeaters	1971	55,725	54,189	1974	46,724	40,842
First grade enrollments	1971	126,034	126,034	1974	124,709	124,709
Estimated first grade rate (%) of repetition	1971	44.2%	43.0%	1974	37.5%	32.7%

[a]Adds correction of 2.1% from Table 6.14.

8.0 *Concluding Remarks*

It is unusual to have all data available to compute by all methods. The summary presented in Table 6.17 will help the analyst to check available data and to determine the method that can be used with the data at hand.

Data required for the first method is the most extensive, and, when available, all remaining models can be computed, as in the case of Paraguay.

Table 6.18 presents a summary of the estimates obtained with each method. Most methods provide alternative estimates for first grade. If the first method is accepted as the most accurate one, the third and fourth methods seem to be the best alternatives when there are not enough data to compute by the first method.

When a new repetition rate is defined for first grade, it is possible to compute the rates for the remaining grades and to compute the number of promoted to second grade. By subtraction, the repetition rate of second grade may be obtained. A similar procedure may be implemented for the next grade.

Table 6.16

Estimated Rates of Repetition for First Grade (Fifth Method) Selected Years, 1971, 1974, 1976

Item	Year	Figures	Year	Figures	Year	Figures	Year	Figures	Year	Figures
Enrollments, 2nd grade	1964	81,181	1967	88,608	1971	99,585	1974	100,324	1976	100,560
Rate of repetition, 2nd grade	1964	25.2	1967	20.7	1971	21.0	1974	19.0	1976	19.6
Repeaters, from 2nd grade	1964	20,360	1967	18,339	1971	20,890	1975	18,703	1976	19,723
Enrollments 2nd grade	1965	84,215	1967	94,760	1972	98,826	1974	99,139	1977	104,848
Promoted from 1st grade	1964	63,855	1967	76,421	1971	77,936	1974	80,436	1976	85,125
Alternative I: Low		5.3%		4.2%		3.1%		2.5%		2.3%
Dropouts from 1st grade	1964	6,219	1967	5,074	1971	3,907	1974	3,242	1976	2,956
Enrollments, 1st grade	1964	117,344	1967	120,810	1971	126,034	1974	124,709	1976	128,537
Repeaters, 1st grade	1964	42,270	1967	39,315	1971	44,691	1974	41,031	1976	40,456
Rate of repetition, 1st grade	1964	40.3	1967	32.5	1971	35.5	1974	32.9	1976	31.5
Alternative II: Middle		5.5%		5.5%		4.9%		4.7%		4.5%
Dropouts from 1st grade	1964	6,454		6,646		6,176		5,861		5,784
Enrollments, 1st grade	1964	117,344		120,810		126,034		124,709		128,537
Repeaters, 1st grade	1964	46,944		37,743		41,922		38,412		37,628
Rate of repetition, 1st grade	1964	40.0		31.2		33.3		30.8		29.3
Alternative III: High		5.6%		6.8%		6.7%		6.7%		6.7%
Dropouts from 1st grade	1964	6,571		8,215		8,444		8,356		8,612
Enrollments, 1st grade	1964	117,344		120,810		126,034		124,709		128,537
Repeaters, 1st grade	1964	46,918		36,174		39,654		35,912		34,800
Rate of repetition, 1st grade	1964	40.0		29.9		31.5		28.8		27.1

Table 6.17

Summary of Data Required to Compute the Five Methods

Type of Information	Information Used by Each Type of Method				
	Method 1	Method 2	Method 3	Method 4	Method 5
7 year-old population	X		X	X	
Population by ages			X		
Enrollments, 1st grade				X	X
Enrollments, 2nd grade					X
Repeaters, 2nd grade					X
Enrollments by grades		X			
Enrollments by ages			X	X	
Enrollment rates by ages				X	X
Enrollments by grades and ages	X				
1st-grade enrollment rates by ages			X		X
1st-grade repeater by ages			X		
Repeater by grades		X			
Promoted by grades		X			

Given the large difference between official rates and the estimates, it is usually enough to have only a rough idea of the gap in order to make decisions. When used in enrollment projections, the estimates may allow for a range of alternative estimates. Simulation of a projection for the future year and a comparison of the results with historical changes may be a way to adjust parameters to reality.

In any case, the methods presented may give the planner a feeling for the quality of the information and some insights into the evolution in the flow of students. The methods offer guidelines for making a more thorough appraisal of the available information, and for building up a deeper knowledge of the enrollment process. Thus, a sounder basis for developing the assumptions underlying an enrollment projection is provided.

Table 6.18

Comparison of the Official and Computed Repetition Rates for Selected Years

Grades	Year 1964			Year 1971			Year 1976		
	Alt.1	Alt.2	Alt.3	Alt.1	Alt.2	Alt.3	Alt.1	Alt.2	Alt.3
First Grade									
Official rate	28.0%			25.0%			22.0%		
First method	--			48.4% [a]			44.2%		
Second method	--			27.3%			25.2%		
Third method	--			40.5%	32.5%		--		
Fourth method	--			44.2%	43.0%		37.5%	32.7%	
Fifth method	40.3%	40.0%	40.0%	35.5%	33.3%	31.5%	31.5%	29.3%	27.1%
Second Grade									
Official rate	23.0%			22.0%			18.0%		
First method	--			36.0%			34.6%		
Second method	--			22.2%			--		
Third Grade									
Official rate	19.0%			16.0%			14.0%		
First method	--			33.0%			30.4%		
Second method	--			--			--		
Fourth Grade									
Official rate	15.0%			11.0%			9.0%		
First method	--			24.3%			24.9%		
Second method	--			--			--		

[a] Computed for 1972

APPENDIX 6.1

Reasons Repetition May Be Incorrectly Estimated

The analysis of data gathering procedures in Paraguay showed that the total enrollment is easily obtained for each course from the "Class Book." By contrast, repeaters were counted by the teacher asking students to raise their hands if they are repeaters. Studies showed several other reasons why repetition might be incorrectly estimated.

The total number of students may be verified through alternative procedures. The 1972 Census recorded 433, 117 students in elementary education. The Ministry Of Education (1978) estimated the number as 440,151. The difference is below 2 percent, adding some support to the results of the field study which indicated that repetition could be the main source of error.[1]

An idea of changes in numbers of new entrants may be obtained by looking at changes in the proportion of each age group enrolled in the educational system. Table A6.1 shows that, in spite of unchanged first-grade enrollments, the percentage enrolled in each age group has been reduced by at least 3 percent (when comparing the peak enrollment rates). On the other hand, the increment is too small to support the possibility of annual enrollments over 100 percent in an age group. Table A6.1 also shows that for ages 9-10 the highest proportion of any age group population (around 90 percent) is reached. Ages 7-12 show small variations (less than 10 percent) around the peak enrollment rate. For 1972, at least 76 percent have attended school for six years. This fact, however, contradicts Census figures showing that 41.6 percent of the "seven years old and more" population had completed two or fewer grades in elementary school. Given that the hypothesis of large enrollment overestimation has been rejected, the data lead once again to the probability of errors in the estimated number of repeaters.

[1]The difference in enrollments may be due to those teachers working with small classes of 10 or 15 students who inflate the enrollments in order to avoid being eliminated. But this also may be the result of the Census underestimation of the population.

Table A6.1

Rates of Attendance by Simple Ages in Paraguay

	1965			1970			1972[a]			1975		
Age group	Pop.	Enrol.	%	Pop.	Enrol.	%	Pop.	Enrol.	%	Pop.	Enrol.	%
6-7	61761	52527	85	68875	61806	90	73185	63921	88	82461	66260	81
7-8	60236	51616	86	67062	89659	89	71117	63698	90	79892	65367	82
8-9	58738	49948	85	65298	60299	92	69138	63265	92	77373	66672	86
9-10	57313	49984	87	64104	59995	94	67215	60813	91	74873	66373	89
10-11	56029	44203	79	62416	52963	85	65313	58187	91	72365	59617	82
11-12	54306						65313	58187	91	72365	59617	82
12-13	51885						61839	42057	68			
13-14	49034						60221	30240	50			
14-15	46291						58603	17801	30			
15-16	43561						57045	11228	20			

Source: PREALC, "Recursos Humanos en Paraguay 1975-1990," PREALC/102,1976. Also additional data from Ministry of Education records.

[a]These and other data indicate that about 76% have attended school at least six years.

Table A6.2

Students Enrolled by Grade and Age (1972)

Grade / Age	First		Second		Third		Fourth		Fifth		Sixth		Total	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
- 7	6470	6801	254	249	25	20	---	---	---	---	---	---	6749	7100
7	6886	25926	4755	5557	343	439	2	10	1	2	---	---	31987	31934
8	15455	13455	12425	12861	3929	4793	287	422	53	18	---	---	32149	31549
9	8118	6617	11938	10929	8519	9427	3183	2771	333	402	15	13	32106	31159
10	4423	3586	9432	7417	8553	8481	6208	6625	2551	2901	309	317	31476	29327
11	2383	1912	6262	4709	7510	6879	6510	6584	5083	5432	2307	2616	30055	28132
12	1414	941	1278	2748	6067	4586	6551	5358	5394	5218	4247	4611	27951	23462
13	640[a]	378	2059	1078	3647	2251	4557	3145	4611	3743	4080	3742	19594	14337
14	274	129	954	439	1863	847	2670	1491	3282	2036	3518	2645	12561	7587
15t	121	54	290	162	741	332	1210	530	1900	918	2938	1740	7200	3736
Total	56184	59499	52647	46179	41197	38055	31178	27936	23208	20640	17414	15684	231828	208323
Totals	125983		98226		79252		59114		43878		33098		440151	

[a] 640 + 274 + 121 = 1035 in first grade beyond the age of 12.

Table A6.3

Students Enrolled by Grade and Age (1977)

Grade / Age	First		Second		Third		Fourth		Fifth		Sixth		Total	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
-7	8568	8616	423	489	18	14	--	--	--	--	--	--	9009	9119
7	28688	27173	6959	7653	521	662	8	10	1	--	--	--	36177	35498
8	14832	12654	15582	15426	5347	6284	509	777	9	9	--	--	36279	35150
9	7060	5812	12810	11063	10257	10723	4322	5224	488	581	10	12	34947	33415
10	3842	3052	8797	6945	9598	9149	8212	9060	3755	4482	315	408	34519	33096
11	2047	1480	5475	3985	7626	6395	8055	7551	6003	7072	3237	3936	33045	30419
12	1153	768	3361	2115	5515	4019	6641	5405	6610	6613	5991	6198	29271	24638
13	512	310	1566	890	3084	1800	4330	2885	5025	3960	5124	4804	19644	4649
14	237	129	651	305	1309	618	2166	1158	3186	1888	3827	2780	11376	6878
15t	99	45	244	109	472	167	869	338	1478	740	2697	1572	5859	2971
Total	67038	60039	55868	48980	43749	39831	35112	32408	27155	24865	21201	19710	250123	225833
Totals	127077		104848		83580		67520		52020		40911		475956	

CHAPTER 7

Trend Analysis and Projection Based on Curve Fitting

1.0 *Introduction*

The planner must deal with changes in social systems over time. The time period of special concern to a planner is the future. The future is not easy to deal with. The only basis for tracing the future is the present and past. Our experience demonstrates that present and past situations will change. The question is how will the situation change and what will be the effects of this change on future events? To address this question the planner attempts to exercise prevision and to stimulate foresight in the management of social systems. The basis of this prevision is often shaky at best. The only near certainty is that things will change. Friedman (1973) divides the planner's time framework into the recent past, the near future, the historical future, and the a-historical future, and centers the domain of planning thought in the near future. He identifies forecasting as a central activity in this domain.

The methodologies employed in forecasting are limited in number and far from rich and satisfying. The present may be intractable but the future is untractable. Yet, a central concern of the planner is providing some basis for dealing with the future; and to do this he has a limited number of techniques, ranging from systematic methods to informed guesses by individuals and groups. *Projection* is one of these systematic techniques. *Extrapolation* based on trend analysis, which in turn is based on curve fitting, is another. Duncan (1969) cites these two among the four major methods of dealing with the future. DeJouvenal (1966) lists extrapolation as the first of five major methods. In the various units on systematic planning methods discussed in this series, projection and extrapolation are used over and over again as a basis for population projection, enrollment forecasting, and the forecasting of manpower requirements. The techniques may be limited in quality and number, but they are applied constantly in the analysis which supports planning. In extrapolation methods based on curve-fitting, we will see that the same few curve forms, or functions, are selected and fitted again and again, because they are simple and familiar to analysts.

In most reports of applied work the distinctions between projection and extrapolation based on trend analysis through curve-fitting are blurred. Many exercises labeled projections use extrapolation and trend analysis based on curve-fitting. The distinction made here is that a projection is the logical and systematic development of a set of assumptions, or hypotheses, about future changes in the major variables that will affect that domain of the future which is under study. The classic examples are found in the population projections of the U.S. Bureau of Census, in which assumptions

about the future changes in mortality, fertility,and migration provide the structure for future population estimates. Extrapolation in the narrowest sense of the term is the act of extending a trend line beyond the data at hand—extending a past trend into the future, in the case of planning. Some extrapolations have no basis in data or systematic analysis. Our interest here is in extrapolation that is based on the analysis of a past trend derived from fitting a curve function to a set of data points. Curve-fitting is perhaps a more satisfactory technical term for this exercise, but by using the term *extrapolation* we are emphasizing the use of curve-fitting in the application that is most relevant to planning: tracing the future, usually the near future, from the recent past.

2.0 *The Uses of Curve-Fitting*

Curve-fitting is a technique for analyzing the relationship among a set of data points plotted in reference to a pair of intersecting lines called axes and describing this relationship mathematically. The equation $y = a + bx$ describes a linear relationship among plotted data points and can be depicted by a straight line. The major purpose of curve-fitting in planning is to discover and measure trends in the plotted data points and to apply this trend by extrapolation to the future, for which there are no data. Not all configurations of plotted points indicate a trend. If the points can be "fitted," in the sense that the relationship can be described by an equation such as $y = a + bx$, then this linear trend can serve as the basis for extrapolating or going beyond the present data. Given the parameters a and b, the value of y can be derived for any x, and the trend can be extrapolated in the form of a line. In the analysis used in planning, curve-fitting can also be applied to analyze past relationships among variables, to explain events, and to infer causality. It can also be used to study trends as an end in itself, but our interest is primarily in trend analysis as a basis for extrapolation.

Curve-fitting can be most simply performed by plotting the data points in reference to the axes and drawing a line that best fits these data points. This can be done roughly by drawing a line with a straightedge and judging by inspection how close the points, as a set, lie to this line.

Figure 7.1

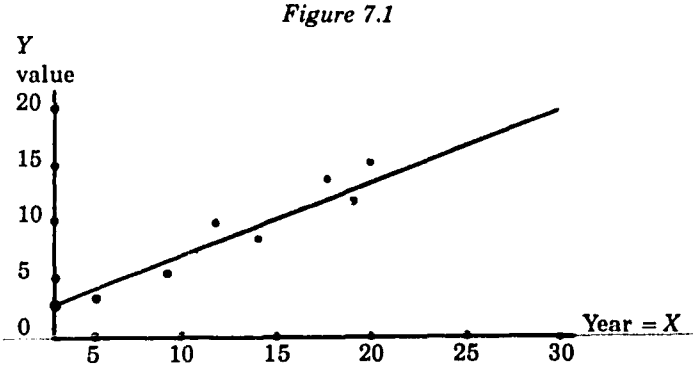


Figure 7.1 illustrates a common example of simple trend analysis performed by planners. The object is to describe how the values of Y (examples might be the number in the population or workforce, or employment in a given occupation) have changed over time, to characterize the trend, and to use this trend to extrapolate to some future year. Years, or time, are shown along the X-axis; the value of the relevant variable along the Y-axis; and hence the points represent the value of the variable under study at given points in time. These paired values, or points, might be ($X = 0$, $Y = 3$) ($X = 5$, $Y = 4$), ($X = 8$, $Y = 10$) . . . ($X = 20$, $Y = 16$). We note that Y increases in a fairly regular pattern as X increases. The analyst can draw a straight line that pretty well fits the relationship of X and Y, or describes the trend. If the analyst wished to extrapolate or extend the line out to $X = 30$, he could read off the corresponding value of Y from the graph. Though all the points do not lie along the line, the trend line fits the configuration of data points well. Hence, the way Y changes as X changes can be reasonably well described by the equation for a straight line $Y = a + bX$. Figure 7.1 illustrates the basic notion of trend analysis and extrapolation through curve-fitting.

The analyst could also compute the parameter values a and b and estimate any Y value on the basis of these parameter values and an X value. Roughly, the parameter value b shows how much the Y value changes as the X value changes; in this example how much Y increases over time. To estimate the parameter a in a preliminary fashion, the analyst can simply read off the value of Y for $X = 0$, or the point where the line passes through the Y-axis. This value is near $Y = 3$. To estimate the parameter b, the analyst requires only a simple calculation, a ratio which shows how much Y changes as X changes, $b = {}^{15-3}/_{20} = {}^{12}/_{20} = .60$ As X goes from 0 to 20 years, Y goes from 3 to 15, and the ratio of change is .60. The analyst can now use these parameter values and any given X value to estimate Y. He can extrapolate the trend out to any number of years beyond the data. (The number of years will depend on the number of years the trend will hold. There is *no* rule here.) If the analyst wishes to project the value of Y at $X = 30$ years, he has the formula $Y = a + bX$, or $Y = 3 + .6(30)$. At 30 years, the value of Y would be 21, if a linear fit does describe this trend and if these data can be taken to represent future years. Note also that the sign of the parameter b is positive, which means the trend line slopes up and to the right: Y increases as X increases.

This is curve-fitting at its simplest. The linear fit seems reasonable, but the precision of the parameter estimates could be improved. This can be done by fitting the line to the data through least-squares. The line to fit is shown in the equation:

$$Y = a + bX \tag{1}$$

3.0 *Curve-fitting through Least-Squares*

The principle that underlies the fitting of a linear trend using least-squares has already been roughly illustrated in the previous exercise. In

least-squares, the principle is applied with more rigor and permits more precise calculation of the parameters a and b. In least-squares a line is fitted according to two conditions:

First, the sum of the vertical deviations of the observed values—that means the data points—from the fitted straight line equals zero. (Note that in the previous exercise there were deviations above and below the line, and the sum of these deviations, when fitted through least-squares, must equal zero.) This is a necessary but not sufficient condition, because any straight line through the means of X and Y would produce deviations that sum to zero. Another condition must be added.

Secondly, the sum of the squares of the deviations is less than the sum of the squares of deviations for any other straight line. This is the condition which gives least-squares its name. The line is fitted so as to minimize the squared sum of the deviations.

The previous example based on Figure 7.1 also showed a rough computation of the parameters a and b, which appear in the equation for a straight line. The straight line involves two constants, a and b, which are computed from the observed data for any given trend analysis. To solve for a and b requires two equations, which are solved simultaneously for the values of a and b. In curve-fitting these are called *normal equations*. The normal equations for a straight line derived on the principle of least-squares permit the analyst to solve for the parameters a and b in terms of the n data points. For the linear fit, or straight line, the *normals* are:

$$\begin{aligned} \Sigma Y &= Na + b\Sigma X \\ \Sigma XY &= a\Sigma X + b\Sigma X^2 \end{aligned} \qquad (2)$$

First, we will illustrate how the ($n = 8$) data points of Figure 7.1 are used to solve the normals for the parameters a and b. This is straightforward arithmetic. It does not explain, however, how the normals for the linear equation were derived on the basis of least-squares. We will illustrate this briefly in a mathematical closing note at the end of this unit.

To solve for a and b we put X and Y values in columns 1 and 2 of table 7.1. The remaining columns show values needed to solve the normals. In this example there are 8 data points, or pairs of X and Y values, which means that the N shown in the normal equations is 8.

In this somewhat more precise calculation, the a and b values are slightly different from those estimated in the first exercise. The slope of the line is now given as $b = .59$, and the place where it intercepts the Y-axis is $a = 2.40$. The previous estimates were .6 and 3. Once the normals are derived by least-squares, the curve can be fitted to the data points by solving the normals for a and b through simple algebra and arithmetic. A closing note will show how the normal equations for the linear fit are derived mathematically through least-squares.

The fit may not be linear, however, and for this reason the analyst generally inspects the relationship between X and Y values, either by tabling them, examining them and analyzing the changes in the tabled values (examining the differences or ratios of changes in the Y values), or by graphing the data points and inspecting the configuration. Although not all

Table 7.1

Data Arranged to Solve Normals for a and b

(N = 8)

X	Y	XY	X^2
0	3	0	0
5	4	20	25
8	10	80	64
8	6	48	64
12	7	84	144
16	14	224	256
19	11	209	361
20	16	320	400
$\Sigma X = 88$	$\Sigma Y = 71$	$\Sigma XY = 985$	$\Sigma X^2 = 1314$

Substituting these values into the normals we get:

$$71 = 8a + 88b$$
$$985 = 88a + 1314b$$

We now have two equations in two unknowns, and we can solve by any simple method, in this case multiplying the first equation through by 11 to remove a and solve for b:

$$781 = 88a + 968b$$
$$985 = 88a + 1314b \text{ (subtracting)}$$
$$204 = -346b$$
$$b = .59$$
$$a = 2.4 \text{ (substituting back for } b \text{ to solve for } a)$$

trends are linear, this form has wide application in analysis of data trends.

Figure 7.2 sketches the shape and the equations for five curves (1, 2, 3, 5, 6) used in extrapolation. Curve 1, which is the linear form we have already examined, is by far the most commonly used.

Almost as widely applied and useful is the exponential, or geometric, which is shown as curve form 5. This curve function can be expressed in various forms. Alternate expressions for curve 5 might be $[e^r]^n$ or $(1 + r)^n$. This last expression is at once recognizable as the compound interest formula, and several applications of it are shown in the curve-fitting and extrapolation applied to the projections of product, productivity, and employment in manpower planning, or applied in simple extrapolations of population or enroll-

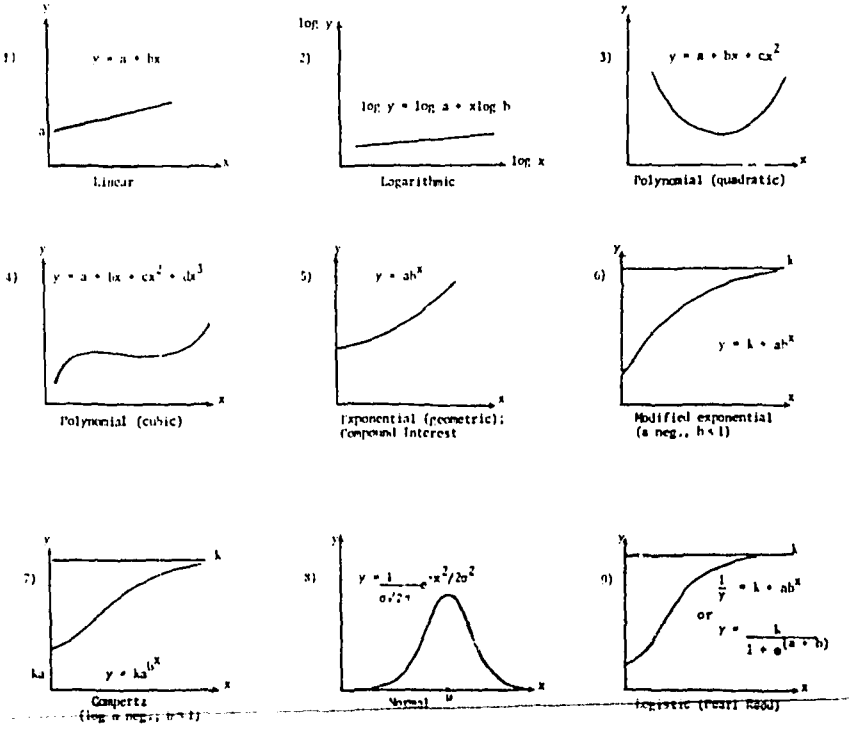
ment. Here r is the rate of increase, or the rate of interest in the compound interest formula application, and n is the number of years of the extrapolation. A rough estimate of the rate of increase between two past periods can be derived from:

$$\sqrt[k]{\frac{Y_t}{Y_{t-k}}} = (1 + r) \qquad (3)$$

Here k, the number of years between the times when the two values of the Y variable are assessed, is taken as the root of the ratio of the two values, and the result is $1 + r$, or 1 plus the annual or compound rate of growth. Computing the rate of growth for a given ratio of increase is unnecessary because the values are tabled. (One useful set of tables is in *Growth Factors . . . Compound Interest Tables:* Menlo Park, Cal.: Stanford Research Institute. Undated.) The Growth Factors tables show the growth factor, the ratio of the values of the variable between two periods, tabled by years from 1 to 50, and the annual growth rates shown in tenths of a percent up to 20 percent, and at cruder groupings, up to 50 percent.

Figure 7.2

Nine Important Curves and General Expressions of Their Forms



Analysts do in fact use this quick method of analyzing a growth trend and computing the annual rate for extrapolating or projecting; but if they do not first analyze time series data to see if the assumed trend fits the data, there is no logical warranty for such use. To warrant the use of the trend and the tables in extrapolation requires prior examination of the data points to see if they fit the trend. In the case of the compound interest form of the exponential this could require:

Plotting the data points to see if they roughly conform to the curve function shown in the Figure 7.2, curve 5. This is not always easy to recognize by inspection, so alternative and more systematic methods can be used.

The tabled data points of two variables, or one variable Y over time, can be analyzed to see if there is a constant ratio of change, or a constant ratio of change in the amount of change in Y.

The most satisfactory method for analyzing the trend, in the case of the exponential, is to fit the curve to the logarithims of the original data. If the first difference (subtracting successive values of the logarithims) is constant, then the exponential fits the data. The fit to a logarithimic transformation of the data should approximate a straight line, if indeed the original data is exponential.

Least-squares can be applied to the logarithims to fit the data, just as in the linear form. The equation for the curve, as shown in Figure 7.2 (curve 2), is $\log Y = \log a + X \log b$. The normal equations are:

$$\begin{aligned} \Sigma \log Y &= N \log a + \log b \Sigma X \\ \Sigma X \log Y &= \log a \Sigma X + \log b \Sigma X^2 \end{aligned} \tag{4}$$

The application of least-squares procedures to the data is just the same as in the linear fit, except that the analyst is dealing in logarithms and must convert back to obtain the values of the parameters a and b. If b is positive and greater than 1, the trend is up. If b is positive and less than 1, the trend is down. Hence the exponential shows a constant percentage of increase or decrease.

In Figure 7.2, curve 3, the fit is to a second-degree polynomial, or quadratic form. The trend shows one distinct bend, as contrasted with the linear. Fits are made to second- and sometimes third-degree polynomials (curve 4). The fitting procedures are essentially the same through least-squares. Establishing whether a quadratic form is an appropriate representation of the trend is much the same as in dealing with the exponential:

— The data points can be plotted on a graph to see if the curve has the characteristic bend shown in curve 3. (Note that the curve can bend upwards or be concave, as shown in curve 3, or bend downward and be convex).

— The values of Y can be subtracted to determine if the second difference is a constant. Such is the case if the Y values were:

Y	1st dif.	2nd dif.
15.5		
	4.9	
10.6		1.3
	3.6	
7.0		1.3
	2.3	
4.7		1.3
	1.0	
3.7		

— The trend can be fitted through least-squares, using the normals for the quadratic, which are:

$$\begin{aligned} \Sigma Y &= Na + b\Sigma X + C\Sigma X^2 \\ \Sigma XY &= a\Sigma X + b\Sigma X^2 + C\Sigma X^3 \\ \Sigma X^2Y &= a\Sigma X^2 + b\Sigma X^3 + C\Sigma X^4 \end{aligned} \qquad (5)$$

The three equations are then solved for the three parameters a, b and c of the quadratic: $Y = a + bX + cX^2$. Though the computation gets more lengthy, the method of fitting is the same as in the linear case. Fits are also made to the third-degree polynomial, or cubic, although this form is rarely used. Four normal equations are necessary for the third-degree polynomial, but there is no merit in showing these at this point.

4.0 *The Modified Exponential and Other Curve Forms*

Figure 7.2 shows other forms which are used in curve-fitting and projection, but they will not be discussed in detail in this reading. These curves, the modified exponential (6), the Gompertz (8) and the Logistic or Pearl Reed curve (9), show increases or decreases that approach an asymptote, which is a limit that is approached but not reached. Curve 6 increases or decreases, in convex or concave form, according to whether the parameter is positive or negative and the parameter b is greater or less than 1. This modified exponential describes a trend in which the amount of growth declines by a constant percentage.

The logistic curve is a form of the modified exponential in which the expression is in terms of reciprocals of the y values. This curve is used to show growth over time, particularly in populations.

The characteristic trend reflected in the logistic, and in the similar Gompertz, is one in which the Y variable increases slowly, then rapidly increases, then reaches a plateau and levels off near the asymptote or limit. It is apparent that this reflects the past dynamics of population change in the world — a period of slow growth, a sudden acceleration, and a leveling-off as limits of resources and space are reached. The logistic curve was applied to extrapolating the population of the United States, and for some decades, up to 1950, produced reasonable results. World War II and the post war baby boom threw the extrapolation off, but at one time the curve was thought to reflect almost a general law of population increase. The curve was based originally on a fit to data that showed the increase of fruit flies in a bottle. It worked well for flies, but the more perverse and versatile humans can always defeat the form, or raise the asymptote. Analysts can deal with this problem of large shifts by splicing in new asymptotes and extending the curve form, but this is beyond our material in this section.

The curve forms 6, 7, and 9 are fitted by methods other than least-squares, and require estimating the k parameter or asymptote, as well as the a and b parameters. We will not go into the fitting methods which are based on segmenting the data to get partial totals for the modified exponential, converting to logarithims in the case of the Gompertz, and fitting by selected points and geometric means in the case of the logistic curve. The methods are

detailed in Croxton and Cowden (1955), which is an old but useful source for methods of curve-fitting.

4.1 *Summary*

In summary, the fitting of a curve function to represent a trend and to serve as a basis of extrapolation should first require examination of the data to which the curve is to be fitted. This can be done by plotting the points on a graph and studying the form of the curve by inspection. It can also be done by tabling the data and observing the changes in the Y value as X changes. The linear trend shows a constant amount of increase or decrease, i.e. the first differences of Y will be constant. The quadratic shows increasing or decreasing amounts of increase or decrease, i.e. the second differences of Y values are constant. The exponential indicates a constant ratio of change, and therefore a constant rate of change in the amount of change. The direction is indicated by the sign of b, and whether it is greater or less than 1. The modified exponential, Gompertz, and logistic curves show growth declining by a constant percentage, and will not be used in analysis as much as the other forms.

The linear, quadratic, and exponential can be fitted through least-squares methods, as described, because the normals are known. The derivation of the normals through least-squares will be the final topic discussed in this section. The topic of curve-fitting goes far beyond this introduction, but analysts who can handle this much on curve-fitting can cope with the work as it is done in the standard practice of planning.

5.0 *Closing Note: The Derivation of the Normal Equation in Least-Squares-Fitting*

The principle of least-squares requires that a line be fitted so as to minimize the square of the differences of the data points from this line. This is shown in equation (6). (The expression within the brackets shows the deviation of the data points (y) from the line, which is $a + bx$).

$$\text{Minimize } \Sigma d^2 = \Sigma[y - (a + bx)]^2 \tag{6}$$

If we multiply out the expression within the brackets and bring the summation sign in, the expression above becomes:

$$\Sigma y^2 + b^2\Sigma x^2 + na^2 - 2b\Sigma xy - 2a\Sigma y + 2ab\Sigma x \tag{7}$$

In order to find the expression that makes the quantity a minimum (which minimizes the squared differences of points from the line), we must have the derivative of the function first with respect to b and then with respect to a, and then set these expressions equal to zero. The quantity changes because of contributions of both a and b, and we differentiate to find where this contribution is minimal according to each taken successively. In addition to setting the first derivatives of the equation equal to zero, we must also verify that the second derivatives with respect to a and b are positive. As may be easily verified, the second derivative of equation (7) with respect to b is $2\Sigma x^2$.

With respect to a, the second derivative is $2n$. Both are clearly positive, indicating that solving for a and b will yield a minimum and not a maximum.

Differentiating with respect to b means treating terms without b as a constant, and hence they are eliminated in the derivative. This gives:

$$2b\Sigma x^2 - 2\Sigma xy + 2a\Sigma x = 0.$$

Differentiating with respect to a yields:

$$2b\Sigma x - 2\Sigma y + 2na = 0$$

By dividing the two equations by 2 and rearranging, we get the normals:

$$b\Sigma x^2 + a\Sigma x + \Sigma xy$$
$$b\Sigma x + an = \Sigma Y$$

These are the same as the normal equations in (2), after a slight rearrangement of terms.

References and Suggested Additional Reading on Curve-Fitting

Croxton, Frederick E. and Cowden, Dudley J. *Applied General Statistics*. 6th printing. Englewood Cliffs, New Jersey: Prentice Hall, 1963. See especially Chapter 12 "Analysis of Time Series: Secular Trend I—The Straight Line" and Chapter 13, Analysis of Time Series: Secular Trend II—Non-Linear Trends"

De Jouvenal, B. *The Art of Conjecture*. New York: Basic Books, 1966.

Duncan, Otis Dudley. "Social Forecasting—The State of the Art." *The Public Interest* 17 (Fall 1969).

Handy Reference on Compound Interest and Growth Factors

Stanford Research Institute. *Growth Factors . . . Compound Interest Tables*. Menlo Park: SRI (undated).

World Bank. *Compounding and Discounting Tables for Project Evaluation*. Washington, D.C.: World Bank (with Johns Hopkins Press), 1973.

Part Three: *Manpower Planning Methods*

Foreword

Content and Form of the Materials

This module is designed to provide introductory instruction on manpower planning methods. The module combines an instructional module and two instructional cases. The instructional module is divided into three instructional units. The first unit introduces the topic of macro-level manpower planning, outlines a basic method and shows an alternate method. It then explains the first step in the basic method—the projection of employment by sectors of the economy. There is a closing section on industry and occupational classification systems.

The second unit completes the steps of the basic method. These steps are then illustrated with the first instructional case, the Chilean Manpower Case, which is Chapter 10.

The third unit offers analytic methods for deriving estimates used in manpower projection methodologies. These methods are mainly based on curve-fitting, which was explained in the previous chapter. The third unit presents two alternate methods used in manpower forecasting. One of the alternate methods is illustrated in the instructional case which follows.

The Instructional Objectives of the Manpower Planning Module

The manpower planning module attempts to provide an overview of the methods of macro-level manpower planning, and an introduction to the basic methodology. The methods and language are technical, but the level of technicality is not beyond that commonly applied in practice in the field. The presentation of the material is straightforward and does not include criticism based on economic theory. These were discussed in Volume I and in other project papers (Snodgrass and Sen 1979). This module stresses the common problems experienced in applied planning.

The curricular objectives of the module are:

- To present an overview of manpower planning methodology.
- To present detailed treatment of a basic method of manpower planning.
- To illustrate the basic method with a case in which the methodology was applied in manpower planning work in a developing country.
- To provide technical background on the projection methodology and estimation methods used in manpower projections.
- To illustrate other methods applied in manpower planning.

— To stimulate interest in continued ading and study in manpower planning methods.

The expected learning outcomes are:

— Develop a background knowledge in manpower planning methods. This means to be able to list the limits of the methods; to learn the technical vocabulary used by those who apply the methods; to be able to describe the methods applied in manpower analysis; and, above all, to realize that no method is applied mindlessly, and that in each situation the analyst must adapt the method to the unique problem encountered.

— Understand the steps of the basic method; specifically, be able to list and explain the steps and explain how these steps are applied in a manpower planning case.

— Be able to describe the data requirements for applying the basic methods and outline the format tables for using the data.

— Understand mechanics of extrapolation based on linear and exponential curve forms. Use tables of compound interest growth factors.

— Understand the alternate method.

These outcomes can be tested upon completion of the module. *The objective of the module is not to create instant manpower experts, for this requires a period of supervised practice and field experience gained in a manpower planning project.* Here, the objective is to prepare analysts who understand the basic approach and methods sufficiently to work on manpower planning under supervision and thereby acquire the necessary experience and depth of understanding to carry out manpower planning on their own.

At the risk of repetition, it is worth emphasizing that these units deal mainly with manpower planning at the macro-, or national level, and not with micro-level planning for an area, city, or single industry.

There is an important epistemological issue to be considered when appraising manpower analysis methodology and the projection of manpower requirements. The methodological underpinning is that of a projection, which means future conditions are traced on the basis of a coherent and logically consistent set of assumptions. In this sense a manpower projection is exactly equivalent to population or enrollment projections. Hence, to fault manpower projections because the analyst has to assume growth in product, productivity, employment, occupational distribution, or educational attainment by occupation is to fail to understand what a projection is. Assumptions are the bone and sinew of projections. In that sense, manpower projections cannot fail to be subjective. Analysis may support some estimates, but the basic framework is supported by a structure of assumptions. The reader should return to ponder this paragraph after completing Chapter 12.

CHAPTER 8

Manpower Planning Methods: Unit One

1.0 *Content and Objectives of Unit One*

Unit One outlines the basic models and methods of manpower planning. It describes the basic method and provides detailed instruction for projecting employment by sectors of the economy. This is called step 1 of the basic method. It also illustrates the basic tables and data formats for step 1, describes where and how the data are obtained, and illustrates how step 1 was carried out in a planning situation.

The objectives of Unit One are:

- — to acquire some general knowledge of manpower models and methods, and the information requirements for manpower planning.
- — to be able to describe the purpose of the basic method of manpower planning.
- — to be able to describe the steps of the basic method in general and in nontechnical terms.
- — to have a detailed knowledge of step 1 of the basic method and be able to describe this step in detail; specifically, to be able to sketch the format of the basic tables used in Step One.

1.1 *Manpower planning approaches and the basic method: Introductory Comment*

Schema 8.1 is an outline sketching out the simple models, methods, and basic information required to forecast manpower requirements and the output, or supply, of education/training systems. Manpower requirements forecasts are sometimes called *estimation of the economic demand for education/training*. An instructional case, which will follow this section on general methods, will use the terms *Manpower Demand* to refer to the forecasts of manpower requirements, and *Educational Supply* to refer to the forecasts of enrollment flows and graduates in the schools of Chile. Demand is not a true demand but simply projected expectations.

This section will explain the basic methodology outlined in points *a* through *c* of I.1 in Schema 8.1, in which employment is projected by sectors of the economy. The Chilean instructional case that follows will illustrate this basic methodology. The manpower planning cases will illustrate the fact that, when the methodology is applied in actual planning, there are always slight variations from the basic method. Some steps are combined in the work tables, or the ordering of steps may be slightly different. It is important to note that this is generally true in so-called rational planning. Models and

Schema 8.1

Outline for Manpower Planning

I. AGGREGATE LEVEL FORECASTS

1. BASIC METHOD

Steps

a) Product forecast by sectors (plan targets)
$P \longrightarrow$

b) Productivity forecasts
$P_{p.w.}$ = product per worker

c) $\frac{a}{b} = E$: Employment / sectors

d) E distributed sectors by occupations

e) Occupation distributed by education (levels and programs).

f) Education "demand" aggregated

2. Alternate Method (Growth in Occupation)

X_{ij} = number in occupation (i); sector (j) in the base year

D_{ij} = future requirements in occupation (i), sector (j)

Steps

a) Project D_{ij}

$$D_{it} = \sum_{j=1}^{n} (X_{ij})_t \; e^{\left[(b_{ij}\, r_{pj} + Y_{Lj})\right]^t}$$

II. DISAGGREGATED (PIECEMEAL) REQUIREMENTS (TO SUPPLEMENT AGGREGATE FORECASTS)

1. Service Sector/Government
   A. Population based service norms/ratios
      a) Education (link to supply)
         i) Social Policy (coverage, demographic)
         ii) Education policy Program staffing, e.g. t/p ratios
      b) Health Services
         i) Coverage needs, demand
         ii) Delivery systems/norms/staffing i.e. Beds/Doctors/Nurses/Parameds
      c) Other Government Services
         i) Defense (numbers, organization manning tables)
         ii) Police, fire sanitation (state, municipal)

2. Core Industry Arrays Input/Output, Forward/Backward Linkages
   a) Scale/Technology/manning tables (present and future)

III. DEMAND/SUPPLY EFFECTS ON FORECASTS

1. General Government Goals/Policies Analysis
   A Growth Rates economy
      a) investment, monetary fiscal
      b) Employment plans, policies
   B. National Education: Demographic/Social targets
      a) access
      b) flow
      c) output, programs/issues
   C. Education Sector Policies
      a) input norms
      b) costs
      c) resource constraints revenue policies/finance H.R. lags(e.g.trained staff)
      d) Admissions/scholarship policies, subventions, systems & institutions
         i) influence access & flow
         ii) Influence incentives choices

Schema 8.1

(continued)

b_{ij} = rate of change of workers in occupation (i) as productivity in sector (j) changes

r_{pj} = National data historical trend productivity rate

Y_{Lj} = Growth in numbers of workers trend

e = Form of the growth curve is exponential

b) Distribute by Education levels and Programs

c) Aggregate Education "Demand"

3. Apply aggregate level ratios as checks, e.g.,

a) Participation rates
b) Demographic rates

b) Establishment surveys
Employment (Present & Future Estimates Wages and Salaries)
X occupation, given market share,
prices, scale, technology

3. Small Industries and Pvt. Services
Linked to other industries & service needs
Linked to population served ratios & technology
Linked to income & effective market

4. Agriculture
Crops/Acreage
Land Tenure Patterns
Cultivation Patterns
Export, World Demand, Export Policies,
Prices Domestic, Numbers, Diet, Income

5. Fill details in cells and check with Aggregates from I. Final iteration deficit Phase I.

Demand: Base stock + wastage - supply = Deficit
Interaction in subsequent iteration phases

2. Demand/Supply/Price Interactions
Econ.
A. Labor Market Information
a) job opportunity
i) openings, promotion
ii) earnings (wages, salaries)*
iii) other returns (phychic)
b) Guidance Information
Voc/Career choice
Educ/Career choice
B. Rate of Return Studies*
a) Earnings profiles
b) Employment probability

3. Social/Cultural Values
a) National
b) Community
c) Family
d) Individual

Value of Education

*Effects on Demand & Supply Choices (Elasticities if possible)

methods are never slavishly followed. Much will depend on the information available, the pressure which deadlines impose on the planner, the technical competence and working style of analysts, and the level of precision required in the results.

In the first column of Schema 8.1, there is also an alternate method of projecting manpower requirements by occupations. This method will be illustrated in a case which describes the forecasting of manpower requirements in the Dominican Republic. A reader unfamiliar with economics can skip over the equations in Schema 8.1. The method will be made clear in our presentation of the case.

Schema 8.1 also outlines other information which may be available to the planner, information that will permit him to deepen and enrich the analysis and improve the result. The basic method for forecasting manpower requirements is primarily useful in providing a structure into which much more detailed and precise information can be incorporated. Manpower planning, in common with other planning approaches and processes, is an unending series of approximations, iterations, and improvements.

The sections that follow will run through the simple steps required to project manpower requirements using the basic method. *The object of the projection is to provide an estimate of the requirements for educated and trained manpower during the future years of a plan. The projected manpower requirements can be expressed in terms of education and training requirements, which can then be compared to projections of supply from the education/training system. The resulting deficits or surpluses can then be used to guide the planning of education and training.* This is a simplified description of how manpower planning is purported to work. Snodgrass and Sen (1979) and Chapter 4 in Volume I have exposed the limitations of this textbook version of manpower planning.

2.0 *The base-year work force: Basic tables and formats*

The first requirement is the base-year workforce by sector, occupation, and education level. (Sector and occupation classification is discussed in the final sections of this unit.)

Schema 8.2 shows the format for the distribution of the workforce by occupation (in the rows of the table), and sectors of the economy in the columns of the table. Schema 8.2 has the workforce distributed for the base year, x, and the target year, n. At this point we will fill in only the entries in column x, for the base year.

Schema 8.3 shows the format for the distribution of the workforce by occupation and educational attainment for the base year. We now have the basic information required for starting the manpower projection. Note that the occupational classification is the common link between the sector classification (Schema 8.2) and the educational classification (Schema 8.3).

Schema 8.2

Distribution of Workforce by Occupation and Sector (Base Year x and Target Year n) of Economic Activity

Sectors / Occupation	Total No.		Total %		Agriculture[a]		Mining		Manufacturing		Services ...	
	x	n	x	n	x	n	x	n	x	n	x	n
0 Professional												
1 Administrative												
2 Clerical												
3 Sales												
⋮												
5 Farmers												
⋮												
7 Artisan-Craftsmen												
8 Operators												
9 Service Workers												
⋮												

[a]Each sector column inlcudes number and percent of workers in occupations within the sector.

Schema 8.3

Educational attainment by occupation in base year (x)

Occupation	Col. 1 Total	Col. 2 University graduate studies complete (19 yrs.)	Col. 3 First degree level university (17 yrs.) Professional and higher normal	Col. 4 Sub-professional (15 yrs.)	Col. 5 Tech. complete (12 yrs.)	Col. 6 Secondary general	Col. 7 Lower normal complete (12 yrs.)	Col. 8 Primary complete (6)	Col. 9 Literacy grade (4 - 6
0. Professional/science No. %						Includes those who finish 12th grade only plus those who finish 12th grade and go on to col. 2 3, and 4 groups		Includes those who finish primary plus those who go on to cols. 5, 6 and 7 groups	Includes those who finish at least 4 grades plus col. 8 group
1. Administrative/managers No. %									
2. Clerical No. % . .									
7. Artisans No. %									
8. Operators No. %									

Note: Educational levels may be grouped in various ways. The basis is arbitrary. Here the groups are
Col. 2 includes all who finish through 19th grade.
Col. 3 includes all who finish 17th through 19th grade.
Col. 4 includes all who finish 15th grade sub-professional.
Col. 5 includes all who finish only 12th grade technical training plus the proportion of those who finish this track and attend higher education (both sub-professional and professional, i.e. lines 3 and 4).
Col. 6 includes all those who finish only 12th grade general preparation plus those who go on to higher education from this track (because schools must produce graduates who terminate at 12 and graduates who continue on.)
Col. 7 includes all those who finish only 12th grade lower normal plus that proportion from this track who go on to higher education.
Col. 8 includes all those who finish primary, plus those who finish grades 7 up to 12 (in the secondary tracks) plus the totals of 5, 6, and 7.
Col. 9 includes 8, plus those who finish at least 4 grades but less than a complete 6 years of primary.

2.1 *Information sources for the basic tables and formats*

Here the object is to sketch out the basic methodology and not to discuss in detail the sources of information for filling in the standard tables. Procedures for collecting the basic information are discussed in other sections of these materials, but a brief note on the information requirements may be helpful. The prime source of information is the national Census, which almost always collects information on the workforce and tables it by sectors, occupations, and educational attainment. There may be a number of limitations on the information as commonly presented in census tables. The information may not be arrayed in the form of occupations by sectors, as in Schema 8.2, or in occupations by educational attainment levels, as in Schema 8.3. Information in the censuses may be biased or invalid, but census experts, *and not manpower planners,* have to deal with this problem.

If the information is not available in the appropriate format, it is possible to have special runs made on the census data to retabulate the data in the proper format. Arrangements and costs vary by situation.

A second common problem is that the data may be too highly aggregated for use. Only single-digit classifications of occupation and sector (as in Schema 8.2) may be available, and special runs may be necessary to get the data into finer occupational or sectoral categories. The same is likely to be true of educational categories. More detail may be required, and special runs may be necessary. These problems are illustrated in the various cases on manpower planning presented in these materials.

Census information may not be in appropriate format; the data may be grouped too crudely; different cross-tabulations may be required; or the information may be out of date. Censuses are decenial, and the plan period may begin from a bse year that is different from the last census year. The first plan year may be 1978 and the most recent census 1970. In this case, the census must be brought forward to current date, or to the base year of the planning exercise. To accomplish this, the planner may use survey data from special work force studies, e.g., skill surveys or establishment surveys. There may also be detailed occupational information for a specific large industry or enterprise. The point is that the basic census data can be updated, supplemented, and made more detailed with results from other studies and surveys of the workforce.

3.0 *The basic projection methodology*

The basic methodology now proceeds in a series of steps that appear straightforward when described as a general method, but which have a variety of modifications when applied in reality. Here we will run through a very simple set of steps and illustrate them with the Chilean Manpower Planning Case.

3.1 *Employment projected to the target year*

Employment Projection (Step 1)

a. Product has been projected from base year to target year by sector in over-all development plan.
b. $\frac{\text{Product}}{\text{Workers}}$, productivity, is analyzed in base year and previous years. On the basis of past trends or future expectations of increase or decrease in sectors, productivity rates are projected from base to target year.
c. Employment is then projected by sectors for target years, by division of a/b.

The projections of product and productivity may be taken directly from development plan estimates. Or the projections may be based on past or historical trends of product growth extrapolated to future years. Or the projection may rest on a combination of the two things, with trends modified by information on plant capacity, technology, and investment plans for expansion. Comparative experience, the growth experienced in other countries or economies, may also be used to guide the projections.

The simplicity of the first step is shown in the following symbols. The aim is to project *employment* from year x to year n. Employment, symbolized E, equals P (product) divided by $P_{\text{p.w.}}$ (product per worker).

$$E = \frac{P}{P_{\text{p.w.}}}$$

Product and product per worker are projected for each year x to n. Employment is projected separately each year for each sector. Sector product P, and product per worker $P_{\text{p.w.}}$ may be taken directly from the national development plan or estimated on the basis of performance of the economy, or assumed on the basis of informed judgments about development potential in sectors or specific industries. The growth experienced in other similar situations in other countries, or in other regions or industries in the same country, may also be used to guide the projections.

From the outset the results may depend on how well the national development planners have estimated product in sectors for the future year. This is a crucial estimate, and it underlies the employment projection, as it underlies almost all other attempts to derive manpower demand from the economy. The adequacy of any employment projection depends on the adequacy of the basic projection of growth in product.

Base-year estimates of product and productivity can be in error. If product and productivity are projected on the basis of a trend extrapolated from past years, the adequacy or representativeness of the base years is in question. If the product/productivity ratio is projected on the basis of what has happened in the sectors and assumptions about probable changes, the adequacy of these assumptions must be examined. The units in which the product is expressed can also be troublesome. Monetary values may have to be adjusted to a base year; and when this is difficult and no indexes are available, the product may have to be expressed in units of physical output.

Census data usually furnish the basic numbers in the work force, employed and unemployed. The census data may have to be updated to the base year by

an establishment's survey which covers new employment. The establishment's survey may also be designed to get management's best estimate of likely expansion and future employment. Hence, it may furnish one basis of workforce estimates for future years.

When countries or industries are growing and changing, the establishment survey will have shortcomings as a basis for future-year estimates. The survey covers only existing industries. Industries that may not yet exist or be identified as possibilities early in a plan period may come into existence and grow rapidly during the plan period. In some areas, planning may have reached the stage where most major industrial possibilities have been studied. Employment for these future industries may have been estimated through feasibility studies which also cover sources of raw material, investment and financing, production problems, and market and sales forecasts. On the basis of these studies, employment can be directly estimated for future years.

Planners may use a general sectoral employment estimate as a first approximation, but usually they go beyond this and work on estimates for individual industries or groups of industries within the sector. A general ratio of product to product-per-worker may be used to derive a first estimate of employment for an entire heavy industry group. Then, detailed employment estimates may be prepared for each individual industry, and the results adjusted and compared with the totals.

Product or productivity may be derived from investment ratios, or estimated on the basis of market demand, minimal effective size of the plant, and assumptions about the percentage of capacity at which it will operate. Product for one industry may be derived from another, e.g., oxygen from steel. Detailed input-output relationships may be built up to derive product for one industry, group of industries, or sector, from another. In the Paraguay case, one sectoral grouping was made up of major industries; a second group was made up of industries supplying goods and services to the major industries; and a third group was made up of industries supplying goods and services to households. The product and employment of the group of industries that supply goods and services to the major industries could be related to growth in the major industries. The product and employment of the industries supplying goods and services to households could be related to growth in population, households, household income, and expenditure.

For light industries, and in the service and commerce sectors, employment may be derived from a ratio to the total population projected for the area. From the size of the population and the effective market, an estimate of the required output can be made; and from output, the number of workers required. Industry fact sheets or manning tables (detailed estimates of number and kinds of workers by jobs) can provide employment estimates and occupational distributions according to scale and technology of the industry. This detailed information may be summed into the general employment estimates for target years.

The result of the first step is employment in the target year by sector of economic activity.

4.0 *Methods for checking employment estimates*

When the data are put into the tables, several check ratios can be applied. Employment can be expanded to population economically active by estimating unemployment and adding it in. The economically active population as a percentage of the total population can serve as a control check. This participation rate can be further broken down for age groups, education levels, and sex, and compared with experience in the past and with data from other similar countries. The percentage distribution of employment by sectors can also serve as a check, e.g., the percentage in services as compared to the percentage in industry. Gross overestimates and underestimates will show up. The percentage of the workforce found in broad sectors of the economy—for example, in the primary sector of agriculture—is also a check.

5.0 *Supplementary reading on sectoral and occupational classification schemes*

To work with manpower data requires the systematic tabulating of sectoral and occupational data. The sectoral and occupational data are tabulated according to standard systems for classifying sectors and occupations. One-digit sectoral and occupational classification schemes were illustrated in Schema 8.2. In the Chilean case, one-digit classifications were also used, although the sectors and occupations were slightly different. In manpower analysis the planner may attempt to work with more refined classification schemes that use two or three digits and break industries and occupations into more detailed groupings. The classification of the workforce by sectors and occupations is central to aggregate level manpower forecasting and requires some additional explanation.

5.1 *Sectoral or Industry Classification*

The United Nations (UN, ST/STAT/Ser./27) defines what it refers to as *industry* (which is also called *branch of economic activity* or *sector* when a one-digit, large group is referred to) as follows.

> Industry refers to the kind of establishment in which the person works (or worked if unemployed). For purposes of international comparability, it is recommended that countries adopt the International Standard Industrial Classification of All Economic Activities (ISIC) most recently approved by the United Nations, or that they tabulate their statistical data so that the categories can be regrouped in accordance with the Standard Classification or at least with the divisions (one digit) of this classification.

The ISIC (United Nations Statistical Office) provides a taxonomy for classifying economically active civil populations. The major divisions or sectors, are: 0 Agriculture; 1 Mining; 2-3 Manufacturing; 4 Construction; 5 Public Utilities; 6 Commerce; 7 Transportation/Communications; 8 Services; 9 Not Specified. The eight divisions are divided into major groups (two-digit

code) and subgroups (three-digit). The standard classification is usually modified for any given country. Government may be added as one of the main divisions. Services may be separated into more than one main division.

The basic scheme used in manpower planning in many countries is the one developed and used in the national census and statistics office, as in the Chilean case. Other government agencies, for example the Ministry of Industry, or the Ministry of Economics, may have slightly different schemes. In the United States, the Bureau of the Budget has developed the Standard Industrial Classification, and the industrial classification system developed by the Bureau of the Census is also used. There are systematic procedures for translating from one system to another. (*Dictionary of Occupational Titles*, 1977)

One of the standard classification systems may be used as a model, with appropriate modifications, according to the economy of the particular country. In any given country application there are usually modifications made, but there are disadvantages when a country departs too widely from one of the standard classifications. Comparability is difficult, and retabulation may require going back to the original census schedules, a difficult and expensive task. Still, simplification of the categories may be necessary because of deficient data. A simple three-sector breakdown (industry, agriculture and services) may be all that is possible.

5.2 *Occupational Classification*

Occupations (see Schema 8.2). The united Nations' *Principles and Recommendations for National Population Census* states:

> Occupation refers to the kind of work done by the person employed (or performed previously by the unemployed) irrespective of the branch of economic activity, or the status (as employer, employee, etc.) in which the person should be classified. For purposes of international comparisons, each country should provide for the necessary subdivisions of its occupational classifications to make possible the classifying or reclassifying of the data in conformity with the latest edition of the International Standard Classification of Occupation (ISCO).

ISCO classes civil populations economically active into nine major occupational groups (shown at the end of this unit). The major groups are subdivided into 70 minor groups (two-digit level) which are subdivided into 200 unit groups (three-digit level). Unit groups can be broken down further. Other systems of occupational classification are used. The U.S. Bureau of Labor Statistics has used a classification system based on the Dictionary of Occupational Titles (1977). The Inter-American Statistical Institute, on the basis of the 1950 census of America and ISCO, worked out a classification scheme for the 1960 Census of America (COTA-1975). This system has been developed in various ways over the years, and it is the one used in the case on manpower planning in Paraguay. In an actual country situation the basic system is modified according to the prevailing occupational structure. Some country

systems tend to follow the original model too blindly. In the Dominican Republic a two-digit activity code space was reserved for hunting, trapping, and repopulation of game supply, a trade that would not be too useful to distinguish in most countries.

Occupational classifications tend to become dated rather quickly, as new technologies and administrative hierarchies develop and new job classifications and occupational titles are created to fit the situation. Not only does the nature of the work change, but the educational requirements — and these are the two main bases for occupational classification — also change. The change is almost always upward, i.e., more training and education are required. In the United States, the *Occupational Outlook Handbook* is designed to keep new workers and guidance counselors informed about recent and possible changes in demand for workers, new work patterns, and new education and training requirements. The compilers state that some of the information will be out of date before the edition appears in print. The *Dictionary of Occupational Titles* is the best reference for complete coverage, and, like the *Occupational Outlook Handbook,* has been revised in recent editions. The most recent *Occupational Outlook Handbook* is the 1978-79 edition (Bureau of Labor Statistics, U.S. Department of Labor).

The Dictionary of Occupational Titles, now in its fourth edition, (U.S. Department of Labor, 1977), reports that work is under way (circa 1977) to relate the classification system in the DOT to other government *occupational language systems* (Note the use of this terminology in contrast to the former term *systems for classifying occupations.*) Examples of other occupational language systems are those of the Bureau of the Census, the Bureau of Labor Statistics, the U.S. Office of Education, and the Office of Management and Budget Standard Occupational Classification (SOC) program. In developing countries the National Office of Census and Statistics, the National Planning Office, the Ministry of Labor, and the Ministry of Finance will be sources of data on workers as well as on schemes of industries.

In general, manpower analysts have a considerable task to keep up with recent sources for coding, classifying, and analyzing employment by occupations and industries. This is true in the United States where there are many codes and systems, and in other countries which use the international systems, ISCO, ISIC and COTA. Many countries have modified standard classification systems in order to adapt them to their own national economy.

6.0 *Summary Comment at the End of Unit One*

At the end of Unit One we have taken one step in the manpower requirements projection: employment has been projected on the basis of product and product-per-worker. We have seen that there is nothing special in the projection process, that it follows the same basic methodologies of population projection or enrollment projection. The aspect of manpower forecasting that is distinctive is the classification of workers by occupation, sector, and educational levels. Systems for classifying workers have been discussed. A following section on references and further reading will provide additional information.

References

COTA[1]. *System for classifying occupations (and industries) in census enumerations for Latin American countries.* Inter-American Statistical Institute, Washington, D.C.

DOT. *Dictionary of Occupational Titles,* 4th edi, 1977. Employment Service, U.S. Department of Labor, Washington, D.C.

ISCO. *International Standard Classification of Occupations.* Second Impression, 1975. International Labor Office, Geneva, 1975.

ISIC. *International Standard Industrial Classification of all Economic Activities.* United Nations Statistical Office.

OOH. *Occupational Outlook Handbook.* 1978-79 edition. Contains forecasts of employment prospects in various occupations (and industries) over near term. Periodically revised and up-dated. Department of Labor, Washington, D.C.

SIC. *Standard Industrial Classification: Manual.* Office of Management and Budget, Washington, D.C.

SOC. *Standard Occupational Classification Program.* Office of Management and Budget, Washington, D.C. (to be keyed to DOT, 1977 system).

United Nations. *Principles and Recommendations for National Population Censuses* (ST/STAT/SER.,/27).

[1]Clasificacion Ocupacional Para El Censo De Toda America De 1970 (COTA-1970)

Comparison of ISCO and COTA Major Occupational Groups

ISCO	COTA (1970)
0-1 Professional, technical related	0. Professional, technical
2. Managers, High Public Officials	1. Managers, Administrators
3. Office, administrative, clerical	2. Office, clerical, administrative
4. Merchants and Sales	3. Merchants, sales
5. Service	4. Farmers
6. Farm and Forrest workers	5. Transport workers
7. Operators	6. Artesans and operators
8. Artesans, skilled craft	7. Other artesans
9. Transport and Other	8. Day laborers, workers
can't be classified	9. Personal Services
	Occupations not identifiable

READING 8.1

*Assumptions and Methods Used in Preparing Employment Projections**

Although the discussions of future job prospects contained in the *Handbook* are written in qualitative terms, the analyses upon which they are based begin with quantitative estimates of projected employment, replacement openings, and—in a few cases—supply.

These projections were developed using the most recent data available on population, industry, and occupational employment, productivity, consumer expenditures, and other factors expected to affect employment. The Bureau's research offices provided many of these data, but many other agencies of the federal government were important contributors.

In addition, experts in industry, unions, professional societies, and trade associations furnished data and supplied information through interviews.

After the information from these sources was compiled, it was analyzed in conjunction with the Bureau's model of the economy in 1985. Like other models used in economic forecasting, it encompasses the major facets of the economy and represents a comprehensive view of its projected structure. The Bureau's model is comprised of internally consistent projections of Gross National Product (GNP) and its components: consumer expenditures, business investment, government expenditures, and net exports; industrial output and productivity; labor force; average weekly hours of work; and employment for detailed industry groups and occupations. The methods used to develop the employment projections in this edition of the *Handbook* are the same as those used in other Bureau of Labor Statistics studies of the economy. Detailed descriptions of these methods appear in *The U.S. Economy in 1985* (BLS Bulletin no. 1809) and the *BLS Handbook of Methods for Surveys and Studies* (Bulletin no. 1910).

Assumptions: The Bureau's projections to 1985 are based on the following general assumptions:

- The institutional framework of the U.S. economy will not change radically.
- Current social, technological, and scientific trends will continue, including values placed on work, education, income, and leisure.
- The economy will gradually recover from the high unemployment levels of the mid-1970's and reach full employment (defined as an unemployment rate of 4 percent) in the mid-1980's.
- No major event such as widespread or long-lasting energy shortages or war will significantly alter the industrial structure of the economy or alter the rate of economic growth.
- Trends in the occupational structure of industries will not

be altered radically by changes in relative wages, technological changes, or other factors.

Methods: Beginning with population projections by age and sex developed by the Bureau of the Census, a projection of the total labor force is derived using expected labor force participation rates for each of these groups. In developing the participation rates, the Bureau takes into account a variety of factors that affect a person's decision to enter the labor force estimate, and the result is multiplied by a projection of output per sponsibilities.

The labor force projection then is translated into the level of GNP that would be produced by a fully employed labor force. Unemployed persons are subtracted from the labor force estimate, and the result is multiplied by a projection of output per worker. The estimates of future output per worker are based on an analysis of trends in productivity (output per work hour) among industries and changes in the average weekly hours of work.

Next, the projection of GNP is divided among its major components: consumer expenditures, business investment, government expenditures—federal, state, and local—and net exports. Each of these components is broken down by producing industry. Thus, consumer expenditures, for example, are divided among industries producing goods and services such as housing, food, automobiles, medical care, and education.

Once estimates are developed for these products and services, they are translated into detailed projections of industry output, not only for the industries producing the final product, but also for the intermediate and basic industries that provide the raw materials, electric power, transportation, component parts, and other inputs required in the production process. To facilitate this translation, the Department of Commerce has developed input-output tables that indicate the amount of output from each industry—steel, glass, plastics, etc.—that is required to produce a final product—automobiles for example.

By using estimates of future output per work-hour based on studies of productivity and technological trends for each industry, industry employment projections are derived from the output estimates.

These projections are then compared with employment projections derived using regression analysis. This analysis develops equations that relate employment by industry to combinations of economic variables, such as population and income, that are considered determinants of long-run changes in employment. By comparing projections resulting from input-output analysis and regression analysis, areas may be identified where one method produces a projection inconsistent with past trends or with the Bureau's economic model. The projections are then adjusted accordingly.

Occupational employment projections: Projections of industry employment are translated into occupational employment projections using an industry-occupation matrix. This matrix, which is divided into 200 industry sectors and 400 occupation sectors, describes the current and projected occupational structure of each industry. By applying the projected occupational structure for each

industry to the industry employment projection and aggregating the resulting estimates, employment projections for each of the 400 occupations contained in the matrix are obtained. The growth rate of an occupation is accordingly determined by (1) changes in the proportion of workers in the occupation to the total work force in each industry, and (2) the growth rate of industries in which an occupation is concentrated. An occupation that is projected to increase as a proportion of the workforce in each industry, for example, or one that is concentrated in industries projected to grow more rapidly than the average for all industries, would be projected to grow faster than the average for all occupations.

In some cases employment is related directly to one of the components of the Bureau's model—for example, the number of cosmetologists is related to consumer expenditures for beauty shop services. In others, employment is related to an independent variable not explicitly projected in the model, but believed to be a primary determinant of employment in that occupation. The projection of automobile mechanics, for example, is based on the expected stock of motor vehicles. Projections that are developed independently are compared with those in the matrix and revised, if necessary, to assume consistency.

Replacement needs: In addition to a projection of employment for each occupation, a projection is made of the number of workers who will be needed as replacements. Separations constitute a significant source of openings. In most occupations, more workers are needed to replace those who retire, die, or leave the occupation than are needed to fill jobs created by growth. Consequently, even some declining occupations offer employment opportunities.

To estimate replacement openings, the Bureau has developed tables of working life based on actuarial experience for deaths and on decennial census data for general patterns of labor force participation by age and sex. Withdrawals from each occupation are calculated separately for men and women by age group and used to compute an overall separation rate for the occupation. These rates are used to estimate average annual replacement needs for each occupation over the projection period.

The Bureau is currently analyzing data from the 1970 Census to determine the effect of occupational transfers on job openings. These transfers have not been taken into account in calculating replacement needs. Some data on occupational transfers have been published in two *Monthly Labor Review* articles, "Occupational Mobility in the American Labor Force" and "Occupational Mobility of Health Workers," January and May 1977, respectively.

Supply: Supply estimates used in analysis of certain *Handbook* occupations represent the numbers of workers who are likely to seek entry to a particular occupation if past trends of entry continue. These estimates are developed independently of the demand estimates. Thus, supply and demand are not discussed in the usual economic sense in which wages play a major role in equating supply and demand. Statistics on college enrollments and graduations by field are the chief sources of information on the potential supply of per-

sonnel in professional, technical, and other occupations requiring extensive formal education. Data on persons completing apprenticeship programs provide some information on new entrants into skilled trades. A Bureau publication, *Occupational Supply: Concepts and Sources of Data for Manpower Analysis* (BLS Bulletin nos. 1816, 1974), explores several aspects of occupational supply.

*Source: *Occupational Outlook Handbook*, 1978-79, pp. 17-18

READING 8.2

Projections of the Labor Force *

Background and Uses: Projections of the future size of the labor force are needed for a variety of planning purposes. They provide a basis for establishing the amount of employment growth the economy must generate to maintain high levels of employment. They serve as the basis for one approach in setting goals for a general economic growth rate consistent with full utilization of human resources. Projections help the planner to gain insight into the characteristics and numbers of workers who will be available for industry, and to see what this implies for education, training, and personnel policies. In addition, labor force projections, together with population projections, are used to estimate demand for products, develop marketing plans, and evaluate expansion programs. The U.S. Department of Labor is particularly concerned with the relationship between the expected labor supply and the need for various skills and training created by our changing technology.

Method: Projections of the labor force as a whole and of the separate age-sex groups are made for quinquennial dates usually for about 15 years ahead. The schedule for preparing the projections has been irregular, owing in part to the timing of new projections of the population of working age. Labor force projections for 1980, 1985, and 1990 were published in July 1973. Work on a new round of projections was begun in late 1975.

Because social and economic factors affect the supply of labor, certain assumptions need to be made about conditions surrounding any set of labor force projections. Generally, projections have been made on the basic assumptions that past trends in labor force participation would continue into the future, and that the economy would continue to expand and maintain high levels of employment opportunity consistent with an unemployment rate of about 4 percent. Another usual assumption is that there would be no major war or significant change in the size of the Armed Forces which might substantially alter the previous work patterns of the population. It also presupposes that the trend toward increased school enrollment beyond the high school level, which has a direct bearing on labor force activity of young persons, would continue, supported by adequate school facilities, staff, and aid to students.

The general approach used in preparing the Bureau's labor force projections is to project the proportion of the population in each age-sex group or subgroup that is expected to be in the labor force, i.e., the labor force participation rate at the specified future date, and to apply these rates to the expected population in each group.

In making projections for a given age-sex group or its subgroup, the standard procedure is to fit a line or curve to a series of points representing the labor force participation

rates for that group for the years since 1947, and to extrapolate the line or curve into the period covered by the projection. The procedure is modified, as appropriate, to discount the temporary effect of factors judged to be operative for only short periods.

The population projections used in projecting the labor force are prepared by the Bureau of the Census on the basis of analyzing past trends in birth rates, death rates, and net immigration, and then projecting these trends. Since the birth rates pose the most uncertainty in projecting the population, the Bureau of the Census prepares several series of population projections on the basis of varying assumptions with respect to birth rates. The uncertainty of projecting birth rates does not directly affect the level of the labor force projections 15 years ahead, since everyone of working age (16 years and over) at that future date has already been born when the projections are made. However, the birth rates do have a bearing on projections of the labor force participation rates of younger married women, because mothers of young children are less likely to work. Because of this indirect effect, it was necessary to select the one series of population projections which seemed most reasonable on the basis of an independent evaluation of past trends in birth rates. For recent labor force projections, series "E" of the population projections published in the Census Bureau's *Current Population Reports,* Series P-25, No. 493, was chosen as the base series. Alternate estimates of the total labor force of women 16 to 49 years of age were made on the basis of the series "D" and "F". (Appendix 4.5, Chapter 4, describes methods.)

The overall size of the labor force is built up by age and sex, not only because the composition is needed for many of the purposes noted earlier, but also because the degree of labor force participation varies among the different age-sex groups, and the historical trends in these rates also vary. Some of the factors which help to explain the behavior of the labor force participation rates which affect particular groups include school attendance, marital status, birth rates, and the availability of social security benefits, and the expansion of private pension plans. The method of projecting the labor force participation rates for the various age-sex groups takes into account the influence of the more important of these specific demographic and social factors. For example, the population of married women aged 20 to 49 is grouped by those who are expected to have children of preschool age and those with no children under 5, on the basis of projected trends in fertility and child spacing.

For each of the demographic subgroups, the projected labor force participation rates are applied to their respective future populations and the resulting labor force summed to provide the total labor force for each age-sex group and for all ages.

Sources of Data: The source of the basic historical data on labor force participation rates by age and sex used to project the labor force is the monthly statistics on the labor force. These data are published by the Bureau of Labor Statistics and are based on the Current Population Survey of the Bureau of the Census. Historical data on labor force activity by various categories within several of the age-sex groups are ob-

tained from the recurring supplementary labor force surveys also based on the Current Population Survey. These include information from the October surveys of the employment of school-age youth and the March surveys of the marital and family characteristics of workers.

The population projections are the latest available projections made by the Bureau of the Census and published in their *Current Population Reports*, Series P-25. Data used in projecting the proportion of women in each age group who will have children under age 5 include published and unpublished data on birth rates, by age of mother and order of birth, from the Division of Vital Statistics of the Public Health Service; fertility and marriage data from reports of the Bureau of the Census, *Current Population Reports*, Series P-20, and data from the decennial censuses of population.

*Source: Bureau of Labor Statistics, *Handbook of Methods*, Bulletin No. 1910 (1976), p. 24-25.

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5. *Population and Labor Force Projections for the U.S., 1960 to 1975*. (BLS Bulletin No. 1242, 1959).

READING 8.3

Economic Growth Studies *

Background: The Bureau of Labor Statistics has developed a program of economic growth studies aimed at providing a framework for analyzing the problems of long-run economic growth. The primary objective of this program is to develop projections of employment opportunities under alternative assumptions. These projections provide a framework for assessing a number of important economic problems, including labor utilization over the next decade and employment requirements of specific government programs.

Methods: A system of economic growth models has been developed to serve as a tool in making economic projections. This system begins by projecting the economic growth rate of the United States under conditions of potential or near-potential utilization of its labor and capital resources. This is referred to as potential Gross National Product (GNP). To do this, the system must project the labor force to the target year, assuming a specified unemployment rate, and project the rates of change in productivity and average hours paid.

This potential GNP is then distributed among the major demand components of GNP by use of a macro-econometric model. This model converts potential GNP into income by sector, such as government revenues, personal income, and business income, and in turn translates income into aggregate purchases or demand. The foreign trade sector and some government accounts are left for exogenous adjustment to permit flexibility in certain assumptions of the projections. The macro-model is designed so that projections of supply GNP and demand GNP are not necessarily equal. The equating or balancing of these is done by making selected changes in government fiscal policy.

The next stage is to develop a projection of the industry composition of demand for each of the major demand categories. For example, the consumer expenditures category includes the amounts spent on rents, automobiles, medical expenses, and other goods and services purchased by consumers. For each of the major demand categories, different analytical procedures are followed in allocating demand to the producing industry. In some cases, submodels are used to assist in this analysis. The industry detail to which the categories of demand are allocated matches the input-output classification used in the subsequent step.

Demand as used in the national income accounts refers only to final demand, i.e., that of the ultimate consumer. To place a value on the output of an industry whose products are sold to ultimate consumers, but are used as inputs to other industries in the course of their own production, an additional set of calculations is necessary using an input-output model. The input-output model

translates final demand for a given product into the output that is required from all other industries to produce the materials needed to manufacture that product of service.

Prior to use of this model, the input-output coefficients** are projected. The input-output tables used as a base in the economic growth model are developed by the Bureau of Economic Analysis, U.S. Department of Commerce. However, these input-output tables incorporate the technology and product mix for a base year and may not reflect the technology and product mix which may prevail during the period for which the projection is being made. Thus, it is necessary to project changes in the input-output coefficients. Two methods are used to do this.

First, detailed analyses are made of the changes taking place in the technology of various industries, as well as the changes expected in product mix due to differing growth rates of product groups within industries. In those industries for which detailed studies are not made, analyses are developed to determine the direction and magnitude of change in the use of its products by other industries.

Second, employment estimates by industry are developed. This is accomplished by use of a set of industry productivity projections. The final stage is to balance the model. Projections contain many complex relationships among economic variables that were developed through a lengthy sequence of operations. It is necessary to have a set of checks and balances to insure that the various stages of the projections make up an internally consistent model. The economic growth model is designed to provide a feedback and balancing procedure with respect to three of its elements: imports, investment, and employment. In practice, all three of these elements must be brought into balance simultaneously.

Uses: long-term employment projections. The projections developed in the economic growth program serve a number of uses. The employment projections by industry are used in developing occupational outlook projections. The projections developed by the Bureau form an important part of the U.S. Government's report to international organizations on long-term economic outlook for the United States.

*Source: Bureau of Labor Statistics, *Handbook of Methods,* Bulletin No. 1910, (1976), pp. 256-257.

**Unit amounts of output from one industry which is input to another industry.

CHAPTER 9

Manpower Planning Methods: Unit Two

1.0 *Introduction to Unit Two*

In Unit One the first step of the basic method was completed. Employment was projected by sectors of the economy. In Unit Two the remaining steps of the basic method will be presented, beginning with the distribution of employment by occupations within sectors for the target year and the base year. The distribution of employment by occupations for the base year is generally taken from census data, as in the Chilean case to follow. Unit Two will explain methods for distributing employment by occupations within sectors, and for relating education attainment levels to occupations.

To summarize the steps:

— The first step of the basic method projected employment by sectors of a national economy.

The remaining steps are:

— Employment is distributed by occupations within the sectors for the target year.

— Educational attainment is related to occupations for the target year. This yields the educational requirements for the target year.

— The outflow of educated workers from the base-year stock is estimated for the period from base year to target year. (This outflow is caused by death and retirement of workers during the projection period. In some areas, emigration is a major cause of outflow.)

— The base-year stock, minus the outflow, is subtracted from the target-year projection of requirements to yield the number of educated workers required during the period.

— The supply of educated and trained workers entering the work force during the period is projected and compared with the numbers of educated workers required (step 5). The deficit or surplus can be used as a target to plan education and manpower development programs according to the so-called demand of the economy.

1.1 *The Objectives of Unit Two*

The objectives of Unit Two are:

— To understand the details of the remaining steps of the basic method; to be able to describe the tables yielded in steps 1 through 6 and explain the purpose of the steps.

— To be able to describe the common data sources and methods used in the steps.

— To be able to discuss shortcomings of of the method.

— To be able to describe the uses of the results of the method.

Instructional Note: Units One, Two and Three should be illustrated with the Chile and Dominican case. The instructional units and the cases were designed to support each other.

2.0 *Distribution of Employment by Occupations Within Sectors* (Step 2)

Step 2 of the basic method distributes the employment (projected in step 1) by occupations within sectors. The base-year distribution of employment by occupations within sectors is provided by census tables supplemented by survey and specific sectoral or industry employment data. This distribution is used as a guide for distributing employment by occupations in the target year. However, over the years of the projection, the occupational distribution will change. The task is to analyze the factors which will affect this occupational distribution and to make assumptions as to how it will change. There will always be growth in occupations requiring more education and training, but the challenge is to develop a systematic method for projecting these changes. The basic method is systematic, but it is not free of subjectivity. The changes are based on the analyst's judgment. The issue, then, as in any projection method, is how adequate are the assumptions on which these changes are based. In the Chilean case the statement is made: "The 1970 distribution is a modification of the 1960 pattern, based upon international comparative information from countries more economically advanced than Chile." In Chile, occupational distributions were based on those found in European countries, and the assumption is that Chile will follow the European experience closely enough so that the projections will serve. This comparative assumption will be discussed. It is often used and mis-used.

2.1 *Setting Occupational Distribution*

In step 2, the percentage of workers in each occupation within each sector is set for the future year. This setting is based on experience, opinion, and percentage distributions in the work forces of other countries. The simplest procedure is to assume that these same base-year percentages will hold in the target year. Usually, however, the planner takes into account the growth projected for the different sectors and industries from base to target year, the expectations of changes of inputs in labor and capital, and the experience of other countries, in order to set a reasonable distribution for the target year. The planner may also take into account the change in occupational structure in past years in the country and its influence on output. The major guidelines come from expected growth in certain key sectors, as assumed or projected in the over-all plan. If growth is planned for the manufacturing industry, the percentages of professionals (0), administrators (1), artisan-craftsmen (7),

and operators (8) might be raised in the manufacturing sector. How much would they be raised? There is no analytic answer to this. It would depend on how high the existing percentages are for the country in the base year, and how high they are in other countries that have similar outputs or industrial structures. It is sometimes possible to select a more developed country and to move the percentages up toward this target.

Distributions of percentages in occupations have been published for various countries. Parnes (1963) has summarized some of these in his appendix tables. OECD, *Occupational and Educational Structures of the Labor Force and Levels of Economic Development* (1970) is another source of guidance. Also the study by Horowitz, Zymelman, and Herrnstadt, *Manpower Requirements for Planning, Statistical Tables* (1966) is useful, as is Zymelman's "Productivity, Skills and Education in Manufacturing Industries" (in *Planning for Advanced Skills and Technologies*, United Nations, New York, 1969). These sources can also provide the basis for setting educational attainment levels by occupations, which is the next step of the Basic Method.

In step 2, as in step 1, it is important to realize that the upgrading of occupational percentages for the target year may depend on a series of assumptions and guesses which are systematized in the projection.

Step 2 is completed by multiplying the occupational percentages set for the target year by the employment projected in step 1. A few cells from Table 9.1 will suffice as an example. This part of the step is purely mechanical. The setting of the percentage distribution requires experience, judgement, and sometimes luck.

Table 9.1

Number in a Given Sector, by Occupation, in Target Year n

Occupation	Total employment in sector, year n	Occupation %, in year n	No. in sector/occupation year n
	200,000		
0 Professionals	.	3	6,000[a]
1 Managers/Admin.	.	2	4,000
.	.	.	.
.	.	.	.
Total	.	100	.

[a] .03 x 200,000 = 6,000

Occupational totals can then be summed for sectors, and the result is a table showing the numbers of workers in each occupation for the target year. Tables 10.3 and 10.4 in the Chilean case, given in the next chapter, show this step. In Table 10.3 the occupational distribution for the target year is set. In Table 10.4 the occupational percentages are multiplied by employment projected for the sector in step 1, and the result shows the number of workers in each occupation for the various sectors.

As in any projection exercise, alternative occupational settings may be

hypothesized. This will yield alternative projection series. For example, one projection might show occupational distributions unchanged from base year to target year; and a second projection may assume a large increase in occupations requiring more education and training. The resulting projections of manpower requirements will be substantially affected, and the policy maker who uses the results has only the reasonablemess of the assumptions which underlie the projection as a basis for judging which alternative is better. This is also true of population projections.

3.0 *Educational Requirements of the Workforce*

The aim in this step is to estimate the educational requirements of the workforce in the target year. Educational classifications are arbitrary. The categories and groupings will depend on the planner's interest, the school system, and available data. The educational classification system used in Table 9.2 was based on the school system in the Chilean case.

3.1 *Distribution of Education by Occupations* (Step 3)

The educational attainment percentages for the target year are then set for the various occupations. Again, this is an operation without hard and fast rules. The general strategy may be to raise university and college attainments in the first two occupational categories, and to raise technical secondary school training attainments for craftsmen and operators. For example, if the professional group having university level preparation in the base year is 65 percent, the strategy might be to raise this to 90 percent for the target year. This is a substantial raise and will create a large demand on the educational system, inasmuch as the professional workforce in the target year will be a much larger base number on which to levy the increase. This is so because the total population, including the workforce, will almost certainly be growing during the plan period, and the percentage of professionals in the work force will have been raised in step 2.

The same sources used for guiding the setting of occupational distributions, which were cited in the previous step, can also be used for setting educational attainment levels by occupations (see OECD, *Occupational and Educational Structures of the Labour Force*, and United Nations, *Planning for Advanced Skills and Technologies*). Great care must be exercised in choosing comparative models. Educational attainment levels in the occupations may differ by countries. One reason is that educational attainment measured in years completed may not mean the same thing in different countries. There is no standard educational attainment unit, although years completed is most often used. The measurement of true product in an educational system is a complex process as studies of educational effects demonstrate (Chapter 2). Learning outcomes may only be assessed by massive achievement testing, as in the International Evaluation of Educational Achievement (IEA Surveys, see Purves and Levine, 1975). Standards for comparisons of outcomes are difficult to apply across systems, inasmuch as the objectives may be quite different. The route to occupational efficiency

Table 9.2

Educational Attainment by Occupation in Target Year n

Occupation	Col. 1 Total	Col. 2 University graduate studies complete (19 yrs.)	Col. 3 First degree level university (17 yrs.) professional and higher normal	Col. 4 Sub-professional (15 yrs.)	Col. 5 Tech. complete (12 yrs.)	Col. 6 Secondary general	Col. 7 Lower normal complete (12 yrs.)	Col. 8 Primary complete (6)	Col. 9 Literacy grade (4-6)
0. Professional/science No. % 1. Administrative/managers No. % 2. Clerical No. % . . 7. Artisans No. % 8. Operators No. %						includes those who finish 12th grade only plus those who finish 12th grade and go on to col. 2, 3, and 4 groups		includes those who finish primary plus those who go on to cols. 5, 6 and 7 groups	includes those who finish at least 4 grades plus col. 8 group

Note: Educational levels may be grouped in various ways. The basis is arbitrary. Here the groups are
Col. 2 includes all who finish through 19th grade.
Col. 3 includes all who finish 17th through 19th grade.
Col. 4 includes all who finish 15th grade sub-professional.
Col. 5 includes all who finish only 12th-grade technical training plus the proportion of those who finish this track and attend higher education (Both sub-professional and professional, i.e. lines 3 and 4).
Col. 6 includes all those who finish only 12th-grade general preparation plus those who go on to higher education from this track. (Because schools must produce graduates who terminate at 12 and graduates who continue on.)
Col. 7 includes all those who finish only 12th-grade lower normal plus that proportion from this track who go on to higher education.
Col. 8 includes all those who finish primary, plus those who finish grades 7 up to 12 (in the secondary tracks) plus the totals of 5, 6, and 7.
Col. 9 includes 8, plus those who finish at least 4 grades but less than a complete 6 years of primary.

may be quite different in different countries. One country may require much more formal education for a comparable occupation.

3.2 *Estimating Education-Occupation Distributions*

Alternate education-occupational settings may be used for the target year. In one set, the educational attainment coefficients of the base year may be maintained into the target year. Even when the coefficients are unchanged, the target-year requirements will be larger absolutely, because employment in higher occupations increases. Sets of educational attainment coefficients can be applied to yield different sets of alternative projections. Before coefficients are raised to some very high level, the consequences of this assumed "demand" on educational output must be checked against the capacity and likely revenues available for expanding the educational and training facilities. Demand and supply projections need not be independent. One can be used to check the other. Note also that projected manpower requirements are not really demand forecasts, since market effects may be omitted; but the term *demand* is used.

The final operation in step 3 would appear as in Table 9.3, which is not a final demand table because no allowance has yet been made for wastage or in-migration of educated and trained people.

Step 3 yields the target-year estimate of educated people required in the workforce. This comes from summing each educational level down the list of occupations. In the case of alternative hypotheses, there will be different totals for each educational level according to the alternative settings of the attainment coefficients that is chosen.

4.0 *A Note on Alternative Steps in Applying the Basic Manpower Requirements*

Method

Beyond step 3, there are alternative ways of arriving at a final demand and supply estimate for educated manpower:

— Reduce the base-year stock of educated workers by applying wastage rates. Wastage is loss from death and retirement over the years of the forecast. The original stock, reduced by wastage, would then be added to the new supply coming in from educational/training programs during the years of the forecast, and the result subtracted from projected requirements to estimate the final deficits and surpluses. This is essentially the procedure followed in the Dominican manpower case. This process was modeled in Figure 1.3, Chapter 1. The second alternative is equivalent.

— Alternatively, the planner can project the output of education and training institutions over the plan years, compare this to the projected requirements, and then add in additional requirements to allow for wastage from the original stock. There will also be some loss among new graduates who enter as workers over the course of the plan. This is the method followed in this text, and it is similar to the Chile case.

Table 9.3

Educational Attainment by Occupation in Target Year (n)

Occupation	Univ. grad. studies complete (19 yrs.)		First degree level university (17 yrs.)		Sub-professional.....15 yrs.		Literacy grade 4-6		
	Hyp. I	Hyp II	Hyp. I	Hyp. II	Hyp. I	Hyp. II	Hyp. I	Hyp. II	Totals[c]
0 Professionals (Total = 100,000)	5,000[a]	7,000[b]							
1 Administrators									
.									
.									
.									
.									
7 Artisans									
8 Operators									
.									
.									
.									
.									
Totals[d]									

[a] .05 x 100,000

[b] .07 x 100,000

[c] Hyp. I = Hyp. II = 100,000

[d] Hyp. I ≠ Hyp. II

The Paraguay manpower study, run as part of the overall project which produced these volumes on planning, was only a projection of manpower requirements. This projection was not compared to the supply of educational and training institutions in order to calculate a final deficit or surplus estimate. (A. Daniere and R. Davis, Paper 79 of USAID/Harvard Planning Project, Cambridge, Mass., 1979).

5.0 *Outflow from Workforce Stocks* (Step 4)

In step 4 we will estimate outflows (loss) from the workforce and add these to the requirements in the target year. To the workforce stock in the base year, we apply death and retirement, or *wastage* rates, over the plan years. The most direct route is to calculate wastage rates for groups classified by educational attainment levels, but usually it is necessary to work through occupations and then education levels. The outflow rate is made of two main components: death rate and retirement. (For areas within countries, emigration affects outflow, and this must be used to modify outflow rates. Transfers from one occupation to another also occur.)

Worker death and retirement rates differ by age. To apply these age-specific rates, the workforce in the base year must be broken down by worker age groups (15-19, 20-24, etc.). Because the outflow rates will be different for occupations, depending on base-year age structure and work life, the workforce in the base year may be cross-classified by occupations and age groups. The outflow rates that will prevail during the plan years are estimated and applied in five-year steps, as in life table methods shown in Chapter 4.

The procedure is sketched in Table 9.4 During each five-year plan period, a certain number in the occupation leave through death or retirement, W_1, W_2, etc. These numbers are summed over the plan period. Outflow by occupations can be converted to outflow by education levels, using the educational attainment coefficients.

If the period between x and target year n is 10 years or more, it may be necessary to apply wastage rates to the new entrants to the workforce during these years. Entrance rates are first applied to the age groups. Then a wastage rate is applied and the result subtracted. This wastage is often ignored unless the plan period is very long. In Venezuela and Chile, demographers have constructed life tables for the economically active population. The tables appear in standard life-table format; but both mortality and retirement rates are applied to reduce the original cohort.

6.0 *Aggregating Requirements by Education Levels* (Step Five)

Table 9.5 shows the requirements by occupations for each education level. The requirements for target-year education by occupation levels were taken from step 3; outflow is added from step 4; and step 5 is simple arithmetic. The number in the stock in the base year is subtracted from the requirements projected in the target year. To this difference is added the outflow over the intervening years (calculated for occupations within the education levels).

Table 9.4

Application of Outflow Rates to an Age-stratified Occupational Group (Base Year x to Target Year n)

Occupation: 0 Professional

Age group	Stock,[a] x	Outflow rate,[b] x to x + 5	Outflow x to x + 5	Stock, x + 5.....	Stock, ...n
30-34	3,000	0.0282	85[c]	2915[d]	
35-39	5,000	0.0375	188	4812	
40-44	6,000	0.0625			
45-49	7,000	0.0915			
.					
.					
.					
70-74	500	0.5081			
75+	120	0.6429			
Total outflows			w_1[d] Period 1, Total	w_2 Period 2, Total	

Note

Repeat process from x + 5 to x + 10, x + 10 to x + 15, until year n is reached.

[a]fictitious

[b]from work force life table

[c]0.0282 x 3000

[d]3000 - 85

Note: The outflow by occupation can be converted to wastage by educational attainment levels because the educational attainment for the occupation is known in year x.

Table 9.5

Demand for Education and Training

Educational Level: University Graduates
Studies Completed (19 years)

Occupation	Number year x (stock)	Number year n (projection)	Difference	Outflow x to n	Total educational requirements x to n
0 Professional	10,000	20,000	10,000	1,500	11,500
1 Administrators					
.					
.					
.					
.					
.					
Totals					

and the final total is the requirements or demand for workers at given education levels, shown in Table 9.5.

Step 5 ends the demand, or requirements projection. These estimates may then be used as targets for the education-training system. The output of the education-training system, or supply, can be compared to this demand estimate.

7.0 *Comparison of Supply with Demand*

To compare the requirements, or demand, with the supply or output of educational and training institutions, requires a projection of the output of the education/training system. Supply is projected by applying enrollment flow models to the education and training system. These methods were dealt with in Chapters 5 6 on enrollment forecasting. Here we will simply note that the projected output, or supply, of the system is compared to the projected requirements to yield an estimate of deficits or surpluses in the supply of educated or trained people.

8.0 *Additional Note: Steps 2 through 6 of Basic Method as Applied in the Chilean Case*

Steps 2 through 5 of the basic method may be traced through the tables of the Chilean Case. Table 10.3 in the Chilean Case shows the occupational distributions within sectors for the base year and the target year (1970). Table 10.4 in the Chilean case shows the result of multiplying the occupational percentages by the sectoral employment forecast in Step One. Table 10.5 shows the educational attainment levels in absolute numbers and percentages by occupations in the base year 1960. Table 10.6 shows the assumed upgrading of these attainment coefficients within occupations for the target year 1970. Table 10.7 multiplies the upgraded educational attainment coefficients by occupational employment to yield the education/occupation requirements for the target year. This yields two projections: Hypothesis 0 maintains the same occupational attainment coefficients as 1960.

Hypothesis I uses moderately upgraded coefficients from Table 10.6.

Table 10.8 subtracts the 1960 stock of educated workers from the 1970 projected requirements. When the requirements for replacing wastage are added in, the result represents the total manpower required. Any forecast using the Basic Method would then project the supply of the education and training system, compare it with the net requirements from Table 10.8 and estimate the surpluses and deficits of educated workers. The final summary of educational demand is Table 10.9 of the Chilean case. The final demand/supply comparison is in Table 10.10.

This final supply projection was not done in the conventional way in Chile because of weaknesses in the enrollment and enrollment flow statistics. This is shown in Table 10.10 (numbered 10 as in the next chapter). Here it must be emphasized that the projection of supply which yielded the numbers in the second column was very crude indeed, and not recommended except when there is no alternative, as in the Chilean case. Whatever the adequacy of the supply projection, the final comparison is the same, and it is a matter of simple arithmetic, as Table 10.10 illustrates.

Table 10.10 (from Chilean Case)

Comparison of Economic Demand and Educational Supply in Chilean Manpower Forecast

	Number Completing, 1960-1970		
	Economic demand[a]	Total supply[b]	Difference (demand-supply)
18 Grades (Univ)	12,213	6,440	+ 5,773 (deficit)
17 Grades (Univ)	38,643	25,920	+ 12,723
12 Grades (All Sec)	117,952	181,570	- 63,618
6 Grades	497,539	1,053,440	- 555,901

[a] From Table 10.8.
[b] 1962 Graduate multiplied by 10 (note problems in this method)
[c] All Secondary except Feminine Technical

The deficit at university level is so large as to suggest that the assumptions we introduced for upgrading the occupational composition and

9.0 *A Note on the Narrowness of Manpower Requirements Approaches*

Here we should also note that these differences between projected requirements and projected supply are deficits or surpluses only under the narrowest interpretation of manpower planning applied to educational systems planning. The educational systems of all countries serve broader goals than merely to supply educated and trained manpower to the workforce. Education must also serve cultural, social, and political ends, and satisfy the needs of both the individual and society. Under the narrow approach to

manpower requirements planning outlined here, these broader aims are not dealt with explicitly. Educational planning methods for dealing with these broad issues are discussed in Volume I. In manpower requirements analysis, the planner narrows his view to deal with people almost as a caricature. He does this for a specific and narrow purpose which is sometimes useful and harmless as long as we keep in mind the narrowness of the focus and the caricature of humans as mere numbers of workers.

READING 9.1

National Industry-Occupational Matrix*

Background

The Bureau of Labor Statistics has developed a comprehensive set of data on the occupational employment composition of all industry sectors in the economy. Presently, industry-occupational matrices are available for 1970, 1974, and 1985. These data are set up to form a matrix or table showing estimated employment in specific occupations, plus groupings of occupations, cross-classified by industry sector. Thus, the occupational pattern of each industry sector is shown, i.e., the proportion of each occupation to total employment in an industry. Looked at another way, the tabulation shows how total employment in an occupation is distributed by industry.

In recent years, a strong interest has developed in determining occupational needs for many purposes, including training new workers, retraining workers displace by automation, and providing state and sub-state occupational information to high school counselors, employment counselors, students, and other persons making career decisions. The Industry-Occupational Matrix provides a systematic approach to developing the desired information.

Sources of Data

Data for the Industry-Occupational Matrices are brought together from a wide variety of sources. A major source for the development of the 1970 matrix was *the Occupation by Industry* report from the 1970 Census of Population. The *Current Population Survey* (CPS) is the source for data on total employment, employment for broad occupational groups, and for a few large, specific occupations. Other sources of occupational employment data included the Bureau of Labor Statistics' annual surveys of occupational wage rates in metropolitan areas and selected industries; regulatory agency statistics on employment by occupation in the telephone, railroad, and air transportation industries; U.S. Civil Service Commission statistics on employment by occupation in the federal government; statistics on selected professional occupations based on licensing data and membership records of professional societies; and surveys of employers by the Bureau and other agencies to obtain estimates of employment in a limited number of highly important occupations such as scientists, engineers, teachers, and police officers.

Specific estimates from sources other than the Census were incorporated into the cells of the matrix; the remaining details in the matrix were derived by forcing 1970 population

census estimates for detailed cells (published in *Occupation by Industry*) into agreement with control totals for occupational groups and industries from sources other than the Census. The occupational control totals were average annual employment by occupational group taken from the CPS. Most of the industry employment totals were based on BLS estimates of private wage- and salary-workers adjusted to include the self-employed, unpaid family workers, and government workers, and to exclude the secondary jobs of dual job holders. Total employment in agriculture and private households was based on CPS estimates. The adjustments of the matrix to consistency with CPS estimates of total employment and industry employment estimates, derived as described above, brings the matrix for 1970 into agreement with data used as the basis for the Bureau's projections of total employment and occupational employment by industry. The Bureau's occupational projections are reflected in, and developed in part through, matrix techniques. (See section on analysis and uses.) The 1985 matrix was developed by examining a variety of historical statistics on the changing occupational structure of industries, including data from the 1950, 1960, and 1970 Censuses, and evaluating the factors likely to influence changes in the future, such as expected new technology, changes in product mix, and the general organization of industries.

The 1970 matrix provided the base for the 1974 and 1985 matrices. Where available, occupational data from other sources, such as those cited above, were incorporated into the updated matrices as fixed cells. For the remaining cells, first approximations of the occupational patterns for 1974 were made by interpolating between the patterns of the 1970 and the 1985 matrices. The resulting patterns (in mining and manufacturing) were then brought into consistency with data on production worker trends available from the Bureau's Current Employment Statistics program. The patterns were then applied to individual industry employment controls and summed to arrive at occupational totals. These occupational control totals were then compared to data from the CPS and other sources of information. When necessary, certain occupations (except for fixed cells) were then forced on a prorated basis to predetermined occupational control levels. This iterative forcing procedure was repeated until the internal matrix cells were consistent with both the industry and the occupational controls. Thus, both the 1974 and the 1985 industry-occupational matrices were consistent with (a) national employment by industry, (b) broad occupational employment levels from the CPS, (c) trends in production (and nonproduction) worker employment by industry, (d) anticipated trends in occupational structure within industries, and (e) reliable estimates of detailed occupational employment available from the CPS and other sources.

Analysis

A basic objective of the project is to have available a comprehensive set of data on national industry-occupational relationships that can be used in projecting employment

requirements by occupation. Although statistics on employment by occupation are relatively thin, particularly between decennial censuses, there is a great deal of information on total employment in detailed industries. Each industry uses a unique combination of occupational skills, together with other factors of production, in its efforts to achieve least cost for its output. Occupational patterns may be markedly different from one industry to another. For example, employment in the insurance industry is primarily of white collar workers such as insurance agents, clerical workers, actuaries, and others. In contrast, the workforce in restaurants is largely made up of food service workers, cooks, and owner-managers. Over periods of 5 years or less, the occupational structure of many industries remains relatively stable. Consequently, if good information is available on the occupational composition of individual industries for a base period, it can be used together with the available statistics on changing employment in each industry to develop estimates of current employment by occupation for later periods. Further, if projections of output and employment are available by industry, the base-period occupational ratios applied to the industry employment projections will yield initial estimates of employment requirements by occupation for future periods.

Although the occupational patterns of many industries are relatively stable over periods of less than 5 years, it is clear that occupational patterns change with the advance of technology and changes in the supply of workers in each occupation. Hence, information on how technology and labor supply are changing the occupational pattern in each industry is used to modify the initial estimates. This improves the estimates of current employment by occupation and of future employment requirements by occupation developed by applying base-period industry-occupational ratios to industry employment estimates. Changing technology and other factors that affect skill requirements are constantly being studied to estimate the future occupational structure of each matrix industry.

*Source: Bureau of Labor Statistics, *Handbook of Methods*, Bulletin 1910 (1976), p. 53-54.

READING 9.2

*Technological Change**

Reviews of Technological Trends in Major Industries

To provide a broad overview of significant trends in the economy, the Bureau prepares a summary report applying to key industries on new types of machinery, processes and products which are believed likely to have an important effect over the next 5 to 10 years. The industries covered compose a cross section of the economy and include those where the pace may be slow, as well as those where change is rapid. The first version of this report, entitled *Technological Trends in 36 Major American Industries*, was issued by the President's Advisory Committee on Labor-Management Policy in 1964. A revised edition covered 40 industries.

Definition of Technological Change

Technological change is defined broadly in the BLS studies, as encompassing significant changes in processes and equipment, products and services produced, and materials, fuels, and energy used. The term "automation," which is sometimes popularly used as a synonym for "technological change," designates, strictly speaking, a particular type of current development. It has been variously defined, for example, as "automatic operation," "the mechanization of sensory, control and thought processes," and "a concern with production processes as a system."

While BLS studies have been concerned with developments in "automation," particularly in anticipating long-term trends in the future, they are not the only technological changes taking place that affect labor requirements and industrial relations. For example, new ways of generating power, piggybacking in transportation, use of synthetic materials in manufacturing, mechanized methods of materials handling, and faster steelmaking processes are important technological developments, not usually covered by technical definitions of "automation," but having significant manpower implications.

Impact on Productivity

Since one of the principal consequences of technological change, so far as manpower utilization is concerned, is an increase in productivity — i.e., output per employee-hour — special attention is given in BLS studies to analyzing changes in industrial productivity. Such trend analysis is a useful method of measuring the pace of technological change. Changes in productivity, however, also reflect changes in capacity utilization and many other nontechnical factors; it is important to recognize that the productivity trend is only a partial measure of the rate of technological change.

In determining the impact of a specific technology, BLS studies try to indicate the reduction in unit labor requirements that the new processes are designed to achieve. In some cases, estimates of labor savings are derived on the basis of comparisons with the estimated average technology of the industry under study; in others, with the best equipment that is available; or in actual plant studies, with the technology that is actually displaced.

It is also important to distinguish between the impact on productivity of the operation directly affected and on productivity of the plant as a whole. An advanced machine tool, for example, may result in a relatively large reduction in unit labor requirements in the machining operation, but would have little impact on finishing, and assembling, and may even require additional labor in engineering and maintenance work. The impact on plant productivity, therefore, would be considerably less than the effect on productivity of any department or operation directly affected.

Impact on Employment

In assessing the impact of technological change on employment, it is necessary to consider the implications of plant manpower policies and the effects of economic changes with which technical changes interact. Analysis of the impact of technological change purely in terms of machinery is incomplete.

At the plant level, for example, the substitution of machinery for labor may substantially reduce job opportunities in operations directly affected. If efforts are made, however, to eliminate these jobs by not filling vacancies created by quits, deaths, and retirement of employees, or by transfer of affected workers to other positions in the plant or office, labor savings could be achieved without displacing the workers affected from the plant.

Moreover, the employment impact of technical change is also interrelated with the effects of the business cycle. Thus, workers whose jobs are eliminated by technical changes may not be displaced from a plant until a decline in demand results in layoffs—a long time after the change has been made in some cases. In the subsequent recovery, however, they may not be hired back because their jobs no longer exist.

Since many changes exert their effects on employment through the competitive market, the employment trend for the industry as a whole must also be examined. The plant which reduces its unit costs through technological improvement may be able to gain a larger share of the market and increase its employment, but at the expense of the less technically advanced competing plants, which may be forced to shut down, displacing workers far from the location of the change.

Because of the whole complex of economic factors that operate through the market, including changes in demand, location, foreign competition, merger, and consumer taste, it is very difficult to isolate the expanding and displacing effects of technological change.

Impact on Occupations

Two aspects of occupational change resulting from technological

changes are examined. Changes in job structure—the distribution of the plant or office workforce by function or broad skill-grouping—are studied to determine the extent of upgrading or downgrading. Since the content of jobs may be altered as a result of changes in equipment or processes, attention also is directed to intensive before-and-after analysis of job duties and the knowledge and abilities required to perform these duties as indicated by job descriptions and observation. The content of newly created jobs, such as programmer, also is studied.

*Source: Bureau of Labor Statistics, *Handbook of Methods*, Bulletin 1910 (1976), p. 235-236.

CHAPTER 10

Manpower Planning: A Case Study of the Basic Method

1.0 *The Chile Manpower Planning Case*

This case, which describes manpower planning in Chile, was selected because it is almost a classic illustration of the basic methodology of macro-level manpower planning. As such, it exemplifies the limitations of the basic method. It also demonstrates the fact that despite the limitations of the method, policy and decision makers in developing countries request such work from visiting analysts. In the Chilean case, "request" is perhaps too weak a word; "demand" might be more accurate. In preliminary discussions in Chile, the team of visiting specialists, after explaining the limitations of quick and general manpower analysis to Chilean officials, were told—"Do the work, and let us judge how useful the results are." The reasons given by officials for wanting the manpower analysis, whatever its limitations, were these:

- Chilean planners wanted a general manpower requirements framework within which to place several studies of requirements for specific occupations (for example, the engineering fields) and sectors (mining). Though separate studies had been done, it was difficult to relate them. The planners wanted a general framework for relating the various economic forecasts.
- They wanted a general manpower accounting framework for monitoring the current development plan.
- They wished some very general estimates of deficits and surpluses for various education types and levels, as a general guideline for the educational reform that they were planning.

The visiting specialists decided to go ahead and do the best they could under the circumstances. The work was carried out in Santiago, Chile, in June 1964. The favorable circumstances were that there had been a recent census (1960) of the workforce, and these basic data could be made available in special runs of the census results. Additionally, officials furnished full cooperation and support because they wanted the work. The visiting team members were experienced analysts and planners; their Chilean counterparts were competent economists and planners, and the working relationships were excellent. The disadvantages were that the task had to be completed in less than a month of full-time work; only one of the visiting team was fluent in Spanish; and the enrollment data for the education training system were wholly inadequate for running systematic projections of supply. In the attempts to project the educational supply of students, the Chilean case

is weak, but because this study revealed this lack of data, Chilean planners later improved enrollment and enrollment flow data for the education system.

The events described in the case took place in 1964, almost 15 years before the preparation of this case. This means the work is outdated; but a compensating advantage is that time has passed and the projections have been compared with subsequent events. In spite of the haste with which the work was done, and the limitations of the data, the projections stood up remarkably well. This does not mean the work was good, but merely that the future actually turned out to be similar to the future that was forecast. Moreover, though these are the methods of 15 years ago, the methodology has not improved all that dramatically. Manpower planning techniques still have weaknesses, and the results depend greatly on judgments and hunches of experienced and skilled analysts. The work was done under the direction of W. Platt, assisted by A.M. Loeb and R.G. Davis. It is described in a monograph: William J. Platt, Al M. Loeb, and Russell G. Davis, *Manpower and Educational Planning in Chile,* Chile-California Program, Vol. 1, Santiago, 1964. Sections from this monograph have been used directly in this case.

1.1 *Introduction*

(Taken directly from report of Platt, Loeb, and Davis 1964).

On April 23, 1964, the Director of the Bureau of the Budget of the Government of Chile and the Director of USAID/Chile agreed that the Chile-California Program would provide technical services to accomplish the following purposes:

> . . . to evaluate existing activities in human resources planning; to recommend possible new orientations, studies and methods that can be useful for the projected objectives of manpower planning in relation to development plan goals; and to recommend institutional arrangements for the collection of human resource data and for its utilization as a basis for policy and planning decisions generally, and specifically in educational planning, especially at the secondary and higher training level, including, most importantly, vocational, technical and professional training of importance to the development process.

We adopt here a broad definition of "human resources planning." We take the term to include: (1) planning that will help Chileans to develop themselves and their country; and (2) planning for the institutions that help allocate proficiencies and skills in such a manner that people are performing as near to their full potential as possible. Within this definition we are concerned for planning that will not only assist the formal education system, but will also help all the formal and informal upgrading of abilities that goes on in training programs and on the job.

We have concentrated on the *economic* requirements for education and training. We recognize that social and political requirements are as impor-

tant as economic requirements, but we interpreted out terms of reference to emphasize the economic needs. Chile must, of course, make policy choices and establish budgets in education that take direct account of social, political, and cultural requirements. We offer the following suggestions only in the hope that they may help clarify some of the connections between education and training policies and economic requirements.

1.2 *Method of Approach and Organization of the Report*

Our approach was determined primarily by three factors: (1) the limited time at our disposal, (2) the priorities expressed by Chilean officials upon our arrival, and (3) the availability of data and previous analyses. On the second count, in our initial meeting, the Director of Planning and his Deputy agreed that the most serious deficiency in human resources planning in Chile was the need for an immediate or early approximation of the economy's future demands upon the educational system. They agreed that they would like this demand to be expressed in the output of graduates by type and level of education. Our own assessment corroborated their opinion that this deficiency was a serious one. In view of this overriding priority, we devoted a substantial effort to working with Chilean counterparts in preparing a first approximation of the economic needs for graduates between 1960 and 1970 to support the ten-year development plan.

2.0 *Estimation of Employment in the Base Year (1959) and Target Year (1970)*

Table 10.1, Employment by Sector, 1959-1970, is the first step. Its objective is to translate the development plan into employment. Employment, both quantitative and qualitative, is one of the considerations that must help shape a development plan. Foreign exchange, investment and savings, and manpower requirements are bases for determining the feasibility of a plan and of selecting among alternative programs of development.

The estimate of employment in 1970 had to make some assumptions as to productivity by sector in that year. An attempt was made to find empirical trends in productivity for output and employment series available for the period from 1958 to 1962. Because of price instabilities and other data difficulties, we decided to rely more heavily on an estimate that established targets for the improvement of productivity. These were based on some inquiry into the sector plans, and upon international comparative experience in productivity changes. We urge that the setting of these targets be done more thoroughly and with greater participation by people who have intimate knowledge of each sector and of major development projects and investments that may take place in the sector.

We also recommend that a new employment projection be based upon a more detailed breakdown of the sectors, particularly of manufacturing and of services, private and public. While we had output figures, past and future, for this further disaggregation, we did not have employment figures to match.

Table 10.1

Employment by Sector, 1959-1970

Economic Sector	Employment 1959	Employment 1970	Assumed annual growth in productivity
Agriculture	657,194	1,084,397	0.8
Mining	91,449	106,956	4.5
Manufacturing	420,818	607,821	3.0
Construction	114,064	154,383	4.0
Services, private	712,278	947,270	2.8
Services, government	197,579	191,312	2.8
Total labor force	2,193,382	3,092,139	
Total population	7,194,258	9,438,867	
Workforce participation rate,	30.5	32.8	

2.1 *Estimate of Employment, 1970*

(a) *Employment, 1959.* Employment figures by sectors, estimated unofficially by Development Corporation Planners for the years 1950-1962, were used as a starting point. Estimates for 1960 were compared with the actual figures supplied by the 1960 Census, obtaining a relationship which was then applied to correct the estimates for 1959.

(b) *Production.* The estimates for 1970 production by sectors were prepared by taking the 1959 figures and then using the sectoral rates of increase as stated in the National Economic Development Plan.

(c) *Productivity.* First, 1959 production by sectors was taken as base because in that year there prevailed in Chile certain characteristics of "stability" (moderate inflation, no major disequilibrium in the balance of payments, etc.); secondly, this was divided by the estimated employment in each sector during that year. Thus, there was obtained a per capita production estimate in 1959 Escudos (National Monetary Unit) for each sector.

(d) *Rates of increase for productivity.* An analysis of the rates of productivity was performed, based on physical production indices and on employment indices by sectors, between 1959 and 1962. Since it was observed that these were not very consistent, another estimate was made for annual growth rates in productivity by sector, starting from 1959. The resulting average annual estimated rates are as follows:

Sector	*Percent*
Agriculture	0.8
Mining	4.5
Industry	3.0
Construction	4.0
General Services	2.8
Governmental Services	2.8

(e) *Estimated employment, 1970.* Using the per capita productivity estimates (see d., above) and the projection of production by sector (see b, above), employment in each sector of the economy was estimated. The results are shown in Table 10.2. The sector general services (all private sector services) is an aggregation of five sectors shown in disaggregated form in Table 10.3. The growth rates were applied to the total of the five sectors to get 1970 employment in *services private* in Tables 10.3 and 10.4.

Table 10.2

Estimated Employment by Sectors

	1959			1970		
SECTOR	(1) Production: millions of 1959 E°	(2) Employment: number of persons	(3) Productivity E° per year	(4) Production: millions of 1959 E°	(5) Productivity E° per year	(6) Employment number of persons
Agriculture	523.4	657,184	796.4	943.1	869.7	1,084,397
Mining	287.6	91,449	3,144.9	545.9	5,104.2	106,956
Industry	842.8	420,818	2,002.7	1,684.7	2,771.7	607,821
Construction	104.4	114,064	915.3	2,174.6	1,408.6	154,383
General Services	1,775.5	712,278	2,492.7	3,199.5	3,377.6	947,270
Governmental Services	327.3	197,579	1,656.5	429.4	2,244.5	191,312
Totals	3,861.0	2,193,381		8,977.2		3,092,312

(1) Provisional figures from the National Accounts. E°stands for Escudos, the National Monetary Unit.
(2) Adjusted figures from unofficial calculations by the Development Corporation Planners.
(3) Obtained by dividing column (1) by column (2).
(4) Estimate made on the basis of sectoral rates of increase as per the National Economic Development Plan.
(5) Based on initial estimates by William Platt of productivity increase rates between 1959 and 1970, made by National Development corporation economists, and modified by Manpower Planning Team.
(6) Obtained by dividing column (4) by column (5).

The next step is shown in Table 10.3, Employment Distribution by Occupation and Sector, 1960 and 1970. This step is undertaken because we want to relate educational requirements to occupations, not to sectors. However, there may be some educational plans that will need sector breakdowns. Table 10.3 is the means of reconverting employment back to a sector breakdown if that is needed.

The 1960 distribution is the actual one calculated for the Census. The 1970 distribution is a modification of the 1960 pattern, based upon international comparative information from countries economically more advanced than Chile (see Parnes 1962, 1963).

2.2 *Note to the Reader of this Case*

The product forecasts were taken from the economic development plan. Productivity estimates were based on past analysis of historical trends, modified by judgments of Chilean economists expert in given industries and

Table 10.3

Occupational Distributions Within Sectors, 1960 and 1970

	Total	1960	Total	1970	Agriculture	%	Mining	%	Manufacturing	%	Construction	%	Elec. Gas Water	%	Services 1960 Commerce	%	Transp. Commun	%	Services	%	Other	%	Services 1970 Services Private	%	Services Govt.	%
		No.	%	No.	%	1960	1970	1960	1970	1960	1970	1960	1970	1960	1970	1960	1970	1960	1970	1960	1970	1960	1970	1970	1970	1970
Total		2388667	100.00	3092139	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
0 Professional		118203	4.94	193016	6.24	0.20	0.50	2.40	3.00	1.35	3.10	2.72	2.50	6.60	0.82	1.08	18.25	0.85	10.00	35.00						
1 Administrative		45952	1.92	65431	2.12	0.12	0.12	1.97	1.97	2.84	3.00	2.29	5.00	1.32	3.03	2.34	2.49	0.77	3.00	4.00						
2 Clerical		162026	6.78	205414	6.64	0.45	0.45	6.90	6.90	5.50	8.00	2.17	3.00	19.15	15.80	19.73	8.90	8.58	14.00	4.00						
3 Salesmen		168219	7.04	136213	6.02	--	--	--	--	0.48	1.00	0.04	0.10	0.13	67.79	0.50	0.27	0.28	10.00	--						
4 Farmers Fishermen		657205	27.52	1047666	33.90	96.30	96.01	0.43	0.43	2.14	1.00	0.34	--	0.56	--	--	1.45	0.94	--	--						
5 Miners		55490	2.32	63831	2.06	--	--	60.20	59.68	0.05	--	0.11	--	0.13	--	--	0.06	0.07	--	--						
6 Transport Workers		77751	3.25	90097	2.91	0.49	0.49	1.47	1.97	1.67	1.67	1.55	1.55	3.48	1.63	45.12	0.79	0.81	7.00	2.00						
7 Artisans Craftsmen		423497	17.74	508280	16.44	1.70	1.70	20.32	20.32	63.91	58.41	66.15	61.64	43.39	1.17	5.08	1.41	3.31	4.00	1.00						
8 Operators		100948	4.23	185028	5.98	0.25	0.25	1.67	1.67	19.48	25.00	0.22	5.00	3.67	4.17	0.20	0.19	1.17	2.00	1.00						
9 Laborers		110980	4.61	93873	3.04	0.27	0.27	1.37	1.37	1.22	1.22	23.12	20.00	18.10	2.72	23.50	1.70	15.85	5.00	2.00						
X Service Workers		321519	13.47	300595	9.72	0.21	0.71	2.09	2.09	1.20	1.20	1.21	1.21	3.27	2.09	2.78	54.77	2.01	23.00	11.00						
Y Armed Forces and Other		147677	6.18	152306	4.93	--	--	--	--	--	--	--	--	--	--	--	9.26	65.15	8.00	90.00						

Source: 1960 Census, Table N323
1970 Occupational Distributions Estimated From International Comparisons

sectors. There was subjectivity in these so-called expert opinions. Productivity is the weak spot in most manpower plans; there are no analytical methods, firm guidelines, or fixed criteria. Although there is no space to demonstrate this, the Chilean planners' analysis was fairly sound, but the estimates would have been used in any case. There was no choice for the foreign analysts.

Table 10.4 applies the distribution percentages estimated in Table 10.3 to the employment projected in Table 10.1, thus completing the transformation from sector employment to occupational employment. (Six sectors were used in Table 10.4).

Table 10.5 shows the educational attainment of Chile's population as of 1960, broken down by occupation. The absolute numbers are Census figures, but with one statistical operation performed to make them adaptable to the methodology. The operation is that of cumulating the number who have attained a given educational level with those who have attained the next educational level. Thus, the numbers shown represent the people who answered the Census-taker by saying the specified number of years was the highest grade they had completed, *plus all others who said they had attended a higher grade.* Logic suggests this cumulative approach, because all those who reported attending the university have obviously completed primary and secondary schooling as a prerequisite.

Table 10.5 also shows the attainments in percentages. This represents the fraction of those in the occupation who have attained each level or more of education. For example, 24.11 percent of people in the administrative occupations had completed at least six years os secondary education. These percentages are called *attainment coefficients.*

For those not accustomed to such tables the results may seem strange. For example, in the occupational category "Professional" (scientific) one might expect mostly college graduates. In fact almost 25 percent do not even report a complete primary schooling (line 15, Table 10.5). Several reasons account for this: i) people report, or code, occupations incorrectly; ii) people report, or code, education incorrectly; iii) in the past, Chileans with little formal schooling entered some professions. There is always a distribution and not a fixed attainment level for an occupation. (See the Dominican Case, Chapter 12.)

The school system in Chile is "the old structure," shown in Appendix 10.1 at the end of this chapter. Groupings used in Table 10.5 are arbitrary. In some cases, the groupings corresponded with job-education requirements, or levels in the system. In one case, Commercial, the planning office wanted the 6th and 7th years separated because many students left after six years.

Table 10.4

Employment in 1970 by Occupation, Based upon 10 Year Development Plan
Percentage Distribution

Occupation	0 Agriculture		1 Mining		2-3 Industry		4 Construction		5 Services Private		6 Services Public		Total 1970	Total 1960	1970[a] / 1960
	%	Empl.	%	Empl.	%	Empl.	%	Empl.	%	Empl.	%	Empl.			
Total Employment 1970		1084397		106956		607821		154383		947270		199312	3092139	2388667	1.30
0 Professional	0.50	5421	3.00	3208	3.10	18842	2.50	3859	10.00	94727	35.00	66959	193016	118203	1.64
1 Administrative	0.12	1301	1.97	2107	3.00	18234	5.00	7719	3.00	28418	4.00	7652	65431	45952	1.42
2 Clerical	0.45	4879	6.90	7379	8.00	48256	3.00	4631	14.00	132667	4.00	7652	205414	162020	1.26
3 Sales Workers	--		--		1.00	6078	0.10	154	79.00	179981	--	--	186213	168219	1.11
4 Farmers Fishermen	96.01	1041129	0.43	459	1.00	6078	--	--	--	--	--	--	1047666	651205	1.56
5 Miners	--		.68	63831	--	--	--	--	--	--	--	--	63831	55490	1.15
6 Transport Workers	0.49	5313	1.97	2107	4.67	10157	1.55	2392	7.00	66308	2.00	3826	90097	77751	1.16
7 Artisan Craftsmen	1.70	18434	20.32	21733	54.81	333147	61.64	95161	4.00	37891	1.00	1913	508280	423491	1.20
8 Operators	0.25	2710	1.67	1786	25.00	151955	5.00	7719	2.00	18945	1.00	1913	185028	100948	1.84
9 Laborers	0.27	2927	1.37	1465	1.22	7415	20.00	30876	5.00	47364	2.00	3826	93873	110180	0.85
X Service Workers	0.21	2277	2.69	2877	1.20	7293	1.21	1868	28.00	265236	77.00	21044	300595	321519	0.94
Y Armed Forces, NEC	--		--	--					8.00	75782	40.00	76524	152306	147679	1.04
Total	100.00		100.00		100.00		100.00				100.00				

Employment from Table 10.1
% distributions from Table 10.3

[a] This was a check ratio to assess growth totals in occupations over ten year period $\frac{1970}{1960}$.

Table 10.5

Educational Attainment by Occupation - 1960

Education Levels*	0 Professional N°.	%	1 Administrative N°.	%	2 Clerical N°.	%	3 Sales N°.	%	4 Farmers & Fisherman N°.	%	5 Miners N°.	%	6 Transport N°.	%	7 N°.	%
1. Total	118.182	100.00	45.957	100.0	162.043	100.00	168.251	100.00	657.139	100.00	55.473	100.00	77.758	100.00	423.513	100.00
2. 6th year, university	8.606	7.28	399	0.86	210	0.12	120	0.07	197	0.029	2	0.003	17	0.02	23	0.005
3. 5th year, university + line 2	26.269	22.22	1.273	2.76	1.265	0.78	585	0.34	985	0.14	5	0.01	50	0.07	94	0.02
4. 4th year, university + line 3	33.039	27.95	1.931	4.20	2.503	1.54	1.092	0.64	1.404	0.21	12	0.02	118	0.15	254	0.06
5. 2nd year, university + line 4	37.002	31.31	2.962	6.45	5.326	3.29	2.177	1.29	2.070	0.31	31	0.05	259	0.33	562	0.13
6. 6th year, secondary + line 5	52,100	44.08	11.094	24.11	43.877	27.08	14.363	8.54	7.010	1.07	186	0.33	2.131	2.74	5.143	1.22
7. 3rd year secondary Ang + 4th + 5th + line 6	66.960	56.66	21.747	53.76	94.282	58.18	43.646	25.94	18.061	2.75	1.204	2.17	11.919	15.33	37.008	8.76
8. 7th year Commercial	137	0.11	316	0.68	4.388	2.70	352	0.20	82	0.012	4	0.007	20	0.02	25	0.006
9. 6th year, Commerical + line 8	436	0.36	880	1.91	11.091	6.84	1.215	0.72	249	0.037	11	0.019	97	0.12	140	0.03
10. 5th year Industrial	804	0.68	183	0.39	287	0.17	125	0.07	71	0.01	23	0.04	92	0.11	1.223	0.28
11. 3rd year Industrial + 4th year + line 10	2.459	2.08	696	1.51	1.715	1.05	837	0.49	567	0.08	313	0.56	941	0.21	7.634	1.80
12. 5th year Agricultural	236	0.19	22	0.04	76	0.04	53	0.03	263	0.04	1	0.0018	16	0.02	18	0.004
13. 3rd year, Agricultural + 4th year + line 12	532	0.45	82	0.17	234	0.14	151	0.09	858	0.13	12	0.02	65	0.08	104	0.02
14. 6th year, Primary + line 13, 11, 9 and 7 (e.g. all totals above)	84.690	71.66	32.955	71.70	125.852	77.04	99.472	59.12	77.743	11.83	12.931	23.31	45.025	57.90	220.812	52.13
15. 4th year, Primary + 5th year + line 14	87.598	74.12	36.779	80.02	130.462	80.51	124.813	74.18	201.349	30.64	26.136	47.11	60.534	77.84	315.739	74.55

* See Appendix for Chilean Education System

Source: 1960 Census

N° and %'s are cumulated downward with respect to educational level. The figures reflect both terminal students and those entering next higher level.

Table 10.5 (cont'd):

Educational Attainment by Occupation - 1960

	Operators		Laborers		Service Workers		Armed Forces, N.E.C.		Total		Men		Women	
	N.	%	N.	%	N.	%	N.	%	N.	%	N.	%	N.	%
1. Total	199.939	100.00	110.182	100.00	321.527	100.00	147.806	100.00	2.388.773	100.00	1.854.454	100.00	534.319	100.00
2. 6th year, university	4	0.04	-	-	20	0.006	159	0.10	9.758	0.40	9.952	0.48	806	0.15
3. 5th year, university + line 2	24	0.02	3	0.007	61	0.02	560	0.37	31.207	1.30	24.531	1.32	6.676	1.24
4. 4th year, university + line 3	54	0.05	15	0.01	167	0.05	919	0.62	41.508	1.73	31.141	1.67	10.367	1.94
5. 2nd year, university + line 4	95	0.09	29	0.02	389	0.12	1.361	0.92	52.263	2.19	38.952	2.10	13.311	2.49
6. 6th year, secondary + line 5	892	0.88	477	0.39	3.823	1.19	8.501	5.75	149.557	6.26	108.309	5.84	41.248	7.72
7. 3rd year secondary + 4th + 5th + line 6	5.848	5.79	3.362	3.05	15.062	4.93	27.264	18.45	347.243	14.53	254.905	13.75	92.338	17.28
8. 7th year Commercial	13	0.01	5	0.004	22	0.006	153	0.10	5.522	0.23	4.242	0.22	1.280	0.23
9. 6th year, Commercial + line 8	42	0.04	26	0.02	133	0.04	424	0.28	14.744	0.61	11.203	0.60	3.541	0.66
10. 5th year Industrial	59	0.05	25	0.02	42	0.01	186	0.12	3.122	0.13	2.122	0.16	---	---
11. 3rd year Industrial + 4th year + line 10	559	3.53	327	0.29	554	0.17	2.046	1.38	18.648	0.78	18.648	1.00	---	---
12. 5th year Agricultural	7	0.007	3	0.002	5	0.001	26	0.016	726	0.03	726	0.04	---	---
13. 3rd year, Agricultural + 4th year + line 12	35	0.03	21	0.02	45	0.01	110	0.07	2.249	0.09	2.249	0.12	---	---
14. 6th year, Primary + line 13, 11, 9 and 7 (e.g. all totals above)	81.984	41.59	34.527	31.33	107.307	33.37	80.171	54.23	962.469	40.29	725.510	39.12	236.959	44.34
15. 4th year, Primary + 5th year + line 14	67.022	66.39	61.800	56.08	183.223	56.98	131.357	88.87	1.396.816	58.47	1.060.341	57.17	336.475	62.97

SOURCE: 1960 Census

[a] N's and %'s are cumulated downward with respect to educational level thus the figures reflect both terminal student and those entering next higher level.

In estimating 1970 educational requirements, we must decide whether the economy will need a labor force with attainments equal to, or higher than, those current in the year of the forecast (1964). Even if only 1960 attainments are assumed, there will be considerable economic demand upon the education system to allow for growth in employment, and for the structural changes in occupational composition that tend toward categories which require more education. (Holding 1960 attainment coefficients constant in the foregoing sense is the basis of our minimum estimate to be shown as "Hypothesis 0" in Table 10.7.)

Since rather sizable increases in the productivity of the labor force are assumed in the plan (and will be necessary if Chile's economy is to remain competitive at home and abroad), it is more logical to assume some upgrading of educational attainments. The upgrading assumptions are shown in Table 10.6. The percentages shown are the annual increases in education levels which are judged right for the occupation and education level shown. The column entitled *factor* is the growth factor, or percent compounded for ten years. It is the quantity by which the 1960 attainment coefficient is multiplied to obtain the 1970 attainment coefficient. Note once more that in setting these education levels, and changes in them, the basis is judgmental or subjective. In Chile, these settings were checked with experts, but just as in the case of productivity estimates, there was much subjectivity.

In Table 10.7 we have applied the attainment coefficients to the employment calculated earlier. This application results in two alternative estimates of the projected requirements of manpower necessary to achieve the development plan. Hypothesis 0 is for educational attainments in each occupation identical to those found in 1960. Hypothesis I is for the moderately upgraded attainments estimated in Table 10.6.

The final step is shown in Table 10.8, which converts the projected requirements of manpower into the ten-year flows necessary to satisfy requirements. The procedure is that of subtracting the 1960 stock from the 1970 projections to find net additions necessary. To this must be added an allowance for outflows, namely, deaths and retirements. A separate calculation of outflow was made by applying Chile's demographic experience in age-specific survival rates to the age distribution reported in each occupation by the 1958 Census. (This calculation is only a first approximation, since it neglects a small attrition that will also apply to some of the new entrants to the labor force.) The results of the outflow calculation are shown in the percentages at the bottom of the table, which are applied against the 1960 stocks, thus obtaining outflows.

A note of caution should be sounded with respect to the results shown for

Table 10.6

Upgrading of Attainment Coefficients, 1960-1970

OCCUPATION	6 yr. Univ. Per Year[a]	6 yr. Univ. Factor	5 yr. Univ. Per Year	5 yr. Univ. Factor	4 yr. Univ. Per Year	4 yr. Univ. Factor	2 yr. Univ. Per Year	2 yr. Univ. Factor	6 yr. Sec. Per Year	6 yr. Sec. Factor	3 yr. Sec. Per Year	3 yr. Sec. Factor	6 yr. Comm'l Per Year	6 yr. Comm'l Factor	5 yr. Indust. Per Year	5 yr. Indust. Factor	3 yr. Indust. Per Year	3 yr. Indust. Factor	5 yr. Agric. Per Year	5 yr. Agric. Factor	3 yr. Agric. Per Year	3 yr. Agric. Factor	Primary Per Year
0 Professional	3%	1.344	3%	1.344	4%	1.480	4%	1.480	1%	1.105	0%	1.000	2%	1.22	2%	1.22	2.5%	1.28	5%	1.629	0%	1.000	0%
1 Administrative	2	1.22	4	1.48	4	1.48	4	1.48	1	1.105	0	1.000	3	1.344	3	1.344	3	1.344	5	1.629	5	1.629	0
2 Clerical	0	1.000	0	1.000	0	1.000	2	1.22	1	1.105	1	1.105	3	1.344	0	1.00	0	1.00	0	1.000	0	1.000	1
3 Salesman	2	1.22	3	1.344	3	1.344	3	1.344	2	1.22	2	1.22	3	1.344	2	1.22	2	1.22	2	1.22	2	1.22	2
4 Farmers	0	1.000	0	1.000	0	1.000	0	1.000	1	1.105	1	1.105	0	1.000	0	1.000	0	1.000	5	1.629	5	1.629	1
5 Miners	0	1.000	0	1.000	0	1.000	0	1.000	1	1.105	1	1.105	0	1.000	0	1.000	0	1.000	-	-	-	-	1
6 Transport Workers	0	1.000	1	1.1u3	2	1.22	3	1.344	1	1.105	2	1.22	2	1.22	0	1.000	0	1.000	-	-	-	-	2
7 Artisans	0	1.000	0	1.000	0	1.000	5	1.629	1	1.105	1	1.105	0	1.000	5	1.629	5	1.629	-	-	-	-	1
8 Operators	0	1.000	0	1.000	0	1.000	3	1.344	1	1.105	1	1.105	-	-	5	1.629	5	1.629	-	-	-	-	1
9 Laborers	-	-	-	-	-	-	-	-	1	1.105	1	1.105	-	-	0	1.000	5	1.629	-	-	-	-	1
X Service Workers	2	1.22	2	1.22	2	1.22	3	1.344	2	1.22	2	1.22	2	1.22	2	1.22	2	1.22	-	-	-	-	2
Y Armed Forces, N.E.C.	3	1.344	3	1.344	3	1.344	3	1.344	2	1.22	3	1.344	3	1.344	3	1.344	3	1.344	2	1.22	2	1.22	2

[a] These show cumulative annual per cent of increase.
Note that the occupational classification did not follow either ISCO or GATA exactly.

Table 10.7

The 1970 Requirements for Manpower, by Educational Attainment and Occupation

		Hypothesis		Total	Professional 0	Admin. 1	Clerical 2	Sales 3
	Employment, 1970				193,016	65,431	205,414	186,213
6 Year University.	1960 Coeff.			0.40	7.28	0.86	0.12	0.07
	1970 Stock[a]	0		15,507	14,051	563	246	130
	1970 Coeff.				9.78	1.04	0.12	0.08
	1970 Stock		I	20,505	18,877	680	246	148
5 Year University.	1960 Coeff.			1.30	22.22	2.76	0.78	0.34
	1970 Stock	0		49,205	42,888	1,806	1,602	633
	1970 Coeff.				29.86	4.08	0.78	.46
	1970 Stock		I	65,246	57,635	2,670	1,602	856
4 Year University.	1960 Coeff.			1.73	27.95	4.20	1.54	0.64
	1970 Stock	0		64,825	53,948	2,748	3,163	1,191
	1970 Coeff.				41.36	6.21	1.54	0.86
	1970 Stock		I	92,786	79,831	4,063	3,163	1,601
2 Year University.	1960 Coeff.			2.19	31.31	6.45	3.29	1.29
	1970 Stock	0		79,819	60,433	4,220	6,758	2,402
	1970 Coeff.				46.33	9.54	4.01	1.73
	1970 Stock		I	114,205	89,424	6,242	8,237	3,221
6 Year Secondary.	1960 Coeff.			6.26	44.08	24.11	27.08	8.54
	1970 Stock	0		205,037	85,031	15,775	55,626	15,902
	1970 Coeff.				48.70	26.64	29.92	10.42
	1970 Stock		I	229,506	93,999	17,430	61,403	19,403
3 Year Secondary.	1960 Coeff.			14.53	56.66	53.76	58.18	25.94
	1970 Stock	0		450,066	109,362	35,175	119,510	48,303
	1970 Coeff.				56.66	53.76	64.28	31.64
	1970 Stock		I	493,361	109,362	35,175	132.040	58,918
6 Year Commercial.	1960 Coeff.			0.61	0.36	1.91	6.84	0.72
	1970 Stock	0		18,565	695	1,250	14,050	1,341
	1970 Coeff.				0.43	2.56	9.19	0.96
	1970 Stock		I	24,489	830	1,675	18,878	1,788
5 Year Industrial.	1960 Coeff.			0.13	0.68	0.39	0.17	0.07
	1970 Stock	0		3,879	1,313	255	349	130
	1970 Coeff.				0.82	0.52	0.17	0.08
	1970 Stock		I	4,998	1,583	340	348	149
3 Year Industrial.	1960 Coeff.			0.78	2.08	1.51	1.05	0.49
	1970 Stock	0		22,208	4,015	988	2,157	912
	1970 Coeff.				2.66	2.03	1.05	0.59
	1970 Stock		I	10,950	5,134	1,328	2,157	1,099
5 Year Agriculture.	1960 Coeff.			0.03	0.19	0.04	0.04	0.03
	1970 Stock	0		1,194	367	26	82	55
	1970 Coeff.				0.30	0.06	0.04	0.06
	1970 Stock		I	1,359	579	39	82	74
3 Year Agriculture.	1960 Coeff.			0.09	0.45	0.17	0.14	0.09
	1970 Stock	0		3,014	869	111	288	168
	1970 Coeff.				0.45	0.27	0.14	0.11
	1970 Stock		I	3,663	869	177	288	204
6 Year Primary.	1960 Coeff.	0			71.66	71.70	77.04	59.12
	1970 Stock			1,149,301	138,315	46,914	158,250	110,089
	1970 Coeff.		I		71 66	71.70	85.12	72.12
	1970 Stock			1,294,460	138,315	46,914	174,848	134,297

1960 Attainment Coefficients from Table 10.5.
1970 Attainment Coefficients calculated from 1960 by factors in Table 10.6.
Employment from Table 10.4.
Hypothesis "0" represents no upgrading.
Hyporthesis "I" represents moderate upgrading per Table 10.6.

[a]Strictly speaking the "1970 Stock" should be labeled "1970 Projected Requirements"

Table 10.7 (cont'd):

The 1970 Requirements for Manpower, by Educational Attainment and Occupation

Farmers 4	Miners 5	Transp. 6	Artisans 7	Operators 8	Laborers 9	Service X	Armed Forces Y
1,047,666	63,831	90,097	508,280	185,028	93,873	152,306	152,306
0.029	0.003	0.02	0.005	0.004	-	0.006	0.10
304	2	18	25	7	-	9	152
0.029	0.003	0.02	0.005	0.004	-	0.007	.13
304	2	18	25	7	-	10	198
0.14	0.009	0.07	0.02	0.02	0.007	0.02	0.37
1,467	6	63	102	37	7	30	564
0.14	0.009	0.08	0.02	0.02	-	0.024	.50
1,467	6	72	102	37	-	37	752
0.21	0.02	0.15	0.06	0.05	0.01	0.03	0.62
2,200	13	135	305	93	9	76	944
0.21	0.02	0.18	0.06	0.05	-	0.06	.83
2,200	13	162	305	93	-	91	1,264
0.31	0.05	0.33	0.13	0.09	0.02	0.12	0.92
3,248	32	297	660	156	19	183	1,401
0.31	0.05	0.44	0.21	0.12	-	0.16	1.23
3,248	32	396	1,067	222	-	243	1,873
1.07	0.33	2.74	1.22	0.88	0.39	1.19	5.75
11,210	210	2,469	6,201	1,628	366	1,812	8,757
1.18	0.36	3.03	1.34	0.97	0.43	1.45	7.01
12,362	230	2,729	6,811	1,794	404	2,208	10,676
2.75	2.17	15.33	8.76	5.79	3.05	4.93	18.45
28,811	1,385	13,811	44,525	10,713	2,863	7,508	28,100
3.04	2.39	18.70	9.68	6.40	3.37	6.01	22.51
31,749	1,526	16,848	49,201	11,841	3,164	9,153	34,284
0.037	0.019	0.12	0.03	0.04	0.02	0.04	0.28
388	12	108	152	74	19	60	426
0.037	0.019	0.14	0.03	-	-	0.05	0.37
388	12	126	152	-	-	76	564
0.01	0.04	0.11	0.28	0.05	0.02	0.01	0.12
105	26	99	1,422	93	19	15	182
0.01	0.04	0.11	0.45	0.08	0.02	0.012	0.016
105	26	99	2,287	148	19	18	24
0.08	0.56	1.21	1.80	0.53	0.29	0.17	1.38
838	357	1,090	9,149	981	272	259	2,102
0.08	0.56	1.21	2.93	0.86	0.47	0.20	1.85
838	357	1,090	14,893	1,591	441	304	2,813
0.04	0.0018	0.02	0.004	0.007	0.002	0.001	0.016
419	1	18	20	13	2	2	244
0.06	-	-	-	-	-	-	0.02
629	-	-	-	-	-	-	30
0.13	0.02	0.08	0.02	0.03	0.02	0.01	0.07
1,362	13	72	102	56	19	15	107
0.21	-	-	-	-	-	-	0.085
2,200	-	-	-	-	-	-	129
11.83	23.31	57.90	52.13	41.59	31.33	33.37	54.23
123,939	14,879	52,166	264,966	76,953	29,410	50,824	82,596
13.07	25.75	70.64	57.60	45.96	34.62	40.71	66.16
136,930	16,436	73,644	292,769	85,038	32,499	62,004	100,766

Table 10.8

Demand for Graduates, by Level and Occupation, 1960-1970 (Hypothesis I)

	Total	Prof-fessional	Admin.	Clerical	Salesmen	Farmers Fishermen	Miners	Transport	Artisans	Operators	Laborers	Service	Armed Forces (N.E.C)
6 Year University													
1 1970 Projection	20505	18877	680	246	148	304	2	18	25*	7*			198
2 1960 Stock	9758	8606	399	210	120	197	2	17	23*	4			159
3 Net Additions	10747	10271	281	36	28	107	0	1	2	3			39
4 Outflow, 1960-1970		1248	89	26	22	34	0	2	3	0			19
5 Graduates required during 10 Years	12213	11519	370	62	50	141	2	3	5	3	0	0	58
5 Year University													
1 1970 Projection	65246	57635	2670	1602	856	1467	6	72	102	37			762
2 1960 Stock	31207	26269	1273	1265	585	985	5	58	94	24			560
3 Net Additions	34039	31366	1397	337	271	482	1	14	8	13			202
4 Outflow, 1960-1970		3809	283	154	59	171	1	7	11	3			54
5 Graduates required during 10 years	36643	35175	1680	491	330	653	2	21	19	16	0	0	256
2 Year University													
1 1970 Projection	114205	89424	6242	8237	3221	3248	32	396	1067	227			1873
2 1960 Stock	52263	37002	2962	5326	2177	2070	31	259	562	95			1361
3 Net Additions	61942	52422	3280	2911	1044	1178	1	137	505	127			512
4 Outflow, 1960-1970		5365	658	650	394	360	5	33	66	12	0	0	131
5 Graduates required during 10 years	69791	57787	3938	3561	1438	1538	6	170	571	139			643
6 Year Secondary													
1 1970 Projection	229594	93959	17430	61460	19403	12362	230	2729	6611	1794	404	2208	10676
2 1960 Stock	149527	52100	11094	43877	14363	7010	186	2131	5148	892	427	3828	8501
3 Net Additions	79945	41399	6336	17583	5040	5352	44	598	1663	902	-23	-1620	2175
4 Outflow, 1960-1970		7555	2463	[illegible]	2600	1220	31	275	607	116	55	459	816
5 Graduates required during 10 years	102660	49454	8799	2,933	7640	6572	75	873	2270	1018	32	0	2991
3 Year Secondary													
1 1970 Projection	493361	109362	35175	132040	58918	31849	1526	16348	49201	11641	3164	9153	34282
2 1960 Stock	347243	66960	21747	94282	43646	18061	1204	11919	37088	5848	3362	15862	27264
3 Net Additions	146118	42402	13428	37758	15272	13788	322	4929	12113	5993	-198	-6709	7020
4 Outflow, 1960-1970		9709	4328	11502	7900	3143	201	1537	4376	760	437	1903	2617
5 Graduates required during 10 years	199837	52111	18256	49260	23172	16931	523	6466	16489	6743	239	0	9637
6 Year Commercial													
1 1970 Projection	24489	830	1675	18878	1788	308	12	176	152				564
2 1960 Stock	14744	436	880	11091	1215	249	11	97	140				424
3 Net Additions	9745	394	795	7787	573	139	1	29	12				140
4 Outflow, 1960-1970		63	195	1353	220	43	2	13	17	0	0	0	41
5 Graduates required during 10 years	11317	457	990	9140	793	182	3	42	29				191

Table 10.8 (cont'd):

Demand for Graduates, by Level and Occupation, 1960-1970 (Hypothesis I)

	5 Year Industrial												
1	1970 Projection	4988	1533	340	349	--	105	28	99	2287	148		
2	1960 Stock	3122	804	183	287	125	71	23	92	1223	59		
3	Net Additions	1866	779	157	62	-125	34	3	7	1064	89	0	0
4	Outflow 1960-1970		122	41	35	23	12	4	12	144	7		
5	Graduates required during 10 years	2662	901	198	97	0	46	7	19	1208	96	0	0	0
	3 Year Industrial												
1	1970 Projections	30950	5134	1328	2157	1099	838	357	1090	14893	1591	441	304	2818
2	1960 Stock	18648	2459	696	1715	837	567	313	941	7634	553	327	554	2046
3	Net Additions	12302	2675	632	442	262	271	44	149	7259	1032	114	-250	772
4	Outflow 1960-1970		357	155	209	151	99	53	214	901	73	63	66	196
5	Graduates required during 10 years	15733	3032	787	651	413	0	97	363	8160	1105	157	0	968
	5 Year Agricultural													
1	1970 Projections	1359	579	19	42	74	629							39
2	1960 Stock	726	236	22	76	53	263							26
3	Net Additions	633	343	17	6	21	366							4
4	Outflow 1960-1970		34	5	9	13	46	0	0		0	0	0	2
5	Graduates required during 10 years	362	377	22	15	31	412	0	0		0	0	0	6
	3 Year Agricultural													
1	1970 Projections	3663	863	177	258	204	2209							129
2	1960 Stock	2249	532	92	234	153	853							110
3	Net Additions	1414	337	85	54	53	1342							19
4	Outflow 1960-1970		114	18	23	27	149	0	0	0	0	0	0	11
5	Graduates required during 10 years	2248	451	113	33	80	1491	0	0	0	0	0	0	30
	6 Year Primary													
1	1970 Projections	1294460	136315	46914	174048	134297	136930	16436	73644	292769	85038	32499	62064	100766
2	1960 Stock	962469	84690	36955	124452	99472	77743	12931	45065	228512	41984	34527	107307	80171
3	Net Additions	331991	51625	10959	49596	34825	59187	3505	28619	71957	43054	-2028	-45303	20595
4	Outflow 1960-1970		12250	7316	15232	18004	13527	2153	5588	26956	5458	4489	12877	7696
5	Graduates required during 10 years	495319	65905	21375	65228	52829	72714	5664	34427	93013	46512	2461	--	28291
	*Outflow factor (wastage % for 10 years)		14.5%	22.2%	12.2%	13.1%	17.4*	16.7%	12.9*	11.5*	13.0%	13.0%	12.0%	9.6*

1970 Stock from Hypothesis I, Table 10.7
1960 Stock from Table 10.5

Outflow based upon death and retirement rates by age group, applied to the age composition of each occupation.

The stock and flow method used here is useful for educational patterns that have reached some maturity. It tends to understate requirements for tracks recently introduced, such as commercial, industrial and agricultural.

Note also that some university graduates are shown in blue collar jobs, e.g., Artisans, Operators, etc. This is based originally on census. Some is false reporting, some miscoding, and some is true but unexplainable.

such specialized types of education as commercial, industrial, and agricultural. Those tracks had not accumulated many graduates until the last decade or two. This projection method tends to understate future requirements when the program in the base year has not yet reached maturity.

Caution should also be observed in reading the requirements for graduates at what are currently intermediate nonterminal points, such as four-year university, two-year university, and three-year secondary. Observations were entered for these levels only because in future schemes of education these may be terminal, as well as preparatory, levels. The flows required may give some guidance as to capacities required at these levels. If the two-year university figures are to be used for estimating demand for the regional colleges, it would first be necessary to subtract from the demand the students who complete year two and go on to third, fourth and higher years of university education. This calculation could easily be made from existing or anticipated dropout patterns in the universities.

2.3 *Final Summary of Demand*

Table 10.9, the final summary table of demand, is based on aggregation of Table 10.8, which was based on the steps yielding Tables 10.1 to 10.7.

Table 10.9

Economic Demand: 10-Year Plan. Required Number Completing, 1960–1970

Occupation	6-year university	5-year university	All types of secondary
Professional	11,519	35,175	51,229
Administrative	370	1,680	10,009
Clerical	62	491	32,188
Sales	50	330	8,464
Farmers, fishermen	141	653	7,212
Miners	2	2	85
Transport workers	3	21	934
Artisans	5	19	3,507
Operators	3	16	1,114
Laborers	0	0	32
Service workers	0	0	0
Armed Forces and others	58	256	3,178
Total	12,213	38,643	117,952

2.4 *A Note on Problems in Supply Projection*

As noted previously, the Chilean case is no model of how to do educational supply projections. There were no enrollment or flow data available in time series, and hence the analysts simply used the last year of reliable data on graduates, and assumed that this same number was the average number of graduates per year over the decade. Hence the number was multiplied by 10

to give a very crude estimate of supply.

In Chile the major focus was on manpower and educational requirements, and not on enrollment projections.

3.0 *A Summary Comparison of Demand and Supply*

The above comment serves as an introduction to an estimate made of the relation between economic demand and total supply. Since no educational output figures were available, this study used the 1962 enrollments in the last year of each level. Data indicate 80 percent to 90 percent of those enrolled in the last year successfully completed the course. Accordingly, these "supply" figures overstate the real output. Perhaps a compensating bias is the use of 1962 as the basis of estimating a ten-year supply. Since the school system is growing, using an estimate of the 1965 graduates might have been more representative of the decade. In any case, the comparison follows:

Table 10.10

Number Completing, 1960-1970

	Economic demand[a]	Total supply[b]	Difference (demand-supply)
18 Grades (Univ)	12,213	6,440	+ 5,773 (deficit)
17 Grades (Univ)	38,643	25,920	+ 12,723
12 Grades (All Sec)	117,952	181,570	- 63,618 (surplus)
6 Grades	497,539	1,053,440	- 555,901

[a] From Table 10.8.
[b] 1962 Graduate multiplied by 10 (note problems in this method)
[c] All Secondary except Feminine Technical

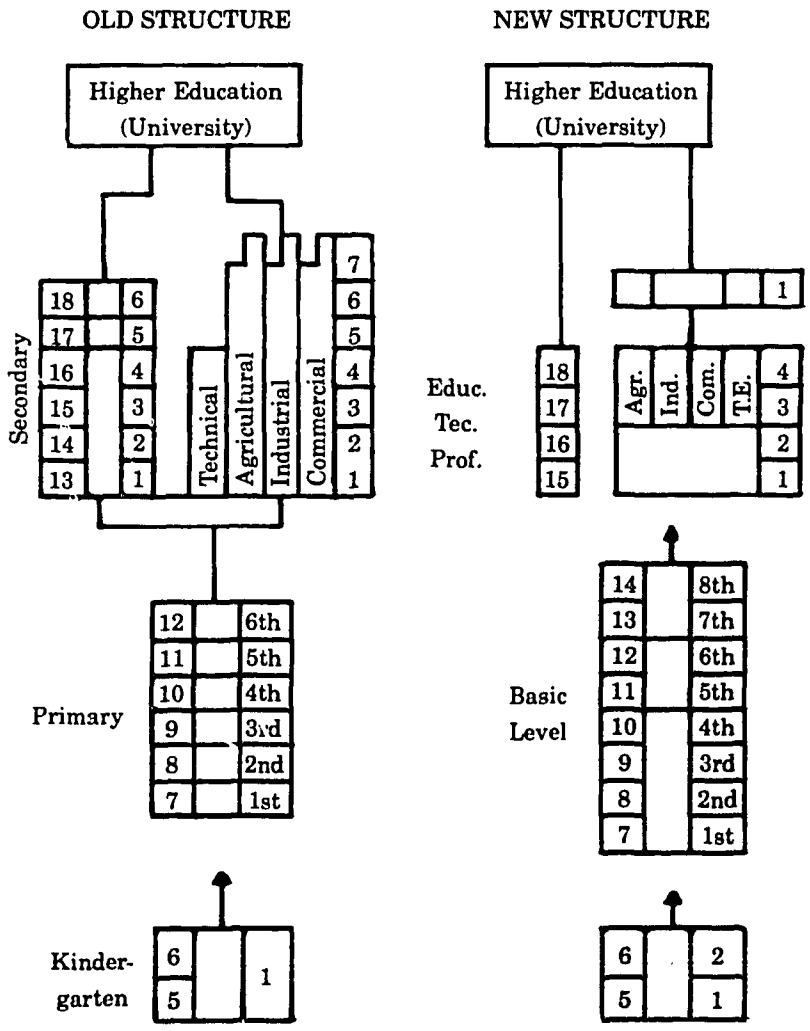
The deficit at university level is so large as to suggest that the assumptions we introduced for upgrading the occupational composition and educational attainments of the labor force were too high. The minimum hypothesis is a more feasible program. However, these deficits may be correct in sign, if not in absolute magnitude. They may suggest that Chile's development plan is an ambitious one in terms of high-level manpower, calling, as it does, for some structural shifts to sectors that require a more sophisticated labor force.

If there is indeed a major shortage, attention should be given to the possibility of meeting some of the needs with graduates of two-year instead of four-year colleges. It may well be that for some occupations a two-year course, plus training, will provide the requisite proficiency.

The apparent surpluses of output at secondary and primary levels may represent social demand for education; but the social demand also includes the amount of education required for the economically inactive population, such as students, housewives, and others temporarily or permanently out of the labor force.

APPENDIX 10.1

School System in Chile Before (Old) and After (New) Educational Reform



Source: Schiefelbein, Ernesto and Russell Davis, *Development of Educational Planning models and Application in the Chilean School Reform*. Lexington, Mass.: Lexington Books, 1974 (p. 59)

Closing Note on Chilean Case

The Chilean Manpower Planning exercise provided the basis for a number of policy and program recommendations made to government officials. Because this case was selected primarily to illustrate the basic methodology, the policy and program recommendations will not be included. As a closing exercise, it is suggested that a brief outline of possible policy and program suggestions be offered. Given the highly aggregated and general results of the projections, the recommendations should be equally general and undetailed.

CHAPTER 11

Manpower Planning Methods: Unit Three

1.0 *Content of Unit Three*

Unit Three deals with methods of fitting curves to past trends in product, productivity, and employment in order to extrapolate employment to future years. It offers an alternative methodology for directly estimating changes in the number of workers in specific occupations. This alternate method is illustrated in the Dominican Republic case, which applied a mix of methods to forecast manpower requirements by educational attainment levels. The Dominican case also illustrates the forecasting of the supply of education/training system, and the comparison of demand (requirements) and supply (output of education/training) to yield estimates of surpluses or deficits in education/training supply.

Unit Three also shows an extrapolation method applied to the projection of manpower requirements, by sector and occupations, for Paraguay. In the Paraguay study there was no forecast of education supply; only a forecast of worker requirements by occupation/sector.

Because curve-fitting and extrapolation are so central to the various methods for projecting manpower requirements, Chapter 7 offered a unit on curve-fitting and extrapolation. The unit discussed the application of curve-fitting to trend analysis, explained the basic mathematics, and illustrated some of the common curve functions used in population forecasting. Chapter 11 will now show how curve-fitting is used in manpower analysis.

1.1 *Objectives of Unit Three*

— To understand and be able to illustrate the Alternate Method of projecting manpower requirements by occupation. Specifically, be able to apply the extrapolation formula in simple arithmetic exercises.

— To be able to follow and understand the steps of basic and alternative methods for projecting product, productivity and employment and distributing employment by occupations within sectors.

— To be able to identify sources of data and information for:
a) Projecting product, productivity, and employment;
b) Guiding assumptions about occupational distributions within sectors and industries;
c) Guiding assumptions about educational attainment levels which correspond to occupations.

Additional objective in conjunction with Chapter 7

— To understand the basic applications of curve-fitting in trend analysis. Several applications in manpower analysis are described here.

2.0 *Estimation Routines in Target Setting*

Underlying the basic method of projection are sub-routines for estimating the component parts. All routines are essentially simple, and beneath an occasional facade of algebra, very similar. All methods and their variants require that product, product per head, and employment be projected, and that occupational composition in the workforce, and educational levels within occupations, be set or estimated. The sources and methods available for doing this were outlined in Chapter 8, Schema 8.1.

— Using sectoral product and productivity estimates and forecasts already available in national planning documents or studies.

— Doing a specific study or establishment survey; or using labor market data from reports on particular industries, groups of industries, or sectors. The plans for large infrastructural projects, for example, dams, irrigation projects, road networks, often have multi-year forecasts of employment and even manning tables by specific occupations. (The tables give worker numbers by job type).

— Deriving employment estimates for one sector or industry from another sector or industry, using some set of input-output relationships. For example, the output of one industry may depend on the input needs of another.

— Deriving employment from ratios to the population and service norms. This is a standard approach to estimating or projecting public service employment in health, public safety, or education. For example, health plan norms may require a certain ratio of hospitals, beds, nurses, or doctors to a given population size. Teaching and educational requirements are almost always derived from enrollment projections, pupil/teacher ratios, and educational staffing norms.

— Using product and productivity growth data and occupational distributions in similar industries in the same or another country, and modifying the occupational and educational attainment structure to correspond to the country situation under consideration.

— Deriving percentage of workers in an occupation in relation to output per worker, using regression analysis of this relationship as it is shown in the data of a number of industries or countries.

— Extrapolation or curve-fitting to growth trends in product, productivity, and occupational numbers on the basis of past economic changes within the country for which the estimates are being made.

— More often, the use of a combination of these sources.

2.1 *Product Estimates*

Product for future years may simply be set both for the economy as a whole or for each sector in the country plan. Or, planners may assume an annual cumulative percentage increase applied to the base year:

$$p_n = p_x(1 + r)^t \tag{1}$$

Here p_x is the product in the base year, r is the annual growth rate compounded over t years, the term of the forecast; and the result is p_n or product at the end of the plan period. Underlying the use of this formula is the assumption, or the observation, that product increases in a pattern that can be described by a particular curve or curve function. In this case the form is that of a geometric increase, or exponential, or, as it is commonly termed, a compound interest formula. In theory, applying this growth curve should first require analysis of past series data to see if the data do follow this form. Methods for doing this were discussed in the material on curve-fitting in Chapter 7. (For exponential form, see curve 5, Fig. 7.2)

The setting of r may not be purely arbitrary. It may be derived from the performance of the economy or sector between two time periods in past years. Again, this simply assumes exponential growth:

$$(1 + r) = \sqrt[t]{\frac{p_x}{p_{x-t}}} \tag{2}$$

Here p_x is, as before, product in present year; and p_{x-t} is product t years before. The root is one plus the past growth rate over t years. If the root $(1 + r)$ turned out 1.07, and if the planner assumed that this annual growth rate of 7 percent would continue over 10 years of the plan period, given a base-year product of 12 billion:

$$p_n = p_x(1 + r)^t = 12(1.07)^{10} = 23.6 \text{ billion} \tag{3}$$

The growth factor $(1.07)^{10} = 1.9672$ can be looked up in compound interest tables. (*Growth Factors: Compound Interest Tables*, Stanford Reserach Institute, 1963). Again, in theory, before assuming the exponential form, analysts should study the data of a series of years to ascertain whether the curve form fits the changes in the data. (See Chapter 7 on curve-fitting.)

The rate may be increased on the basis of growth observed in another, presumably similar, economy. Or it may be based on knowledge of future likely investment, capital/output ratios, the establishment of new industries, the opening of new markets, and the country's likely share and earnings.

The analysis may be incorporated into an econometric growth model of the national economy, supplemented and checked by studies of specialists who analyze the growth potential in specific industries and sectors. (A growth model is described in the reading at the end of this chapter.)

The estimated product of one country may be used for another country. The estimate may be based on the average of a group of countries, or derived by fitting some growth curve to the past of the home country and extrapolating, as discussed in the section on curve-fitting. A fit to a linear form is used most

often. Or quadratic and exponentials transformed to linear forms by logarithms. These curve functions are simple and easy to work with, and the data do behave in this way. In the case of the compound interest formula, the computational tables are readily available and easy to use. World Bank (1973) and Stanford Research Institute (1963) have prepared such tables.

2.2 *Productivity Forecasts*

Productivity growth is handled in much the same way as product, with assumptions about employment, output, and the relationships among labor, capital, and technology included. Reading 11.2 at the end of this chapter discusses productivity estimation. The three growth rates, product, productivity and employment are related: product rate equals the sum of the other two. (See Appendix A12.1 in Chapter 12, Dominican Manpower Case).

2.3 *Occupational Distribution: Simple Methods*

The percentages and numbers of workforce members in occupations in future years are set in a variety of ways. But they are *set*, and the process is not free of pure guesswork. In the simplest situation, the percentages are merely raised for the higher and skilled occupations in the sectors which are marked for growth. A specific occupational percentage may simply be raised arithmetically, e.g., from 3 to 5 percent as in the Chilean case. Or the percentages which prevail in the same sector in another country may be taken as a target toward which percentages in the plan are raised.

Two basic methods may be used to estimate numbers in a specific occupation in some future year. The first uses a simple proportion:

$$\frac{w_n}{w_x} \cdot o_x = o_n \qquad (4)$$

where:

w_n = work force year n,
w_x = work force year x,
o_n = number in occupation in year n

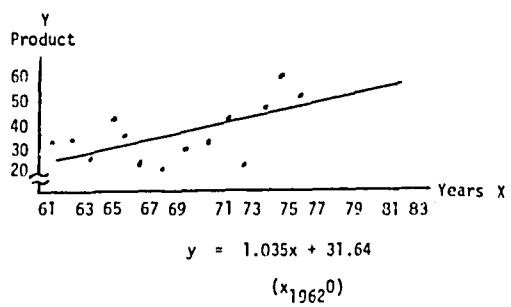
Here the number in the occupation in the base year (o_x) is increased as the workforce w increases from year x to n, i.e., if the workforce doubles the number in the occupation doubles. In the alternative method, shown in Chapter 8, Schema 8.1, and applied in the Dominican case, the number in the occupation in the sectors changes according to three change rates: change in the number of workers in the sector; change in productivity; and change in proportion to an elasticity coefficient that reflects occupational growth as productivity changes. (This is illustrated in Section 4.1 and in Chapter 12, the Dominican Case.)

3.0 *Curve-Fitting to Estimate Product, Productivity, or Employment*

A linear trend can be extrapolated from past data to estimate increase in product, employment, or productivity.

Product over past years is simply graphed; a line is fitted to the points, and extended or extrapolated to future years. With product on the Y-axis and years along the X-axis, the line can be extended into future years on the assumption of a continuation of the same linear trend. The calculation is straightforward and illustrated in the curve-fitting material of Chapter 7. The method is general. Figure 11.1 illustrates a fit to linear growth trend in product over a period of years.

Figure 11.1



In addition to fitting to the linear form $y = a + bx$, a second-degree curve $y = a + bx + cx^2$ or a logarithmic adaptation ($\log y = \log a + x \log b$) of an exponential are common curve forms for fitting trends, because the normals (derived equations in which the data from the problem can be directly substituted in order to solve for the constants) are known, and results can be readily computed. (Chapter 7)

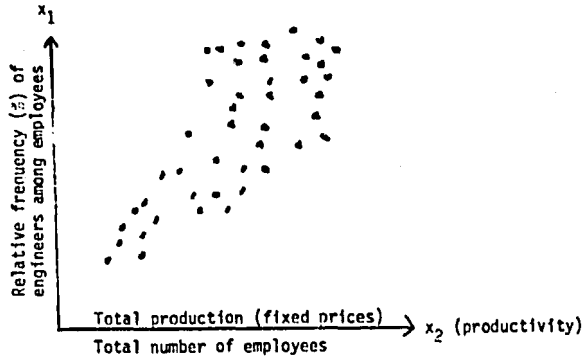
Fitting data to curves is simple enough, but when the poor and inadequate historical data of most developing countries are used, results should be checked if this is possible. Census and population forecasts are the reference points against which most social and economic forecasts are checked.

The analysis in Figure 11.1 can be used to estimate productivity, changes in the number of workers in occupations, or changes in their education. The method is general.

A simple linear regression model may also be used to estimate the value of one variate (e.g., employment of members of a specific occupation) from another (productivity or product per head) through regression. Figure 11.2 shows a typical example of this. The dots in the scattergram represent the bivariate distribution (from 40 countries) of data on the relative frequency of engineers to total workers graphed against total production over total workers, i.e., the relation of engineers to productivity. The objective would be to estimate x_1 (percentage of engineers) from x_2 (productivity expected in the sector) by the linear equation $x_1 = a = bx_2$. Given the expected production

Figure 11.2

Sector i (or industry)



and workforce of the sector for some future year and using the values of the constants computed on the basis of the 40 countries, the percentage of engineers in the firm, industry, or workforce is estimated. This result is like the elasticity b_{ij} in equation 5 below.

The simplicity of the logic underlying such models may provoke a slight queasiness. Why should a haphazardly chosen collection of countries or industries, yield—through simple regression—a general answer? And what is the warranty for choosing this one aspect of human resource education and training (relative frequency of engineers in the workforce) and this general estimate of productivity?

4.0 *Employment Forecasting by the Alternate Method Shown in Schema 8.1*

Alternate methods of manpower requirements forecasting make use of the same essential projection methodologies in which a curve is fitted to past series data and a trend extrapolated to the future. In an alternate method which will be illustrated in the Dominican case, the fit is to an exponential form:

$$D_{it} = \sum_{j=1}^{n} X_{ij} \; e^{(b_{ij} r_{pj} + Y_{Lj})\, t} \tag{5}$$

where:

D_{it} = requirements in occupation i, future year t;
X_{ij} = number of workers in occupation i, sector j;
e = 2.71828 . . . (Base of Natural Log System); this shows curve form;
Y_{Lj} = change (increase or decrease) in number of workers (employment) in the sector j;
r_{pj} = change in productivity in sector j;
b_{ij} = elasticity coefficient which relates change in productivity in sector j to change in the numbers of workers in occupation i.

The demand in the occupation is then totaled across all sectors in which the occupation is found. Demand might better be called *requirements*.

4.1 *The Alternate Method Applied in the Dominican Case*

To apply equation (5) to project changes in numbers in occupations from 1970 to 1985 requires the rate of change in productivity (r_{pj}), the rate of change in employment (r_{Lj}) and the elasticity coefficient (b_{ij}). The rates for productivity and employment are shown in Table 11.1 They are derived from fitting a curve to past changes in product, productivity and employment in the Dominican Economy. The b_{ij} rates for selected industry and occupational classes are shown in Table 11.2. These are based on international or comparative analysis of kind shown in Figure 11.2.

Table 11.1

Product, Productivity and Employment Growth Rates For Selected Industries
(Dominican Republic)

Sectors	Natural rates of growth (based on analysis of past trends)		
Manufacturing	Product	Employment Y_{Lj}	Productivity r_{pj}
Food and beverages	.062	.022	.040
Textiles	.107	.007	.100
Wood products	.160	.086	.074
Sugar	.092	.043	.049
Etc.	...	...	...

The elasticity coefficients b_{if} would then be applied to occupations within sectors. Note: product growth rate = employment rate + productivity rate.

Table 11.2

Elasticity Coefficients for Sector Growth and Occupational Growth

	Professional/ technical	Managers	Office workers	Sales	Manual workers
Food and beverages	.55	.31	.09	.00	-.04
Textiles	.58	.30	.13	.24	-.04
Wood products	.56	.29	.19	.11	-.03
Sugar	.55	.31	.09	.00	-.04
Etc.	...	...	...	...	...

Source: Zymelaman, Manuel. "Productivity, Skills and Education in Manufacturing Industries," (in Planning for Advanced Skills and Technologies, United Nations; New York, 1969, pp. 103-138).

The Dominican case illustrates that analysts use different methods for projecting occupations for different sectors. The curve function shown in equation (5) was used to forecast the numbers in occupations in the major industries of the manufacturing sector. This application will be illustrated in a numerical example.

For occupations in the sectors of Construction, Transport, Communication, and Electricity/Gas/Water, the product for the sectors was first projected to the target year 1985, on the basis of a curve fit to past growth trends and a modification to reflect present and future expansion projects and plans. Productivity estimates were projected in the same exercise, and employment was obtained by dividing productivity into product, as in the basic method illustrated in the Chilean case. Employment was then distributed by occupations on the basis of past growth trends and comparative analysis. The occupational structure of the Argentine economy was used as a basis, and this basic structure was modified according to Dominican reality.

A different method was used to project occupations in agriculture, government, and services. For agriculture, product was extrapolated on the basis of past growth and future plans. The occupational structure used for 1985 is an upgraded version of the one revealed in the 1970 Census in the Dominican Republic.

For the government services of education and health, employment and occupational distributions were based on population forecasts and service norms and on staffing ratios. For mining, where the sector is dominated by a few large modern enterprises, the expansion plans, including detailed manpower requirement forecasts, were incorporated directly into the general sectoral manpower requirements forecasts. Manning table data were also directly used.

In this section we will present a detailed example of the projection of occupations in manufacturing, using the growth curve shown in equation (5). This requires curve-fitting to extrapolate growth trends in product, employment, and productivity. These were shown in Table 11.1 which furnishes the basis for the productivity growth rate (r_{pj}) and the employment growth rate (r_{Lj}) used in equation (5). These two growth rates are derived from the growth trend of product by sector. Product growth equals growth in employment plus growth in productivity. Product growth is derived from a curve fit to past growth in product for the sectors and industries of the Dominican economy. (These are shown in Appendix 12.3 of Chapter 12, the Dominican case.)

To complete the projection, shown in equation (5), requires estimates of b_{ij}, the elasticity coefficient that relates growth in productivity to growth in occupations within the sector. These are shown in Table 11.2. Once the analyst has the coefficients r_{pj}, Y_{Lj}, and b_{ij}, they are applied, as shown in Table 11.3 to the base-year number (1970) in the occupation. This is done for all manufacturing industries.

We will demonstrate the extrapolation of numbers in occupations from 1970 to 1985, using only a few selected examples of industries and occupations. In the Dominican case, the large number of extrapolations was done by computer. Here are two examples of the arithmetic:

Table 11.3

Dominican Examples: Manufacturing Sector

Industry	Occupation		1985 extrapolation
Sugar	Engineers	Number 1970 = 22	$22\left[e^{.55(.049)+.043}\right]^{15}$
			$= 22(1.07)^{15} = 22(2.759) = 61$
Textiles	Managers	Number 1970 = 62	$62\left[e^{.30(.10)+.007}\right]^{15}$
			$= 62(1.037)^{15} = 62(1.7246) = 107$

This procedure is carried through for all industries in the manufacturing sector. In some cases the numbers projected are raised or lowered slightly to reflect modifying assumptions not built into the extrapolation equation. Table results will differ slightly from equation estimates.

5.0 *The Remaining Steps in the Dominican Manpower and Education Requirements Forecast*

The remaining steps in the Dominican case are similar to the steps in the basic method. With the numbers forecast by occupations for 1985, the analyst converts occupational membership to educational attainment levels. In the Dominican case, this required adjusting the occupations according to the educational attainment levels found in the 1970 census, and upgrading the educational attainment of professional and skilled occupations. With occupations translated into educational requirements, the next steps require a forecast of the supply, or education/training output in the Dominican Republic, and the comparison of this supply projection with the educational requirements projection, to indicate deficits or surpluses.

In the Dominican case, the supply forecasts were much more adequately done than in Chile. The essentials of the methodology are covered in the section on enrollment forecasting. In general, the method first requires estimating the coefficients of promotion, repetition, and dropout. These flow coefficients are tabulated in a matrix and multiplied by enrollments in the twelve grades of the elementary and secondary school structure. New entrants into the system during the years of the projection were estimated separately on the basis of projected population and entrance rates.

The flow coefficients (promotion, repetition, and dropout) are multiplied by the grade enrollments, new entrants are added in, and the result is the enrollment for the following year. This process is repeated for the number of years there is in the forecast. During the forecast, the flow coefficients and the entrance rates change according to system plans for improvement. In addition to projections of enrollments and graduates of primary and secondary school, projections were run for enrollments and graduates at

post-secondary level, for schools and universities. Enrollments and graduates were also projected for training programs outside the formal school system. All of these supplies of educated and trained people were aggregated and compared with the forecast of requirements to estimate deficits and surpluses in education and training programs.

The logic of the method can be traced through by reading the case, which is a summary of the forecast of supply, demand, and the comparison of supply and demand to yield estimated deficits and surpluses. Technical appendices are included at the end of Chapter 12 to illustrate the methods of projecting demand.

6.0 *Other Methodologies*

There are as many other different methods or modifications of the basic methodology as there are planners and analysts at work on macro-level manpower forecasting. Here we will conclude by describing briefly some of the features of the forecasting method used in a Paraguay study. Paraguay illustrates only the projection of requirements by occupations and not by educational attainment levels. There are three essential features of the methodology used by Daniere in the Paraguay case to project manpower requirements by occupations:

- Methods for adjusting detailed sample survey data to update census data, and provide occupational distributions of the sectorial employment projected. (Similar to BLS matrix adjustments, readings 8.2 and 8.3, Chapter 8).
- Arrangement of sectors in a quasi input-output arrangement so that employment projections of one sector guide projections in another sector. (See BLS use of input-output relations; Reading 8.3).
- The basic projection methodology of sectoral employment.

Here we will discuss only methodological feature B and C. (Daniere and Davis describe the full method in USAID/Harvard Project, Paper 79, 1979.

7.0 *The Inter-Sectoral Arrangements in the Paraguay Case*

This part of the methodology consists in systematically grouping sectors of the Paraguayan economy into these major groups or classes:

Group A: This consists mainly of industrial sectors where growth depends on the international market and major development plans. It may be thought of as a *basic* group of sectors, because it is used partly as a basis for projecting growth in product and employment for Groups C and D.

Group B: This is a group of sectors, usually characterized by large development projects (agriculture, mining, large public works) for which there may be independent and detailed employment forecasts made as part of long-term plans. These employment forecasts often include detailed occupational requirements which can be entered directly into future year aggregate forecast totals.

Group C consists of sectors which serve the industries and projects in Groups A and B. Growth in Group C can in a sense be related to growth in the sectors of the combined Groups A and B.

Group D consists of sectors that furnish goods or services to Groups A, B, and C, and also to households.

The inter-sectoral relationships among the groups is taken into account in the methodology which follows this sequence.

— The employment for Group A is projected (by regions and nationally) by the extrapolation formula that will be outlined in the following section.

— The employment for Group B is projected by a similar extrapolation formula and, in some sectors, detailed forecasts of employment in large projects or planned developments are added directly into the estimates.

— The employment forecasts for Groups A and B are added, and the total is used as the basis for projecting employment in Group C.

— The employment forecasts for Groups A, B, and C are added, and the total is used as one basis for projecting employment in Group D. (The original intention of the methodology was to project the employment in this sector as a function of two growth factors: one would be the growth in the total of sectors A, B, and C; the other would be the growth of the general population. The logic is that growth would be proportionate to both population increase (household services) and increase in the basic sectors (A, B, and C), since Group D served both industries and households. The household growth data were unavailable, however, and growth in D was made proportional only to growth in the total of sectors A, B, and C.

7.1 *Basic Employment Forecasting Method for Sectoral Groups*

The basic forecasting method is simply a straight linear extrapolation of employment on the basis of past increases in sectoral output and sectoral employment. These forecasts will be varied to take into account inter-group relationships described in the previous section. For Group A, the basic method for projecting employment to 1980 is:

Group A:

$$_jE^i_{80} = {}_jE^i_{72} + \frac{_jE^i_{72} - {}_jE^i_{62}}{_jB_{72} - {}_jB_{62}} \cdot ({}_jB_{80} - {}_jB_{72}), \qquad (6)$$

where:

E = Employment in year shown
B = Gross Domestic Product, GDP

This is simply a straight linear extrapolation of employment in sector j, region i for the year 1980 ($_jE^i_{80}$), which is equal to the employment in the sector and region in the year 1972 ($_jE^i_{72}$) plus the difference between the employment in 1972 and the employment in 1962 (i.e., the growth in em-

ployment in past years) divided by the difference in the Gross Domestic Product between 1972 and 1962 ($B_{72} - B_{62}$), multiplied by the difference in the GDP in the base year (B_{72}) and the projection of target year (B_{80}). Hence, the base year 1972 employment is increased by a ratio of past employment growth to past product growth multiplied by the difference between product in the base year and target year. This assumes a straight linear trend based on past changes in employment related to past changes in product. The method is simpler to illustrate with numbers than to explain words. To project E_{80}, employment in 1980, by region and sector:

E_{62} = Employment in 1962 = 800
E_{72} = Employment in 1972 = 1200
B_{62} = GDP in 1962 = 100 million (national monetary unit)
B_{72} = GDP in 1972 = 200 million
B_{80} = Projected GDP for 1980 = 350 million

$$E_{80} = 1200 + \frac{(1200 - 800)}{(200 - 100)} \cdot (350 - 200)$$

$$= 1200 + \frac{400}{100} \cdot 150 = 1200 + 4 \cdot 150 = 1800$$

This is an outline of the extrapolation method for projecting employment for Sector Group A.

7.2 *Projection for Other Sector Groups B, C, D, and E*

The projections for Group B are done by the same formulation as Group A. Additionally, detailed employment estimates for large projects are obtained from plans and engineering studies.

For the projections for Group C, the same essential formulation is followed, except that employment estimates for Groups A and B are added to give a new variable, F_i^j, which is then used in the following formulation:

Group C:

$$E_i^j = {}_jE^i{}_{72} + \frac{({}_jE^i{}_{72} - {}_jE^i{}_{62})}{F^i{}_{72} - F^i{}_{62}} \cdot (F_i^j - F^i{}_{72}) \qquad (7)$$

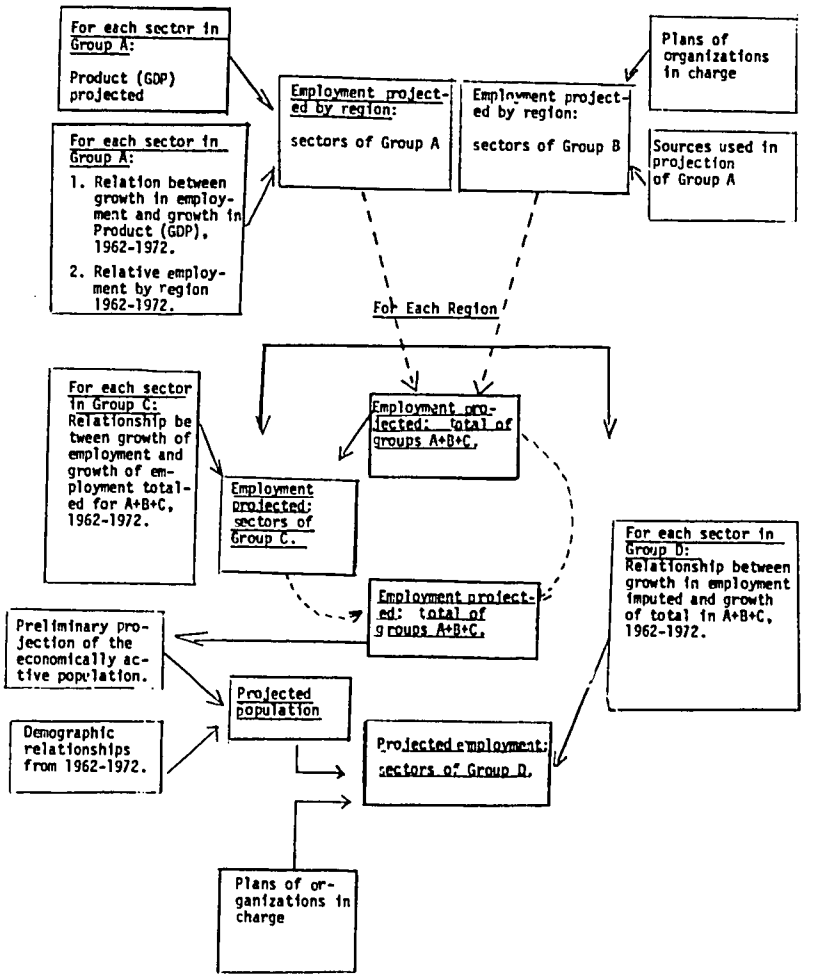
Because the F^i totals for the years 1962 and 1972 and the target year of the forecast, F_i^j, have been provided in the previous projections, the employment for Group C can be forecast with equation (7).

For the projection for Group D, the employment estimates for Groups A, B, and C are added together to give the variable G_i^j, which represents the combined employment of the three groups.

The final step in the Paraguay case consists of adjusting the occupational coefficients or distributions derived from a census sample and applying them to the projected employment. The approach is outlined in Figure 11.3, based on Daniere's methodology.

Figure 11.3

Sequential Schema of Phase 2



Source: Report of Andre Daniere to Ministry of Justice and Labor, Paraguay

8.0 *Closing Note on Manpower Methods*

A review of the simpler approaches to manpower planning and the illustration of these methods in the cases to follow should convince the planner of the following truths, which have been dealt with in preceding thematic papers:

— The focus in manpower planning is on a very narrow interpretation of the goals of education-training systems. Educational systems do more than produce educated and trained workers for the workforce, but this is momentarily ignored in manpower planning, and graduates are treated as output and called *supply*, and worker requirements are treated by the numbers and termed *demand.*

— Underlying most manpower requirements forecasts are a host of simplifying assumptions about relationships between product, productivity, (product per worker), employment, occupational structures, and educational levels. The use of fixed coefficients to reflect sector/occupation and occupation/education distributions is a weakness known to analysts, but it is sometimes not stressed in their reports.

— The underlying models and methods are essentially simple, depend on extrapolations based on simple curve-fitting, and are varied in applications in different situations.

— There is also some different and additional information that can enrich the simple forecasts of manpower requirements (the second and third columns of Schema 8.1), but there are no general models for incorporating all of this information into a single analysis. Manpower analysis proceeds through a series of approximations and simple iterations, incorporating new and additional data to update and improve successive rounds of forecasting.

— With all its limitations, manpower analysis has been widely applied in planning, and is still being applied. The record is clear that it is used and that there is a demand for it. The record is not so clear that it has been wisely used to influence policy and program changes in education and training. Still, there is little evidence that manpower planning has been useless or harmful. These issues are discussed in other papers in this series. Different applications of manpower planning have led to unstable results, and sometimes to no results, but this could be said of almost any application of any of the methodologies of social science.

READING 11.1

General Description of Economic Growth Model Used in Manpower Forecast

Source: Bureau of Labor Statistics, *Handbook of Methods,* Bulletin No. 1910 (1976), pp. 256-257.

Background

The Bureau of Labor Statistics has developed a program of economic growth studies aimed at providing a framework for analyzing the problems of long-run economic growth. The primary objective of this program is to develop projections of employment opportunities under alternative assumptions. These projections provide a framework for assessing a number of important economic problems including labor utilization over the next decade and employment requirements of specific government programs.

Methods

A system of economic growth models has been developed to serve as a tool in making economic projections. This system begins by projecting the economic growth rate of the United States under conditions of potential or near potential utilization of its labor and capital resources. This is referred to as potential gross national product (GNP). To do this, the system must project the labor force to the target year, assuming a specified unemployment rate, and project the rates of change in productivity and average hours paid.

This potential gross national product (GNP) is then distributed among the major demand components of GNP by use of a macro-econometric model. This model converts potential GNP into income by sector, such as government revenues, personal income and business income, and in turn translates income into aggregate purchases or demand. The foreign trade sector and some government accounts are left for exogenous adjustment to permit flexibility in certain assumptions of the projections. The macro-model is designed so that projections of supply GNP and demand GNP are not necessarily equal. The equating or balancing of these is done by making selected changes in government fiscal policy.

The next stage in the projections is to develop a projection of the industry composition of demand for each of the major demand categories. For example, the consumer expenditures category includes the amounts spent on rents, automobiles, medical expenses, and other goods and services purchased by consumers. For each of the major demand categories, different analytical procedures are followed in allocating demand to the producing industry. In some cases submodels are used to assist in this analysis. The industry detail to which the categories of demand are allocated matches the input-output classification used in the subsequent step.

Demand as used in the national income accounts refers only to final demand, i.e., that of the ultimate consumer. To place a value on the output of an industry whose products are not sold to ultimate consumers, but are used instead by other industries in the course of their own production, an additional set of calculations is necessary using an input-output model. The input-output model translates final demand for a given product into the output that is required from all other industries to produce the materials needed to manufacture that product or service.

Prior to use of this model, the input-output coefficients are projected. The input-output tables used as a base in the economic growth model are developed by the Bureau of Economic Analysis, U.S. Department of Commerce. However, these input-output tables incorporate the technology and product mix for a base year, and may not reflect the technology and product mix which may prevail during the period for which the projection is being made. Thus, it is necessary to project changes in the input-output coefficients. Two methods are used to do this: Detailed analyses are made of the changes taking place in the technology of various industries as well as the changes expected in product mix due to differing growth rates of product groups within industries. For industries for which detailed studies are not made, analyses are developed to determine the direction and magnitude of change in the use of its products by other industries.

Next, employment estimates by industry are developed. This is accomplished by use of a set of industry productivity projections. The final stage is to balance the model. Projections contain many complex relationships among economic variables that were developed through a lengthy sequence of operations. It is necessary to have a set of checks and balances to insure that the various stages of the projections make up an internally consistent model. The economic growth model is designed to provide a feed-back and balancing procedure with respect to three of its elements: Imports, investment, and employment. In practice, all three of these elements must be brought into balance simultaneously.

READING 11.2

Productivity: General Objectives and Definitions

1. An assured source of accurate information on sectoral productivity is required in order to accomplish the following objectives basic to planning:

— To provide a basis for economic growth forecasts, in order to project and plan growth and development, especially in key sectors.

— To provide the basis for developing priorities for selecting appropriate technologies.

— To provide a basis for forecasting employment and for development of employment policies for key sectors and occupations.

— To provide a basis for estimating manpower requirements in terms of given patterns of growth in input and employment, and to guide the planning of education and training.

— To provide a basis for monitoring the performance of the economy (by sectors and later by industries and by firms). Also to monitor workforce developments and establish wage and price policies.

2. Though analysis of productivity will require some study of the comprehensive relationship of output to major factors of production or inputs (labor, equipment, methods, organization), the focus here will be on the study of labor productivity. The definition of productivity can be broad, e.g. *the measure of the economy of means,* or narrow, e.g. *the product/factors ratio,* or specialized for one factor, e.g. *labor time expended per unit of output.* Total factor productivity analysis is one basic approach, and labor productivity analysis is a second. The current trend seems to be to emphasize total factor productivity analysis, but here the term *productivity* used alone will generally be used in its specialized sense, and *labor productivity* will be understood.

3. The limitations of narrow approaches to the analysis of productivity are recognized from the outset. These problems include: (i) the difficulty of defining and measuring output in the services and especially in some government services (regulation, defense); (ii) problems of attributing inputs to joint products; (iii) variations over time in qualitative characteristics of physical output units; (iv) combining physical and monetary measures; (v) difficulties in developing deflator indices and weights; (vi) difficulties in accounting for different labor input types, and for direct and indirect labor and contract labor, and attributing and measuring the contribution of research and development, supervision and communications staff. A general problem of basic methodological approach is whether to analyze the sectors (industries, services) close-up, with many micro level work-study and

methods-study efforts (which produce large and complex volumes of data difficult to manage), as opposed to developing aggregate, indirect complex indicators and indices which would be difficult to construct, maintain and interpret. What is certain is that the problem of analyzing productivity must be dealt with by economic planners. Productivity estimates are at once the most critical and the most vulnerable parts of general economic and manpower planning. Productivity estimation is the Achilles Heel of manpower planning.

Schema A11.1 outlines a number of major issues in the conceptualization and measurement of Productivity. The columns cover the common variables dealt with in the measurement of Output, or Product; the measurement of Input (factors of production, labor inputs etc); and the measurement of Classificatory Variables, i.e. variables which affect the relationship between Input and Output, and hence variables which affect the measurement of Productivity.

In the measurement of Output (Product), the analyst has various choices. He can choose to measure Gross Output or Net Output; he can measure Total Value (the total of quantity times price) or Value Added, (the Total Value less Factor contributions to product). To avoid problems of pricing, market imperfections, and inflation, analysts in order to obtain more reliability in measuring and comparing products, may base the comparison on physical units of output. Schema 11.1, also outlines the difficult problems and choices in the definition and measurement of Output in the service sectors. In Education there is no real agreement as to how output, and hence productivity, should be measured. Quantitative measures of enrollment flow and efficiency and numbers of graduates can serve as crude indicators of Output in Education, but these measures do not capture the qualitative differences in the education process or qualitative differences in learning output. Tests of achievement, skills and attitudes may reflect some aspects of quality in output, but there are subtle and deep lying elements of knowledge and skill that may not be captured in standardized tests.

Even if the tests measured learning *output* in any real sense, there are few tests or measurement procedures for assessing the supposed *outcomes* of education. These include enhanced worker productivity (which is difficult to measure and even more difficult to attribute uniquely to education), the performance of civic functions by citizens, and generally improved social and cultural performance by educated people. There is no easy or accepted measure of the outcomes of education, and hence product can not be fully assessed and educational productivity determined.

The same problems plague the measurement of output in other service sectors, such as in health and in government services generally. How is output measured in government regulatory agencies, or in the military services in time of peace? Perhaps the fact that there is peace is the true measure of output. Measurement of output in the services is difficult. In government agencies the wage bill may be taken as the product, but this can lead to absurdities when applied to productivity. For instance, in the situation where more workers are hired and paid more for doing less, productivity

appears to be increased. In some social sectors the true gain in product can not be assessed except in reference to national goals and values. Where distribution and equity are the goals then moral philosophers are still struggling with the issues that arise from the fact that when one individual, or group, is benefitted, it may be at the cost of another. For example, total agricultural output may decrease while distribution and equity are sought through land reform. The measurement of output can not cope well with these issues.

There are equally difficult problems in measurement of Input. A major choice is between assessment of total factor productivity, or concentration on a central factor such as labor. Parceiling out the effects of the various factors which go into output is difficult, and attributing these effects to specific inputs, types of inputs, and quantities of inputs is equally difficult. The application of regression based approaches and least squares models to the study of educational effects has been discussed in Chapter II. The limitations of ordinary least squares are familiar to analysts, but there have been further methodological developments through the use of multi-stage least-squares analysis and the use of models based on flexible functional forms which permit systematic analysis of the relationships between pairs of inputs. The translog (transcendental logarithmic) function allows variable elasticities of substitution both among input factors and through time. No model and no form of analysis gets completely around the problem of uniquely attributing products to given kinds and amounts of inputs used in a complex process.

In addition to complications in modeling the effects of inputs on outputs there are also questions about the units in which inputs are expressed, and difficulties in reflecting qualitative differences in outputs, e.g. qualitative differences in worker crafts. The effects of some kinds of labor are difficult to measure and attribute, for example, research and development effort which has a long term and subtle payoff in a production process. There are also problems of weighting and combining inputs, and deflating and indexing outputs.

In any study of process effects there is also the difficulty of characterizing the context and charting its effect on inputs and outputs. Hence, there is a need to identify, classify and measure historical and contextual variables that interact with inputs, and sets of inputs, to produce unique effects. The analyst must struggle with all of these issues and difficulties to measure productivity, and after years of effort and vast investment, productivity analysis is still a research enterprise for all but the most straightforward production situations.

Schema A11.1:

An Outline of Variables for Productivity Analysis

OUTPUT (Choices)

1. Gross Output versus Net Output
2. Value (pq) versus Value Added
3. Physical Product versus Monetized Product
   a. Product measured
   b. Unit of measure
   c. Net versus gross output
4. Service Unit Outputs

   More straightforward

   a. Education — attainment, enrollment, graduates, flow, input/output, expenditures, (unit-costs)
   b. Health — patient/treatments preventive service units

   Less Straightforward

   a. Education — quality schooling, achievement, Outcomes (effects, i.e., employment, earnings, social adjustment, rate-of-return).
   b. Type of Health services (e.g. preventive, curative issues, MCH).

INPUT (Choices)

1. Major issue is whether to use total factor approach or selected inputs such as labor. It is difficult to parcel out and attribute effects of varying factors such as labor, land, capital equipment, materials, energy . . . organization, method . . .
2. Various ways of expressing units of labor:
   a. Worker numbers (per capita)
   b. Man hours, weeks, months, years, weighted and unweighted
   c. Visible versus Incorporated Labor
   d. Production versus Non Production Labor (inputs)
   e. Preparation in support of production: supervision, administration distribution, transportation, research and development, public relations . . .
   f. Worker characteristics, education, occupation, salary/wage/benefits, experience, organizational hierarchy . . . nationality

CLASSIFICATORY VARIABLES

1. Classification of Economy and Level of Analysis Issues:
   a. Sectors (kind and number, e.g. more aggregate, less . . .
   b. Sub-sectors, where products and outcomes differ markedly, e.g. Labor and Social Affairs; Education, types and levels.
   c. Industries, classified at varying levels of specificity for product (service); joint product.
   d. Firms, within each individual firm what size and type? plant? department? profit center?
   e. Individual and small group service enterprises; cut off level (see size).
2. Industry type (formal, nonformal, modern, traditional, primary secondary, tertiary; by type; segment of labor market.

(cont. following page)

Schema A11.1

(continued)

c. Other services where output is difficult to measure — Communication, Regulation, Security, Governance
d. Note that some basic value or normative position may be required before social productivity can be assessed, even in straightforward services. Examples might be, Basic Needs Approach (Universal education, literacy, etc.), distributive equity norms etc.; national security goals, public safety norms . . .

5. Costs, budget, expenditure measures outlays, e.g. per-pupil costs

6. Attainment of service norms

7. Other Considerations
   a. Product and service mix as well as quantity and level
   b. Degree of disaggregation by commodity
   c. Combining and weighting commodities in composite index
   d. Qualitative changes
   e. Adaptation to local need and preference
   f. Indirect indicator chains

3. Other Inputs
   a. Land (arable etc.)
   b. Energy use (renewable etc.)
   c. Capital, costs, etc.
   d. Resources and materials used (raw materials, water, semi-finished)

Considerations

a. Problems of attributing indirect and support labor or inputs serving many commodities or service outcomes.
b. Problems of contract labor.
c. Voluntary labor.
d. Creative labor.
e. Use of standard worker classification schemes (ISCO, DOT) or classification by factor analysis.

Other Measurement Issues

1. Weighting problems for combinations of inputs/outputs.

2. Indexing problems (pq weights) choosing periods, choosing mixes.

3. Basic issue of many disaggregated estimates of PMH, or aggregate composite indexes and indirect indicators.

3. Industry Size Classification
   a. By employers (workers, production/other
   b. By sales volume, value, etc.
   c. By social capital
   d. By technology
   e. Other, Information Based, etc.

4. Ownership and auspices (national, other, public/private)

5. Management

6. Location

CHAPTER 12

Manpower Planning with an Alternative Method: The Dominican Republic Case

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José Dominguez-Urosa, then Director of International Activities in the Educational Development Center, was in charge of the project, Ernesto Schiefelbein was the Technical Director, and Juan Llado was Field Study Coordinator in the Dominican Republic.

The cooperation of all those organizations and individuals and the contributions of countless unnamed researchers are gratefully acknowledged.

1.0 *Introduction*

The main study of the manpower requirements of the Dominican Labor Force was structued in this form:

- *A description of the Dominican Labor Force in the base year of the study, 1970.* This section describes the occupational strucure by economic sectors and relates the occupations to the educational level of the workers.
- *The structure, capacity, and dynamics of the formal system of education in the Dominican Republic.* This section has been reduced in this version (English) of the case.
- *Supply projections of the educational and training system in the Dominican Republic (1970–1985).* This section has been cut down in this version of the case, and included in the previous section.
- *Demand Projections for the Labor Force (1970–1985).*
- *Comparison of projections of demand and supply and the balance between demand and supply of trained workers (1970-1985).*

— *Summary of conclusions and recommendations made as a result of the study.* This is a concise summary of the study's wide range of recommendations on policies and programs to be adopted.

The main report is followed by a technical appendix that explains the methodology used to project requirements, called here *demand.*

2.0 *The Dominican Labor Force: General Analysis*

Any opportunity for future development that is planned in the Dominican Republic will, of course, grow out of present conditions. The increase in trained and educated persons must be added to the pool of those who currently comprise the labor force. The characteristics of these workers appear in the first set of tables, which are based on the population census data for 1970 and adjusted by the additional analysis made for this study.

The following comments on the occupational and sectoral distribution of workers are quoted directly from the original Dominican report by Davis (1974). The reader can make his own observations, based on Table 12.1

> The distribution of employed workers, by occupation and sectors of economic activity (Table 12.1), indicates that the Dominican Republic has the labor force structure which is typical of a developing country, where primary production in agriculture predominates. Unskilled and casual employment has been high, and industrial employment, and other areas requiring skilled manpower, have scarcely begun to grow.
>
> The level of technical and professional employment is normal for the state of the economy in the base year, slightly over 3 percent, but there is considerable spread in the distribution of the educational levels of those who were classified as professionals and technicians. More than half of them have less than 12 years of education (a point which will be discussed when the supply of educated professionals is analyzed). The percentage of administrative and executive personnel seems to be very low for the Dominican situation, .5 percent (4848/833,057 = .0058). Either the occupational category was not clearly defined in the census or the vital role of administration was underestimated or under-recorded. It is important to note that this occupation would require specific training programs which, in turn, would affect the demand as well as the supply. The educational level of those classified in this key category is low; more than 70 percent have less than 12 years of education. The representation of office workers in the labor force is similar to the average in other comparable countries.
>
> Skilled workers seem to be under counted, because artisans other than Plumbers, Electricians and Mechanics were classified as Other Workers. Most of those in the Other Worker grouping are farmers and laborers, but some in the Industry and Other Services sectors may be skilled. More than three-fourths of the labor force are classified as Other Workers.*
>
> The distribution of occupational groups according to sectors of economic activity is also shown in Table 12.1. High proportions of technical and professional workers are found in Other Services, Government, Commerce, Construction and Industry sectors. About 70 percent of the social scientists and economists work in the Com-

merce and Finance sector and Government, and are distributed more or less evenly between the two. Almost all the school teachers work in the government sector, although there are many who were classified in the non-university professions (Table 12.1) who really work as teachers in institutions of the private sector. Therefore, they are included in the sector category of Other Services. Seventy percent of the agronomists and veterinarians are included in the Agricultural sector. Only a small percentage of them work for the government. This is rare in other similar countries.

The proportion of lawyers in the Government sector appears low. Lawyers are distributed in different sectors, with a few classified into other services; but 90 percent are found in the Commerce and Finance sector. The 6 percent in government employ is low. Office employees are distributed according to anticipated patterns; about 75 percent work in either Government or Commerce and Finance.

*The low education level of workers may account for some misclassification, but readers should note that analysts must often work with shaky occupational data. That's the challenge.

The comments made on the distributions in occupations and in sectors, and in occupations by sectors, should illustrate the kind of observations which experienced manpower analysts make on occupation by sector distributions of the workforce. Not all the observations made in the original report are given in this case. Even in the report itself, not all the analyst's observations were offered. The purpose in giving some observations here is to indicate what a manpower analyst looks at and to show the mistakes he makes in his observations.

2.1 *The Educational Attainment Level of the Workforce*

Table 12.2 indicated a low level of educational qualification for the economically active population. Only 22 percent had completed primary or a higher educational level. Workers 34 years and over have an educational level significantly lower than that of younger workers. (The chi-square for the difference in ages and educational level is significant at the .001 level). This situation reflects a history of educational deprivation for the older groups in the workforce.

Through the census and a special labor market survey of employees and employers, three categories of skilled workers could be studied: the first group, plumbers and related jobs, includes metallurgists; the second group is composed of electricians who work principally in repair services; and the third group is made up of machinists and auto mechanics. This labor market study showed how skilled workers were recruited, paid, trained, and promoted in the Dominican workforce. Only a portion of these results were incorporated into the general manpower study. The interested reader can consult the original and complete set of reports (Dominican Republic, 1974). The labor market study revealed several interesting aspects of the Dominican labor market which are not directly connected to this manpower study: (1) there was no systematic information either collected or exchanged on job openings or labor supply in the Dominican Republic, and there was a critical

Table 12.1

Occupational Structure of the Labor Force by Productive Sectors: 1970

Occupational Categories	Sectors									
	Agriculture	Mining	Industry[a]	Construction	Transport and communications	Electricity, gas, and water	Commerce and finance	Other services[b]	Government[c]	Total
Engineers, architects	24	-	44	1,119[f]	11	48	44	39	86	1,415
Chemists, physicists and pharmacists	10	-	128	-	-	-	38	493	95	764
Agronomists, veterinarians	358	-	28	-	-	-	25	52	28	491
Economists, sociologists mathematicians	-	-	8	-	8	-	75	46	72	209
Lawyers, judges	-	26	12	-	-	-	1,160	19	43	1,260
Accountants, bookeepers	-	14	120	-	-	23	1,106	33	85	1,381
Doctors, surgeons, dentists	-	-	-	-	-	-	10	1,553	41	1,604
Other professionals	-	-	9	3	-	-	31	587	166	796
Production technicians and others	390	9	278	1,440	50	44	371	2,084	182	4,848
Paramedics, medical technicians	-	-	-	-	-	-	-	282	12	294
Nurses, midwives	-	-	-	-	9	-	10	2,834	36	2,889
Professors[d]	-	-	-	-	-	-	28	34	13,748	13,810
Managers and administrators	200	12	600	235	105	12	1,804	294	1,286	4,548
Office employees	527	86	6,269	481	3,469	787	25,873	4,319	27,642	69,453
Salesmen and related	184	9	911	39	1,170	-	50,073	514	54	52,954
Plumbers and related	-	-	672	19	-	33	45	1,822	74	2,665
Electricians and related	-	-	281	21	47	298	79	3,119	33	3,878
Automobile mechanics	42	19	757	116	124	51	281	12,504	160	14,054
Other mechanics	9	-	814	39	121	-	90	482	22	1,577
Other workers[e]	397,961	530	77,878	18,654	44,996	537	7,799	85,806	8,247	642,408
Military personnel	-	-	-	-	-	-	-	-	11,759	-
Total	399,705	705	88,809	22,166	50,110	1,833	88,942	116,916	63,871	833,057

Source: Appendix 7, Volume II, Human Resources and Employment in the Dominican Republic, Educational Development Center, Inc.

[a] Includes the sugar industry.

[b] Includes tourism, medical services, cleaning, domestics and others.

[c] Includes education and public administration.

[d] Includes university professors, secondary teachers, primary teachers and others.

[e] Includes farmers and miners, day labor and other workers.

[f] This number can be misleading; of the 1,119 "Architects and Engineers" registered in the base number of 1970, only 385 were really civil engineers or architects. For more details, see the methodological note in Volume II.

Table 12.2

Eonomically Active Population: Age by Educational Groups
(from 15 to 34 years and 35+ in 1970)

Educational level / Age	Not specified	Without education	Less than 6 years	6 years	7 and 8 years	9, 10, and 11 years	12 years	13,14,and 15 years	16 years	Total
From 15 to 34	64,400	179,707	258,098	35,144	51,565	28,594	48,381	8,491	4,916	679,296
	(9.5)[a]	(26.5)	(38.0)	(5.2)	(7.6)	(4.2)	(7.1)	(1.2)	(.7)	(100.0)
From 35 to 65	50,363	180,666	151,193	16,220	30,893	11,088	7,896	4,894	5,052	458,265
	(11.0)	(39.4)	(33.0)	(3.5)	(6.7)	(2.4)	(1.7)	(1.1)	(1.1)	(100.0)
TOTAL	114,763	360,373	409,291	51,364	82,458	39,682	56,277	13,385	9,968	1,137,561*

[a]Percents in parentheses sum across the age groups

Age \ Educational Level (Grades)	< 6	> 6	
< 35	502	177	679
> 35	383	76	459
	885	253	1,138

Chi-Square = 14.3

Probability that the result is due to chance: $\leq .001$

Conclusion: Age and educational level are related: older workers have less education

[a]This total of the Economically Active Population differs from other figures presented in this document because of adjustments that were made.

Source: Special tabulations from the 1970 Census.

need for a labor market information system; (2) there was a haphazard and personalized system of hiring skilled workers for jobs; (3) there was little mobility for skilled workers because the market was so haphazard; (4) skilled workers were underpaid and undervalued by employers; (5) there was almost no realization of the need to train workers within firms.

3.0 *Education and Training System; Actual Capacity and 1985 Projection*

The quantitative characteristics of the Dominican educational system appear in Schemas 12.1 and 12.2, which show the structure and flow of the system for the year 1970, as well as for the target year 1985. The projection to 1985 is a neutral one, i.e. assumes present structures and trends continue as they are. It provides a basis for showing needed changes that should be made in plans and policies. The primary level comprises grades 1-6, while the secondary level is divided into two cycles. The first cycle lasts two years and the second, or diversified cycle, (Table 12.3), has a duration of three years, depending on the programs. The third level, higher education, is better described in Table 12.4, where institutional details and the fields of study in the universities of the country are presented. This is followed by Table 12.5 showing projections in supply of university level programs. Outside the formal schools, nonformal programs of education and special programs for training are run parallel to the educational system.

Schema 12.2 shows that the enrollment structure has a pyramidal form. The broad base (primary grades) reflects educational policies of 15 years ago, when there was an effort to transform the educational system into one that could reach the goal of universal primary education. This attempt has not yet succeeded.

Table 12.3

Structure of Secondary Education (Diversified Cycle) 1970 and 1975

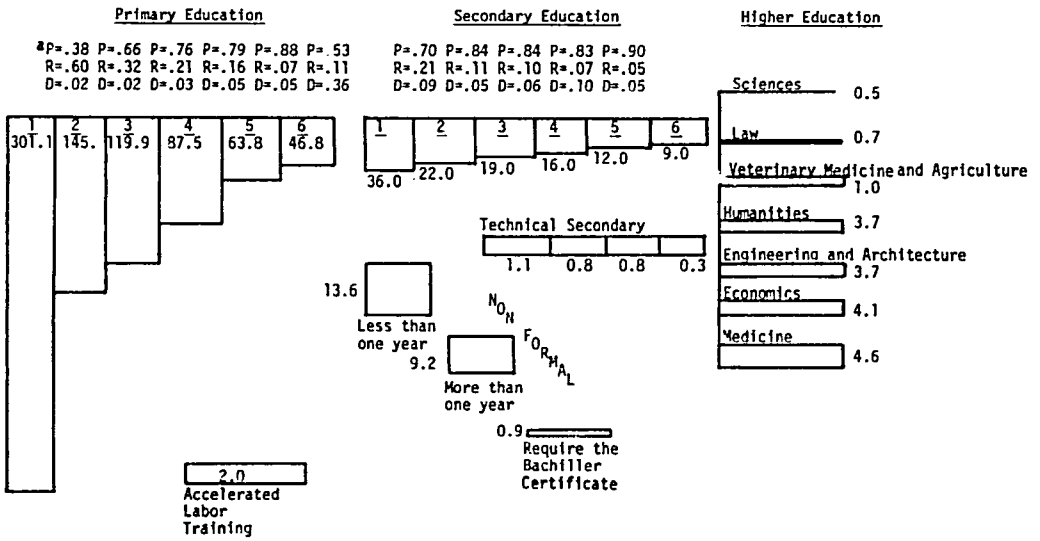
Type of Education	1970				1975			
	Enrolled		Graduated		Enrolled		Graduated	
	Number	%	Number	%	Number	%	Number	%
Commercial	1,097	1.0	173	2.2	2,596	1.5	294	1.7
Industrial	684	0.7	79	1.0	1,012	0.6	105	0.6
Agricultural	619	0.6	180	2.3	654	0.4	135	0.8
Normal	540	0.5	148	1.9	603	0.3	240	1.4
Academic	100,260	97.2	7,120	92.5	170,535	97.2	16,726	95.6
Total	103,200	100.0	7,700	100.0	175,400	100.0	17,500	100.0

4.0 *General Projection of the Workforce (1970-1985)*

The general forecast of the labor force, using two alternative projection series, appears in Table 12.6.

Schema 12.1

Diagram of the Dominican Educational Sector Flow in 1970

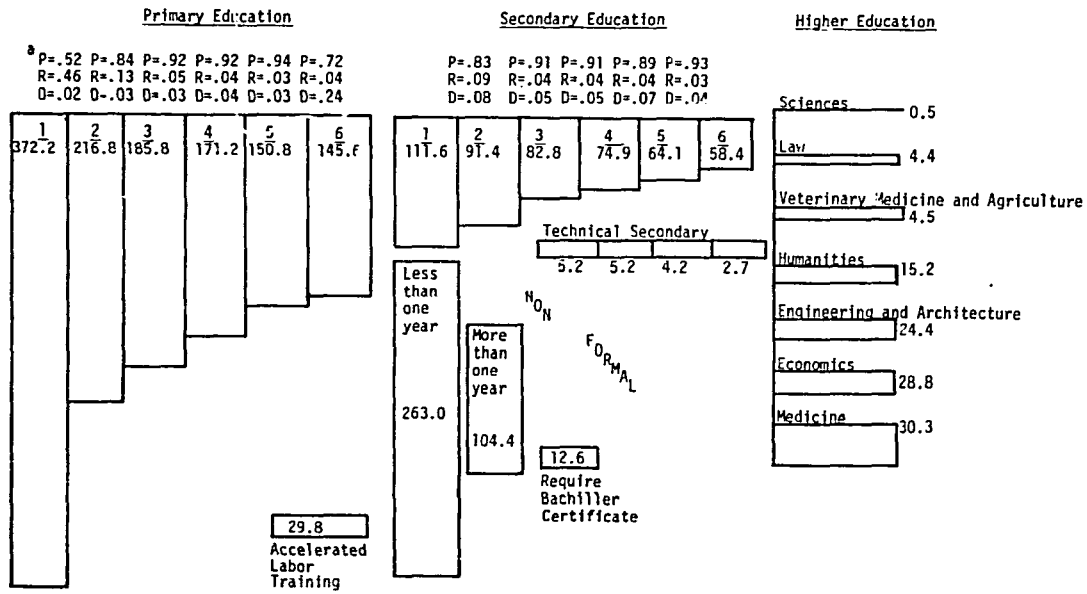


Note: The enrollment figures are expressed in thousands and the rates of transition as decimal fractions.

[a]P = Promotion R = Repetition D = Dropout

Schema 12.2

Diagram of the Dominican Educational Sector Flow in 1985



Note: The enrollment figures are expressed in thousands and the rates of transition as decimal fractions.

[a] P = Promotion R = Repetition D = Dropout

Table 12.4

Distribution of Student Population by Institutions and Faculties of Higher Education for the Year 1973

Faculties	Institutions						Total	
	University A	University B	University C	University D[b]	University E[b]	University F[b]	Number	%
Humanities	1,849	461	1,079	129	336	--	3,854	17.8
Science	466	--	92	--	--	--	558	2.6
Veterinary medicine and agriculture	576	249	152	--	--	--	877	4.1
Medicine	4,349	31	501	667	--	99	5,647	26.1
Economics	3,513	370	874	201	445	52	5,455	25.2
Law	373	247	357	40	--	--	917	4.2
Engineering and architecture	3,034	582	560	105	--	65	4,346	20.0
Total	14,160	1,740	3,615	1,142	781	216	21,654	
Percentages	(65.4)	(8.0)	(16.7)	(5.3)	(3.6)	(1.0)	(100.0)	(100.0)

Source: Obtained from the records of the respective higher education institutions (Schema II-2. Volume II, page 262, Human Resources and Employment in the Dominican Republic, Educational Development Center, Inc.)

[a]These figures do not include enrollment for "Colegio Universitario."

[b]These figures correspond to 1974.

Table 12.5

Projections of Supply in University Level Programs

University Programs	1972		1975		1980		1985		Cumulative 1970-1985			
										Dropouts by year		
	Enr.	Grad.	Enr.	Grad.	Enr.	Grad.	Enr.	Grad.	Grad.	1-2	>2	Total
Engineering, Architect	3725	83	6815	296	13379	923	24438	2156	11946	9382	2166	11548
Medicine	4633	101	8101	362	16019	879	30286	1947	11493	7380	5142	12522
Law	670	51	1149	70	2398	142	4429	306	1974	2242	666	2908
Economic Sciences	4099	242	7840	573	15463	1563	27975	3058	19303	14182	2838	17020
Humanities	3687	232	4847	452	8392	762	15203	1505	10569	11659	2714	14373
Agriculture/Veterniary	1021	59	1471	137	2488	236	4549	491	3237	1729	756	2485
Sciences (Physical)	486	52	644	54	1155	101	2095	202	1426	1895	520	2415
Total	18321	818	30867	1944	59294	4579	108975	9665	59948	48469	14802	63271

Growth Rates for Higher Education
(Cumulative Annual Percentage Increase)

Rates of increase	Present	Projected		
	1972-1975	1975-1980	1980-1985	1972-1985
Total enrollment	19.0	13.9	12.9	14.7
Total graduates	33.4	18.6	14.9	20.9

Source: Working Document 7 of the Section on Projection of Supply

Alternative 1, beginning in 1970, with an economically active population of 1.2 million, 836,000 employed and a cumulative annual rate of growth of 3.2 percent, would result in an economically active population of almost 2 million in 1985, with 1.5 million employed. This means an annual increase in employment of 4.1 percent in that period, and a rate of unemployment of 23 percent of the economically active population in 1985. These are optimistic rates with respect to the increase in employment, but they are within the limits of national capability.

Alternative 2 results in a smaller active population, beginning with a slightly smaller E.A.P. for the base year. With the same rate of growth for the economically active population and employment, this alternative would result in a smaller economically active population and a lower rate of unemployment, 15 percent for 1985.

Employment is maintained at the same level in both alternatives; the difference results from the variation in methods of measuring the economically active population. Within these limits, the projection of demand for employment, by sectors and occupations, is derived.

Table 12.6

Economically Active Population (E.A.P.) 1970 and 1985

E.A.P.	1970	Rate 1970-1985	1985	Rate of unemployment
Alternative 1				
E.A.P.	1,225,000	3.2%	1,964,000	
Employed	836,000	4.1%	1,519,000	
Unemployed	389,000		445,000	23%
Alternative 2				
E.A.P.	1,109,000	3.2%	1,778,000	
Employed	836,000	4.1%	1,519,000	
Unemployed	273,000		259,000	15%

Source: Based on 1970 Census; Work Document No. 6, Volume II.

4.1 *Economic Growth Forecast*

Table 12.7 shows economic growth projected by principal sectors. The first column gives the growth of value added, or production, from which employment growth is derived. Mining shows a significant growth as a result of its expansion in years previous to the base year, although it did not generate much employment due to its small capacity when compared to other sectors. The growth of the construction sector is more important, because it presents a greater share of product and employment, and it also employs a high percentage of professionals, qualified workers, and technicians.

The rate of growth of industrial production is double that of industrial employment. This implies a sustained growth in productivity, which is in agreement with recent and expected trends in investment, technology, and education. The same relative growth between production and employment is projected in the public sector, a sector that will employ the majority of highly

Table 12.7

Value Added and Employment Growth for 1975 and 1985

Economic Sectors	Value added of production			Employment		
	1970	1985	Rate of Growth 1970-1985	1970	1985	National Rate of Growth 1970-1985
Agriculture	297.4	642.2	5.3	399,705	627,070	3.0
Mining	18.1	489.8	24.6	705	6,274	14.5
Industry[a]	222.7	984.5	10.4	88,809	186,658	4.95
Construction	64.2	416.3	13.3	22,166	72,099	7.86
Transportation and communication	82.0	228.6	7.1	50,110	111,990	5.36
Electricity and gas	19.6	97.7	11.3	1,833	2,498	2.06
Commerce and finance	343.5	1,017.7	7.5	88,942	131,732	2.61
Services[b]	97.9	270.5	7.0	116,916	269,022	5.55
Government	127.6	357.6	7.1	63,871[c]	114,065	3.86
Total	1,273.0	4,504.9	8.79	833,057	1,521,408	4.01

Source: Based on 1970 Census: Appendix 5, Volume II; and Appendix 9, Volume II.

[a]Includes sugar industry.

[b]Includes medical services and veterinarians; public services, recreation, repair services, domestic service, other services, and tourism.

[c]Includes military personnel.

educated professionals. Agriculture, which would have a larger share in product and employment, shows a strong increase in production and an average growth in productivity and employment. The share of agricultural employment in the labor force will decrease slightly, from 48 percent in 1970 to 41 percent in 1985.

4.2 *Demand Forecast of the Workforce by Sector and Occupation (1970-1985)*

Some important points should be noted about the detailed projections of labor force demand for occupations, which are shown in Table 12.8.

— Special fields within engineering are presented in aggregate form, as was done in the projections of supply, because in the census data for the base year these specializations were not differentiated. Generally the demand comes out much less than the supply, but, in some specializations, the supply is greater than the demand.

— The demand for agronomists and veterinarians is high, but not out of line with the increased share in product and employment implied by the overall growth trend of the agricultural sector. The demand for social scientists is very low, but the analysis of the labor market indicates that graduates in this field could work in many sectors and occupations.

— In the case of lawyers, the moderate demand and supply could be reasonably well adjusted. Lawyers have occupational as well as sectorial mobility within the workforce in the Dominican Republic.

— Teachers, together with educated professionals at the university level, occupy a very important position within the professional categories of the demand table. They will work in secondary and higher education and at various levels in the private schools. If the supply forecasts for the primary school level are as high as projected, additional teachers will be required to take care of the increase in the number of students enrolled.

— The demand for office workers seems to be low, but jobs for office employees with some degree of administrative ability will be available. Sometimes it is difficult to separate one type of occupation from the other. In the category of sales administrator, there are jobs with two functions—salesmen and administrators.

— According to the special study of the labor market, the demand for skilled workers is high. Electricians and plumbers are required principally for repair services, whereas specialized workers in metals are required in industry. The demand for motor and auto mechanics will be very high, principally in the service sector, but also in industry, construction, and transportation.

— The demand for unskilled and untrained workers in agriculture, services, and manual labor, will grow at a slower pace than the demand for trained workers. Demand will decline for all unskilled workers.

Table 12.8

Projections of Demand for Occupations

Occupational categories	1970	1985	Rate[a]
Engineers and architects	1,415[d]	2,106	2.65
Chemists, physicists and pharmacists	764	2,069	6.64
Agronomists and veterinarians	491	1,152	5.69
Economists, sociologists, and mathematicians	209	439	4.95
Lawyers, judges	1,260	1,660	1.84
Accountants, bookkeepers	1,381	2,165	3.00
Doctors and dentists	1,604	4,135	6.31
Other professionals with university education	796	2,286	7.03
Professionals without university education [b]	4,848	13,097	6.62
Medical technicians	294	806	6.72
Nurses	2,809	7,515	6.37
Professors (all included)	13,810	36,474	6.47
Managers and administrators	4,548	9,958	5.22
Office employees	69,453	121,456	3.73
Salesmen and related jobs	52,954	86,819	3.30
Plumbers and metalworkers	2,665	8.737	7.92
Electricians and related	3,878	9,725	6.13
Auto mechanics	14,054	36,215	6.31
Other mechanics	1,577	4,948	7.62
Other workers[c]	642,408	1,155,937	3.91
Military personnel	11,759	13,709	1.02
Total	833,057	1,521,408	4.02

Source: Volume II, Appendix 9, Employment and Occupational Structure by Productive Sector: Projection for 1985, Human Resources and Employment in the Dominican Republic, Educational Development Center, Inc.

[a]Normal rate of growth.

[b]Includes professionals without university education and production technicians

[c]Includes farmers and miners, day labor and other workers.

[d]See methodological note in Vol. II, p. 156; and note 6 of Table 1, Vol. I., p. 21.

5.0 *Projection of the Balance between Supply and Demand in Education and Training (1970-1985)*

Table 12.9 presents the principal features of the supply and demand projections of the workforce between 1970 and 1985. The supply for 1985 includes the supply of the base year (1970) shown in Table 12.7, reduced by mortality, retirement, and migration. This is added to the increase over time, adjusted for attrition. Increases in supply result from the growth of educational and training institutions in the Dominican Republic. The resulting supply is compared with the demand in 1985 to find the surpluses and deficits in each of the occupational categories.

5.1 *Projections of the Balance between Supply and Demand in Professional Occupations*

In general, the supply exceeds the demand by 261,254 workers in all occupations, implying a rate of unemployment of 15 percent in the labor force. However, this is not a pessimistic workforce forecast. It implies a reduction of 11 percent in the rate of unemployment from 1970. The excesses and deficits of the supply over the demand for various occupations are presented in Table 12.9. The results indicate:

Table 12.9

Balance between Manpower Supply and Demand by Occupational Groups (1985)

Occupational Categories	Inventory 1970	Demand 1985	Supply 1985	Excess
Professionals and Technicians				
Engineers and architects	1,415	2,106	10,572	8,466
Economists, sociologists, scientists, and mathematicians	209	439	8,056	7,617
Accountants, bookeepers	1,381	2,165	7,592	5,427
Paramedics, medical technicians	294	806	4,552	3,746
Doctors, surgeons and dentists	1,604	4,135	6,636	2,501
Agronomists and veterinarians	491	1,152	2,329	1,177
Physicists, chemists and pharmacists	764	2,069	3,108	1,149
Lawyers, judges	1,260	1,660	2,559	899
Subtotal	7,418	14,532	45,404	30,872
				Deficit
Professionals without university education	1,106	5,304	4,598	-706
Professionals with some university education	796	2,286	1,519	-767
Production technicians	3,742	7,793	3,292	-4,501
Professors[b]	5,603	14,789	12,078	-2,711
Nurses, midwives	2,889	7,515	4,497	-3,018
Subtotal	14,136	37,687	25,984[e]	-11,703
Managers and administrators	4,548	9,958	4,000	-5,958
Other professors	8,207	21,685	-	
Office employees	69,453	121,456	348,000	+110,040
Salesmen and related jobs	52,954	86,819		
Subtotal	135,162	239,918	352,000	+112,082
Manual Workers				
Semiskilled and unskilled workers[c]	642,408	1,155,937	1,303,000	147,063
Other mechanics	1,577	4,948	14,830	9,882
Subtotal	643,985	1,160,885	1,317,830	156,945
				Deficit
Electricians and related jobs	3,878	9,725	8,239	-1,486
Plumbers and metalworkers	7,665	8,737	4,839	-3,898
Auto mechanics	14,054	36,215	14,657	-21,558
Subtotal	20,597	54,677	27,735	-26,942
Total[d]	821,298	1,507,699	1,768,953	261,254

Source: Projection Tables in Demand and Supply Studies, Human Resources and Employment in the Dominican Republic, Educational Development Center, Inc.

[a] According to the minimum hypothesis.

[b] Includes university professors, secondary and primary teachers.

[c] Includes farmers, miners, day-laborers, and other workers.

[d] Does not include military personnel.

[e] The supply deficit will be filled by the excess in professionals.

— Occupations that require some university education show a large excess of supply over demand in the Dominican Republic. It is worthwhile turning back to Table 12.5 to see where this excess comes from. The demand is for 52,219 workers with professional and subprofessional education. Projections of supply indicate that there will be 59,948 graduates of university professional level programs and another 63,000 who complete some years of the university or post-secondary, but less than full university professional, program. With a demand for 52,219 workers with post-secondary education and a supply of 123,000, there is a possible excess of supply over demand of about 70,000. Some of these can be used in other occupational categories and will not become a waste of educational resources in a manpower sense. For example, over 20,000 of them can be used down in the category called other professors for which no specific supply was projected. Another 10,000 can be absorved as managers or office workers. Still, there is an excess supply of people with some university training of about 40,000. The specific matches of demand and supply in Table 12.8 do not reflect this excess, which will be caused primarily by nongraduates (and some graduates) of general university programs in humanities, law, and social sciences. Even with this excess of supply over demand for general education, there is a deficit in supply of people with specific post-secondary training.

— All the professional occupations that require a university education, show an excess, sometimes a very large one. (See first group in Table 12.8). For the entire group, the excess is 30,872. Within the group, engineers and architects represent the greater excess, 8,466. It is not true that this profession always offers stable employment. In the state of West Bengal, India, there were 20,000 unemployed engineers registered in the offices of employment security between 1970 and 1972. In the United States, cuts in special programs and in defense, which began in the early seventies, caused a period of unemployment for engineers. The situation, however, changes quickly. Current data indicate that U.S. universities are graduating 59,000 engineers a year, while the demand is for 75,000 (1973).

The case of the engineers serves as an example to indicate that deficits and excesses change rapidly, even though future opportunities in employment are not immediately perceived by students, parents, and institutions. According to projections, the Dominican Republic might face a surplus situation, but engineers can be employed in administrative positions or can generate their own job market by starting up small industries or service enterprises. Finally, it should be noted that the estimations of the balance between supply and demand do not hold for long periods. They simply provide signals for the orientation of policies. Employment perspectives for some specialized branches of engineering will be quite good.

Projections of demand in the social sciences indicate excess supply. Demand, for social scientists as a defined profession, is low, although graduates of these programs could find employment as professors and, without doubt, in office positions. Still, the data suggest policies that would control the increase in admissions to programs of study for these professions.

There is also an excess of accountants, who have the option of obtaining

office employment where they would replace bookeepers with less training. The number of medical technicians exceeds the demand. Here, a follow-up study made it possible to analyze the future unemployment problem of this group. The transfer of excess technicians to similar but lower-level health jobs is not practical, but demand could be increased by a change in medical and health services or by an increase in state health services.

The supply of doctors shows a surplus, and if emigration is restricted, especially to the United States, the problem could become worse. As in the case of technicians, employment opportunities for doctors could be improved by an increase in health services. The surplus of doctors could increase the employment problems of medical technicians, or vice versa, because the doctors could, on their own, perform support duties; or, in the case of a reorganization of the provision of services, medical technicians could replace some doctors.

Nurses, although not belonging to the first occupational group, present the opposite problem, a deficit. A more precise study of the general situation of workers in the field of health and medicine, would require, besides the supply and demand analysis, a study of how future official policies, such as a change in salary, technology, or the organization of health services, would affect the demand in health professions.

The supply of chemists, physicists, and pharmacists will also exceed the demand. Among the professions, the employment of lawyers shows the lowest increase, This situation probably reflects a reaction against the warning circulated in Latin American universities some years ago that there were too many lawyers and not enough scientists and engineers. The demand projection, as well as the market conditions for lawyers, indicates that law does not have a bad outlook, at least until the profession becomes crowded once again.

— Technical occupations and those with professional support have a brighter future with regard to employment opportunities. According to projections, there will be a scarcity of "other" technicians and production technicians, with a deficit of about 4,500 production technicians. The labor market research showed that job satisfaction of the group that called themselves production technicians was not high. This may explain the low supply, given the existing demand. Given the excess of engineers, it is possible that a displacement of technicians may be produced, as engineers move down into technicians' jobs. This would reduce the deficit of technicians and also the surplus of engineers with professional studies.

— Nurses and teachers are projected as deficits, although the figure for teachers is not exact, given that unemployed university graduates in various study areas, especially in the humanities, could satisfy the demand. The supply projection was for 10,000 graduates from humanities during the period, and another 14,000 with a year or more of study in the humanities. The excess of social scientists can also be guided toward teaching in order to fill the deficit between supply and demand that appears in the third grouping of Table 12.8.

In the managers and administrators category, there is an approximate deficit of 6,000 on the supply side, but these positions can be occupied by graduates from humanities and social science, by graduates from secondary education, and by engineers and other specialists who could be trained and attracted to management positions. An exact balance between supply and demand is not possible in this category, nor in that of "other" professors.

In summing up, the total demand for all teachers, estimated as slightly above 36,000, can be satisfied by the excess of supply in different programs of secondary and higher eduation.

— Office employees and salesmen, jointly, show a surplus of almost 120,000, with a great number of office employees trained in programs supported by the private sector. The programs that are actually offered should be directed toward the education of sales personnel who need training that combines office management and salesmanship.

— The excess of unclassified workers indicates potential unemployment problems for this category of workers. Among the skilled workers differentiated in a more detailed labor market study, only the group, "other" mechanics shows an excess. This may reflect problems of classification. Electricians, plumbers, metal workers, and especially automobile mechanics, show a deficit on the supply side. These indications are based on the projection of the number of students in identified specialized training programs. The demand can also be met with workers who improve their skills and knowledge of their job by means of experience and practice in the auto service stations and other small auto workshops. This has been, after all, the traditional source of supply of the automobile mechanics who are actually in the labor force. The acquired training and skills of mechanics trained in military service has also contributed to this source of supply.

5.2 *General Policies of Development of Human Resources Based on Projections of Supply and Demand in Education and Training*

From the analysis of the supply and demand situation of the labor force in 1985, some conclusions follow. They will be annotated briefly here and will be used to develop a more systematic framework of policies presented in the summary of policy conclusions that accompany the main part of this study.

— Continuation of rapid expansion in higher and secondary education does not appear to be justified by the projections of supply and demand of the labor force in 1985. Most of the professions and occupations that require higher levels of education now show an excess of supply, even when they are compared with estimated demand based on high rates of growth of production (value added) (8.7%) and employment (4.1%).

— The balance between supply and demand is more favorable for some technicians and supporting professions than it is for professionals at the university level. In the professional category there can exist a small number of specialized fields that require attention, as, for example, within the fields of specialized engineering

and the sciences. However, the small number of specialists required does not justify opening new university specializations, since it would imply high unitary costs because of the problem of scale (efficient size). Special, modularized programs could be built into the so-called standard brands of engineering, such as mechanical, electrical/electronic, chemical and civil engineering.

— The workforce requires basic education and literacy.

— Concern for employment policies should have priority over concern for better opportunities to obtain a general education, although both policies can be addressed within an adequate system of education oriented toward work. No educational or training program outside the work and employment context can satisfy the demands of the economy and the labor force in future years. Unemployment can reach up to 15 percent, even with the ambitious rates of growth that have been projected. Education and training, oriented toward employment, should be developed within the appropriate policy structures which permit creation and expansion of employment and career opportunities.

APPENDIX 12.1:

Estimating the Labor Force Demand

This work to estimate the Labor Force Demand was done by Manual Zymelman supplemented by work by Juan Llado, David Woodward, Ernesto Schiefelbein, and Russell Davis.

In the demand projection of the Dominican labor force the first basic table (Table A 12.1) shows the distribution of occupations by industrial sector and is based on the 1970 Census.

The following equation, using the number of workers in each occupation and sector, projects the demand for each occupation until 1985.

$$D_{ij}\ 1985 = X_{ij}\ 1970\ \ e^{\left(b_{ij}r_{pj} + Y_{Lj}\right)15} \qquad (1)$$

where

D_{ij} = the demand for workers by occupation (i) and sector (j) in 1985,
X_{ij} = the number of workers by occupation (i) and sector (j) in 1970 from Table 12.1, (based on 1970 Census),
Y_{Lj} = the growth rate of employment in the sector (j),
r_{pj} = the growth rate of productivity in the sector (j),
b_{ij} = the elasticity, or change in the number of workers in each occupation (i) relative to the change in productivity of each sector (j),
e = base of natural log system, 2,71928 . . .

The projection method then requires the following steps:

1. A projection of change in the product or value added. For this purpose, a curve is fitted to changes in the product during a series of recent years, and a growth rate is derived from this projection. The form is exponential.
2. Estimate that part of change in the product that can be attributed to changes in the number of workers in each sector. Such a change is represented by Y_{Lj} in equation (1).
3. Estimate the portion of change in the product that is attributed to changes in workers' productivity in the sector. This portion of change corresponds to r_{pj} in equation (1).
4. Estimate or obtain elasticity coefficient that shows the relative change in number of workers in each occupation as productivity changes. These coefficients are represented by b_{ij} in equation (1).

Product, Productivity, and Employment Growth Rates Analysis

To project employment by occupations using equation (1), rates of growth in product, productivity and employment had to be analyzed. These growth rates are shown in Table A12.2. They were derived from the analysis of growth in the various sectors. For this analysis, a series of historical data on

the sectors shown in Table A12.3 were obtained. Table 12.4 is an illustrative example showing growth series for only some of the Table A12.3 sectors. The analyses that were actually made, however, included all the principal sectors of the Dominican economy.

To derive the growth rates of product, employment, and productivity that appear in Table A12.2, the curve was first fitted to the growth trend in the historical series of the sectors that appear in Table A12.3. Then the trend was projected as shown in Figure A12.4, using the following equation:

$$Y_t = Y_0 e^{rt} \tag{2}$$

where

Y_0 is the index of the base year;
r is the annual rate of growth;
t is the time in years.

In the Dominican Republic, only growth based on the time series between 1966 and 1972 was used to estimate the trend. Data on product were available for a longer series, from 1960 to 1972. In some cases, when additional information referring to plans or specific expansion of projects was available, the basic growth indexes were modified for certain sectors.

Use of the Elasticity Coefficients on Projections by Occupation in 1985

Once values of Y_{Lj} and r_{pj} have been estimated, as given in Table A12.2, the elasticity coefficients b_{ij} were estimated. These are shown in Table A12.5. Rates of change in employment (Y_{Lj}) and productivity (r_{pj}), as well as the elasticity coefficients (b_{ij}), were put into equation (1). For example, the estimate for Administrators and Managers in the Food and Beverages sector gave the following results:

$$Y_{Lj} = .022$$
$$r_{pj} = .040$$
$$b_{ij} = .31$$

These coefficients were then used in equation (1), along with the number of workers in each occupation and sector of the base year in Table A12.1, to project the number of corresponding workers in 1985, as shown in Table A12.6.

$$301\left[e^{.31(.04)} + .022\right]^{15} = 301\left[e^{.034}\right]^{15} = 496$$

Results might be slightly different in Table A12.6 from the results which would be yielded by strict application of the formula. This is true because the manpower analyst also incorporates additional information (and hunches) from experts on changes in sectors and occupation. This supports the view that, despite formulas, manpower forecasting is not scientific or mechanical; it is subjective and artistic.

Table A12.1

Occupational Structure by Economic Activity Sector: 1970

OCCUPATIONAL CATEGORIES	TOTAL	1 to 3 Agriculture	4 Mining	5 to 14 except 6 Manufacturing Industry	5 Foods and Beverages
I. PROFESSIONALS AND TECHNICIANS	29,761	782	49	367	85
1. Engineers Architects	1,415	24	-	22	-
2. Chemists, Physicists	191	10	-	36	5
3. Agronomists, Veterinarians	491	358	-	20	20
4. Economists, Sociologists, Mathematicians	209	-	-	8	8
5. Lawyers, Judges	1,260	-	26	12	12
6. Accountants, Bookeepers	1,381	-	14	68	16
7. Doctors, Surgeons	1,304	-	-	-	-
8. Dentists	300	-	-	-	-
9. Pharmacists	573	-	-	25	-
10. Paramedics, Medical Technicians	294	-	-	-	-
11. Nurses, Midwives	2,889	-	-	-	-
12. Professors - University	509	-	-	-	-
13. Teachers - Secondary	946	-	-	-	-
14. Teachers - Primary	4,148	-	-	-	-
15. Teachers - Others	8,207	-	-	-	-
16. Production Technicians	4,848	390	9	167	24
17. Other professionals	796	-	-	9	-
II. MANAGERS AND ADMINISTRATORS	4,548	200	12	578	301
III. OFFICE PERSONNEL	69,453	527	86	3,389	1,494
IV. SALES AND RELATED PERSONNEL	52,954	184	9	866	325
V. MANUAL WORKERS	664,562	398,012	549	43,557	9,896
18. Farmers, Miners	397,764	395,694	234	508	508
19. Plumbers	2,665	-	-	602	-
20. Electricians	3,878	-	-	89	-
21. Auto Mechanics	14,054	42	19	169	43
22. Other Mechanics	1,577	9	-	630	47
23. Day-Laborers	114,110	-	194	6,925	1,366
24. Other Workers	120,534	2,267	102	34,631	7,932
VI. MILITARY PERSONNEL	11,759	-	-	-	-
TOTAL	233,057	399,705	705	48,757	12,101

Table A12.1

Continued

7 Textiles	8 Wood Products	9 Paper Products	10 Chemical Products	11 Mineral Products	12 Basic Metals	13 Metal Products	14 Other manufacturing Industries	6 SUGAR INDUSTRY	15-31 except 24 SERVICES
40	15	28	133	12		36	18	260	28,303
-	-	-	10	-	-	12	-	22	1,347
-	-	-	31	-	-	-	-	67	78
-	-	-	-	-	-	-	-	8	105
-	-	-	-	-	-	-	-	-	201
-	-	-	-	-	-	-	-	-	1,222
9	6	7	25	-	-	5	-	52	1,247
-	-	-	-	-	-	-	-	-	1,304
-	-	-	-	-	-	-	-	-	300
-	-	-	25	-	-	-	-	-	548
-	-	-	-	-	-	-	-	-	294
-	-	-	-	-	-	-	-	-	2,889
-	-	-	-	-	-	-	-	-	509
-	-	-	-	-	-	-	-	-	940
-	-	-	-	-	-	-	-	-	4,148
-	-	-	-	-	-	-	-	-	8,207
31	9	21	42	8	-	19	13	111	4,171
-	-	-	-	4	-	-	5	-	787
62	4	26	52	13	12	29	79	22	3,736
521	82	218	603	185	64	132	90	2,880	62,571
57	66	55	302	10	-	33	18	45	51,850
15,223	10,959	1,010	763	833	646	2,512	1,715	36,845	135,619
-	-	-	-	-	-	-	-	1,328	-
-	11	-	-	12	65	514	-	70	1,993
24	-	24	-	9	23	9	-	192	3,597
48	-	12	11	-	20	35	-	588	13,236
37	68	50	-	102	45	212	69	184	754
1,088	399	149	352	422	103	1,465	1,581	3,194	103,797
14,026	10,481	775	400	288	390	277	65	21,289	62,242
-	-	-	-	-	-	-	-	-	11,759
15,903	11,126	1,337	1,853	1,053	722	2,742	1,920	40,952	343,838

Table A12.1

Continued

Occupational Categories (Repeat from page 264)	15-31 except 24 SERVICES	15 Electricity, Water, Gas, Steam	16 Construction	17 Wholesale Commerce	18 Retail Commerce	19 Tourism	20 Transportation	21 Communications	22 Finances
	28,303	115	2,562	49	179	21	46	32	2,670
	1,347	48	1,119	-	-	-	11	-	44
	78	-	-	-	-	-	-	-	12
	105	-	-	-	-	-	-	-	25
	201	-	-	-	-	-	-	8	75
	1,222	-	-	-	-	-	-	-	1,160
	1,247	23	-	12	128	-	-	-	966
	1,304	-	-	-	-	-	-	-	10
	300	-	-	-	-	-	-	-	-
	548	-	-	11	15	-	-	-	-
	294	-	-	-	-	-	-	-	-
	2,889	-	-	-	-	-	9	-	10
	509	-	-	-	-	-	-	-	-
	946	-	-	-	-	-	-	-	9
	4,148	-	-	-	-	-	-	-	19
	8,207	-	-	-	-	-	-	-	-
	4,171	44	1,440	26	30	16	26	24	315
	787	-	3	-	6	5	-	-	25
	3,736	12	235	225	1,141	125	90	15	438
	62,571	787	481	1,468	8,278	416	1,300	2,169	16,127
	51,850	-	39	1,923	47,852	386	890	280	298
	135,619	919	18,849	645	5,270	2,534	44,986	302	2,379
	-	-	-	-	-	-	-	-	-
	1,993	33	19	24	12	-	-	-	9
	3,597	298	21	29	29	-	21	26	21
	13,236	51	116	80	41	-	112	12	160
	754	-	39	27	36	12	119	2	27
	103,797	420	4,634	357	2,139	2,461	6,614	67	1,472
	62,242	117	14,020	88	3,013	61	38,120	195	690
	11,759	-	-	-	-	-	-	-	-
	343,838	1,833	22,166	4,310	62,720	3,482	47,312	2,798	21,912

Table A12.1

Continued

23 Public Administration and Defense	25 Education	26 Medical Services	27 Public Services	28 Recreation Services	29 Repair Services	30 Other Services	31 Domestic Services	
553	14,041	3,280	3,040	1,487	138	90	-	I
74	12	-	4	-	35	-	-	1
-	56	-	-	-	-	10	-	2
28	-	47	5	-	-	-	-	3
32	40	-	23	21	-	2	-	4
32	11	-	-	9	-	10	-	5
85	-	-	14	8	-	11	-	6
21	-	826	436	-	-	11	-	7
20	-	260	20	-	-	-	-	8
28	11	385	70	8	-	20	-	9
12	-	173	99	10	-	-	-	10
9	27	980	1,854	-	-	-	-	11
-	509	-	-	-	-	-	-	12
-	937	-	-	-	-	-	-	13
30	4,075	-	-	24	-	-	-	14
64	8,133	-	-	-	-	10	-	15
107	75	609	360	980	103	16	-	16
11	155	-	155	427	-	-	-	17
1,189	97	24	44	90	-	11	-	II
26,699	943	906	1,464	506	520	507	-	III
43	11	32	11	32	32	21	-	IV
7,780	756	431	2,741	2,429	23,667	10,749	61,182	V
-	-	-	-	-	-	-	-	18
74	-	-	-	12	1,810	-	-	19
33	-	-	-	53	3,066	-	-	20
160	-	-	12	-	12,492	-	-	21
22	-	-	26	-	444	-	-	22
6,888	704	384	2,488	1,686	1,557	10,704	61,182	23
603	52	47	215	678	4,298	45	-	24
11,759	-	-	-	-	-	-	-	VI
48,023	15,848	4,673	7,300	4,544	24,357	11,378	61,182	TOTAL

Table A12.2

Normal Rates of Growth in Production, Employment and Productivity, by Industrial Sector
(in percentages)

Industrial Sector	Category No.	CIIU[b] No.	Production r_q	Employment r_L	Productivity r_p
All sectors	1 to 31	0 to 9	8.5	4.1	4.4
Agriculture	1 to 3	1	5.1	3.0	2.1
Mining	4	2	22.0	14.5	7.5
Manufacturing Industry[a]	(5 to 14)-(6)	3-3118	10.2	5.5	4.7
Foods and beverages	5	31-3118	6.2	2.2	4.0
Textiles	7	32	10.7	0.7	10.0
Wood products	8	33	16.0	8.6	7.4
Paper products	9	34	12.5	7.7	4.8
Chemical products	10	35	14.3	8.5	5.8
Mineral products	11	36	13.5	8.5	5.0
Basic metals	12	37	7.0	2.9	4.1
Metal products	13	38	16.1	12.5	3.6
Other manufactured products	14	39	4.4	1.0	3.4
Sugar Industry	6	3118	9.2	4.3	4.9
Services	15 to 22				
Electricity, water, gas, steam	15	4101	10.7	1.9	8.8
Construction	16	50	12.5	7.8	4.7
Wholesale commerce	17	61	6.2	2.8	3.4
Retail commerce	18	62	6.2	2.8	3.4
Tourism	19	63	17.1	15.1	2.0
Transportation, storage	20	71	6.9	5.4	1.5
Communications	21	72	6.2	4.7	1.5
Financial Services	22	8	4.1	1.7	2.4
Government	23 to 31		6.9	4.7	2.2
Administration and defense	23	91	3.7	2.7	1.0
Health	24	92	15.2	12.2	3.0
Education	25	931,932	7.5	6.5	1.0
Medical and veterinarian services	26	9331,9332	7.2	6.2	1.0
Public services	27	934,935,939	8.8	7.8	1.0
Recreation services	28	94	-	7.1	-
Repair services	29	951,952	10.2	6.5	3.7
Other services	30	959,960	8.3	5.5	2.8
Domestic services	31	953	-	3.8	-

[a] Excludes the sugar industry which is shown as a separate sector.

[b] CIIU - International Standard Industrial Classification

Table A12.3

List of the Series on Value Added by Sectors

CIIU No.	Sector Description
	Total of industries (1965-71)
11	Agriculture and livestock
	Agriculture only
	Livestock
12	Forestry (1968)
13	Fishing
21-29	Mining
31-39	Major categories of manufacturing industries
31-3118	Foods, beverages and tobacco (excludes sugar)
3118	Sugar mills and refineries
32	Textiles, etc. (1965-71)
33	Lumber, etc.
34	Paper, etc.
35	Chemicals, etc.
36	Mineral products
37	Basic metals industry
38	Manufacturing of metal products
39	Other manufacturing industries
4101	Electricity
50	Construction
61 & 62	Commerce (does not include restaurants and hotels)
61	Wholesale commerce
62	Retail commerce
71	Transporation
72	Communications
8	Finance (1965-71)
91	Public administration and defense
	Education
	Public services
951	Repair services

Sources: CN = National Accounts
IPIM = Manufacturing Industry Production Index
CIIU = International Standard Industrial Classification

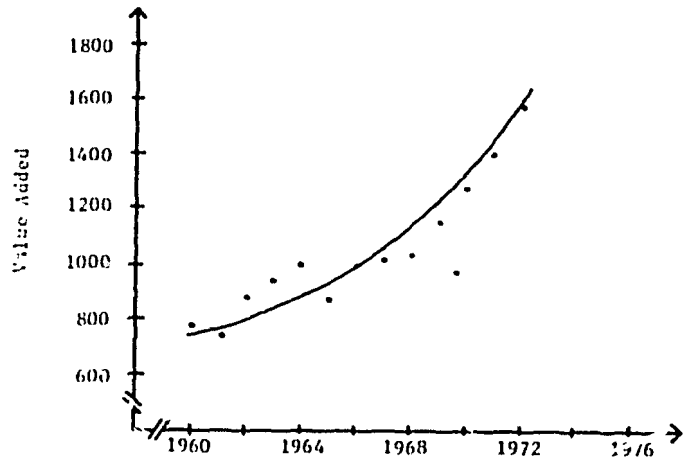
Table A12.4

Example of Product Series

Total of Industries					Sugar Mills and Refineries				Textiles
Value added from 1962 prices	Volume of production 1962=100	Price index 1962=100	Value added at current prices	YEAR	Value added from prices 1962	1968	Volume of production 1962	1968	Value added from 1962 prices
776	87.4	93.3	724 x 10^6	1960	58.00	89.99	120.2	170.4	7394
758	85.5	92.9	704 x 10^6	1961	45.45	67.39	94.2	127.6	8285
887	100.0	100.0	887 x 10^6	1962	48.25	70.45	100.0	133.4	9410
945	106.5	107.2	1013 x 10^6	1963	43.81	63.32	90.8	119.9	8994
1008	113.7	109.5	1104 x 10^6	1964	43.71	65.17	90.6	123.4	7016
883	99.5	108.4	957 x 10^6	1965	31.85	47.58	66.0	90.1	4943
1001	112.9	105.8	1060 x 10^6	1966	37.73	55.19	78.2	104.5	7368
1035	116.7	107.7	1115 x 10^6	1967	45.31	64.96	93.9	123.0	8207
1040	117.3	111.0	1155 x 10^6	1968	36.28	52.81	75.2	100.0	9164
1167	131.6	112.5	1314 x 10^6	1969	46.95	70.40	97.3	133.3	11041
1287	145.0	114.4	1472 x 10^6	1970	53.56	80.48	111.0	152.4	12954
1414	159.4	115.5	1633 x 10^6	1971	59.11	88.62	122.5	167.8	14403
1591	179.5	124.7	1970 x 10^6	1972	--	--	--	--	--

Figure A12.4

Exponential Curve Fitted to Value Added Data



Exercise: Figure A12.4 shows the curve fitted to series data of Value Added in Total of Industries (1962 prices). It indicates that the exponential fit is adequate. This same fit was used for all series and for projections based on Equation (1) of this appendix. As an exercise try the same fit with Sugar Mills or Textile Industries. Note some fits are better in some series.

Table A12.5

Elasticity Coefficients b

Industrial sector	Professional and technical		Office workers	Sales	Manual workers
Foods, Beverages	.55	.31	.09	.00	-.04
Textiles	.58	.30	.13	.24	-.04
Wood Products	.56	.29	.19	.31	-.03
Paper Products	.75	.17	.16	.25	-.04
Chemical Products	.48	.28	.02	.37	-.10
Glassware	.43	.35	.18	.60	-.05
Basic Metals	.38	-.03	.00	.18	-.02
Metal Products	.97	.26	.23	.40	-.08
Other manufacturing	.80	.29	.36	.40	-.11
Sugar	.55	.31	.09	.00	-.04

Source: Manuel Zymelman, "Productivity Skills and Education in Manufacturing Industries", in Planning for Advanced Skills and Technologies. New York: United Nations, 1969. pp. 103-138.

Table A12.6

Occupational Structure by Economic Activity Sector Projected for 1985

OCCUPATIONAL CATEGORIES	Inventory 1970	Normal rates of annual growth	Projection 1985	1 to 3 Agriculture	4 Mining
I. PROFESSIONALS AND TECHNICIANS	29,761	6.06	73,904	2,369	447
1. Engineers, Architects	1,415	2.65	2,106	60	140
2. Chemists, Physicists	191	7.76	612	86	10
3. Agronomists, Veterinarians	491	5.69	1,152	880	-
4. Economists, Sociologists, Mathematicians	209	4.95	439	-	8
5. Lawyers, Judges	1,260	1.84	1,660	-	10
6. Accountants, Bookeepers	1,381	3.00	2,165	-	40
7. Doctors, Surgeons	1,304	6.26	3,335	-	-
8. Dentists	300	6.54	800	-	-
9. Pharmacists	573	6.22	1,457	-	-
10. Paramedics, Medical Technicians	294	6.72	806	-	-
11. Nurses, Midwives	2,889	6.37	7,515	-	-
12. Professors - University	509	6.50	1,350	-	-
13. Teachers - Secondary	946	6.47	2,495	-	-
14. Teachers - Primary	4,148	6.47	10,944	-	-
15. Teachers - Others	8,207	6.48	21,685	-	-
16. Production Technicians	3,742	4.89	7,793	1,343	224
17.1. Other professionals with some university education	796	7.03	2,286	-	15
17.2. Other professionas without university education	1,106	10.45	5,304	-	-
II. MANAGERS AND ADMINISTRATORS	4,548	5.22	9,958	365	100
III. OFFICE PERSONNEL	69,453	3.73	121,456	960	400
IV. SALES AND RELATED PERSONNEL	52,954	3.30	86,819	335	35
V. MANUAL WORKERS	664,582	4.03	1,215,562	623,041	5,292
18. Farmers, Miners	397,764	2.99	622,961	517,341	2,452
19. Plumbers	2,665	7.92	8,737	-	-
20. Electricians	3,878	6.13	9,725	-	80
21. Auto Mechanics	14,054	6.31	36,215	103	30
22. Other Mechanics	1,577	7.62	4,948	22	300
23. Day-Laborers	114,110	4.92	238,853	-	120
24. Other Workers	130,534	5.42	294,123	5,575	2,310
VI. MILITARY PERSONNEL	11,759	1.02	13,709	-	-
TOTAL	833,057	4.02	1,521,408	627,070	6,274

Table A12.6

Continued

5 to 14 except 6	5	7	8	9	10	11	12	13	14
Manufacturing Industry	Foods and Beverages	Textiles	Wood Products	Paper Products	Chemical Products	Mineral Products	Basic Metals	Metal Products	Other manufacturing industries
1,761	180	152	127	196	506	75	14	479	32
163	-	-	-	-	31	-	-	132	-
146	10	-	-	-	136	-	-	-	-
39	39	-	-	-	-	-	-	-	-
10	10	-	-	-	-	-	-	-	-
23	23	-	-	-	-	-	-	-	-
266	31	26	39	37	78	-	-	55	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
78	-	-	-	-	78	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-
1,010	67	126	88	159	183	56	14	292	25
26	-	-	-	-	-	19	-	-	7
-	-	-	-	-	-	-	-	-	-
1,271	426	113	33	93	237	60	41	183	85
8,759	2,357	726	385	776	2,702	652	111	940	110
1,889	452	95	350	113	566	31	20	237	25
96,005	13,428	16,613	39,440	3,111	2,503	2,966	933	16,136	1,675
889	889	-	-	-	-	-	-	-	-
3,479	-	-	40	-	-	41	94	3,302	-
226	-	29	-	74	-	32	33	58	-
438	58	53	-	37	36	-	29	225	-
2,354	64	41	244	154	-	363	58	1,362	68
18,691	1,892	1,187	1,436	459	1,155	1,502	149	9,410	1,540
70,928	10,763	15,303	37,720	2,387	1,312	1,026	570	1,779	67
-	-	-	-	-	-	-	-	-	-
110,485	16,843	17,699	40,335	4,289	6,514	3,784	1,119	17,975	1,927

Table A12.6

Continued

6	7-31 except 24	15	16	17	18	19	20	21
SUGAR INDUSTRY	SERVICES	Electricity, Water, Gas, Steam	Construction	Wholesale Commerce	Retail Commerce	Tourism	Transportation, Storage	Communications
837	68,490	174	3,537	58	300	165	81	85
61	1,682	64	1,288	-	-	-	22	-
184	186	-	-	-	-	-	-	-
21	212	-	-	-	-	-	-	-
-	421	-	-	-	-	-	-	28
-	1,627	-	-	-	-	-	-	-
143	1,716	29	-	14	200	-	-	-
-	3,335	-	-	-	-	-	-	-
-	800	-	-	-	-	-	-	-
-	1,379	-	-	13	24	-	-	-
-	806	-	-	-	-	-	-	-
-	7,515	-	-	-	-	-	-	-
-	1,350	-	-	-	-	-	-	-
-	2,495	-	-	-	-	-	-	-
-	10,944	-	-	-	-	-	-	-
-	21,685	-	-	-	-	-	-	-
428	4,788	81	2,245	43	66	-	-	-
-	2,245	-	4	-	10	33	-	-
-	5,304	-	-	-	-	132	59	57
53	8,169	30	1,428	262	1,789	1,156	213	57
6,405	104,932	809	1,500	2,402	12,299	3,931	2,871	4,134
86	84,474	173	150	3,159	74,121	3,534	1,915	567
68,792	421,632	1,312	65,456	750	8,265	23,984	101,247	820
2,474	-	-	-	-	-	-	-	-
131	5,127	47	66	28	19	-	-	-
358	9,061	425	73	34	46	-	47	73
1,098	34,546	73	403	93	64	-	252	34
343	1,979	-	135	31	57	100	267	6
5,963	214,079	600	16,100	461	3,354	23,324	14,868	190
58,420	156,890	167	48,706	103	4,725	560	85,813	517
-	13,709	-	-	-	-	-	-	-
76,173	701,406	2,498	72,099	6,643	96,774	32,870	106,327	5,663

Table A12.6

Continued

22	23	25	26	27	28	29		31	
Finances	Public Administration and Defense	Education	Medical Services and Veterinarians	Public Services	Recreation Services	Repair Services	Other Services	Domestic Services	
3,465	1,033	37,236	9,879	8,874	4,311	475	205	-	I
54	116	32	-	13	-	93	-	-	1
15	-	148	-	-	-	-	23	-	2
32	44	-	120	16	-	-	-	-	3
97	50	106	-	74	61	-	5	-	4
1,497	51	30	-	-	26	-	23	-	5
1,246	134	-	-	45	23	-	25	-	6
13	33	-	2,109	1,155	-	-	21	-	7
-	32	-	715	53	-	-	-	-	8
-	44	29	976	225	23	-	45	-	9
-	19	-	439	319	29	-	-	-	10
13	14	71	2,502	4,915	-	-	-	-	11
-	-	1,338	-	-	-	-	-	-	12
11	-	2,484	-	-	-	-	-	-	13
25	47	10,803	-	-	69	-	-	-	14
-	101	21,561	-	-	-	-	23	-	15
136	131	41	1,663	-	-	182	-	-	16
32	17	411	-	500	1,238	-	-	-	17.1
294	200	170	355	1,159	2,842	-	36	-	17.2
566	1,923	257	61	141	261	-	25	-	II
20,804	42,547	2,500	2,157	4,977	1,467	1,378	1,156	-	III
384	-	29	81	35	93	85	48	-	IV
3,096	12,826	2,005	1,677	9,893	7,045	62,745	24,531	95,952	V
-	-	-	-	-	-	-	-	-	18
12	122	-	-	-	35	4,798	-	-	19
27	24	-	-	-	154	8,128	-	-	20
206	264	-	-	39	-	33,118	-	-	21
35	36	-	-	84	-	1,177	-	-	22
1,926	11,355	1,867	1,557	9,077	4,890	4,130	24,428	95,952	23
890	995	138	120	693	1,968	11,394	103	-	24
-	13,709	-	-	-	-	-	-	-	VI
28,315	72,038	42,027	12,855	23,520	13,177	64,683	25,965	95,952	

The Conversion of Demand in Educational Terms

Tables A12.7, A12.8, A12.9 illustrate the steps necessary to convert projected occupations into projected levels of education.

The demand for a university education in the labor market is tied to specific occupations, such as doctors, engineers, etc., as well as to less specific occupations that are generally filled by people who possess a university education, such as administrators, office managers, stock and bonds brokers, etc.

Because the occupational data do not allow for a more detailed breakdown, we must assume that the cross-classification of occupation by education is valid to determine the percentage of occupations that are filled with university-educated people.

In our case, the large occupational groups requiring a university education are the administrators and managers, office employees and salesmen. Professional and technical workers are sufficiently distinct to be able to determine, case by case, the demand for secondary or higher education. We have accepted that manual workers do not require university training. Table A12.7 shows the distribution of occupations by education according to the 1970 Census.

Table A12.7

Occupation by Educational Level in 1970
(in percentages)

Years of school / Occupation	16+	13-14-15	9-10-11-12	Total people
Managers and Administrators	5.4%	7.5%	18.6%	4,548
Office Employees	3.0	5.5	28.4	69,453
Sales	.7	1.6	11.2	52,954

Source: Special analysis of the 1970 Census with corrections.

However, these percentages cannot be applied to the projected number of occupations for 1985, since there is an "upward trend" in educational requirements throughout the country. Younger members have more schooling. For this reason, we assume that the average educational attainment for all occupations in 1985 will be the same as that found in the 25-29 age group in 1970. The resulting percentages are shown in Table A12.8.

The number of people with different levels of education in the three principal groups can be estimated by multiplying the coefficients by the total number of people in these occupations (see Table A12.9). The totals shown in Table A12.9 would be added to the demand for education which has been derived from the occupational structure of professional and technical workers.

Table A12.8

Occupation by Education of the 25-29 Age Group in 1970 (in percentages)

Years of school / Occupation	16+	13-14-15	9-10-11-12
Managers and administrators	17.3%	18.0%	27.9%
Office	3.4	8.5	24.6
Sales	.5	2.0	10.2

Source: 1970 Census

Table A12.9

Demand in Three Occupations

Occupation	1985 Number of people	Number of people by years of school		
		16+	13-14-15	9-10-11-12
Managers and administrators	9,958	1,722	1,792	2,778
Office employees	121,456	4,129	10,323	42,023
Sales	86,819	434	1,736	8,855
Total		6,285	13,851	53,656

Note Regarding the Definition of Educational Demand Requirements

In our occupational classification it was decided that some university education was a requirement to be able to work as engineers, agronomists, etc. Basically, at the present time, many people are performing professional duties without a degree. However, from the educational planning viewpoint it is perfectly legitimate to assume that the increase in demand for professionals must be filled with persons who have obtained a degree. This policy is justified on the grounds that it is necessary to upgrade the quality of the professional force. As a result, university dropouts have to be channeled into technical or para-professional jobs.

Part IV: *Other Planning Methods*

CHAPTER 13

Scheduling

Gary Lewis and Russell Davis

1.0 *Introduction*

Planners must deal with the future, and scheduling is one of several different methodologies for charting future activities. Futurology is used for sketching out the distant future; projection methodologies are applied to the mid-term future, the three to 15-year time periods planners attempt to chart; and scheduling is used to lay out in logical fashion a time sequence of events and activities for the immediate future. In addition to being applied to the shorter ranges of planning, scheduling also implies more of an attempt to intervene in the immediate future, to shape events and activities, in short to manage the implementation of plans and programs.

In management, administrators as well as planners make use of scheduling techniques. In education, many major projects require several months or years to complete. There are stages along the path to completion that must be scheduled. These are events. Between events are the activities which make events happen. These activities require resources, the allocation and delivery of money, people, and materials. Resources are interdependent when applied jointly in an activity, and hence—the timely and joint arrival of resources must be scheduled.

Educational planners are accustomed to think of scheduling when it comes to the planning and management of large capital projects that require buildings and equipment. Here time/materials dependencies are clear. The roof will go on after the supports are in place. Less obvious, but more often, the cause of failures in large educational projects in developing countries is the timely allocation and arrival of human resources—the right person for the right job. Development projects chronicle the horrors of hospitals built and equipped and unused because staff did not arrive; and of schools empty because there were no staffs assigned. The longest lead time required in planning is for the development and assignment of human resources.

1.1 *Scheduling*

For scheduling, planners use a variety of techniques and procedures with a common purpose, to lay out in logical fashion a time sequence of events and activities. As used here, scheduling, broadly defined, is appropriate for man-

agers who are concerned with the planning and control of a project. A project is *also* broadly defined to mean any task with a beginning and an ending. While all scheduling procedures vary from the very simple to the seemingly complex, they are based upon the common-sense notions that most people use in everyday life. If someone has an appointment at 3:00 p.m. and a certain number of things must be done between the present time and the time of the appointment, then most people would schedule activities in such a way as to complete them by the appointed time. The scheduling technique to be illustrated here, called Program Evaluation and Review Technique (PERT), is only a systematization of the common-sense methods that people use every day.

There are two principal advantages to scheduling the activities in a project. The first is that it forces planners or managers to think the project through. When it is necessary to identify and arrange in time sequence the activities required to complete a project, a comprehensive picture of the project can result. Or the opposite may happen. The planner may realize he has not thought through all the ramifications or potential conflicts. The second advantage is that scheduling can aid the planner or manager in making decisions. The process of scheduling won't result in decisions, but it does inform them by revealing information about potential trouble spots, which the decision maker can then take into account to guide choice and action.

This unit will discuss the definitions, notations, and conventions involved in PERT, and examples of typical PERT exercises will be given. These will be followed by an illustration of a modified PERT procedure that is applicable when it is desirable to identify specific decision points in a scheduling scheme.

2.0 *The Traditional PERT Network*

The basic features of the PERT procedure are events and activities, defined below.

An *event* is the start or completion of a task.

An *activity* is the ongoing performance of a task.

PERT activities consume time and require people, material, space, facilities, or other resources. PERT events, on the other hand, do not consume time or resources, but must indicate significant points in the project. If one is concerned with a project that will terminate in the completed building of a middle school, then one of many activities that must take place is the detailed study of the terrain on which the school is to be built. There are two events connected with this activity: one is the *start* of the study and the second is the *completion* of the study activity.

It is helpful, in scheduling, to display the events and activities, and a special networking diagram has been developed for this purpose. A PERT event is normally depicted with a circle; a PERT activity by an arrow connecting two events. Figure 13.1 shows the two events and the activity of studying the school terrain in the example just given. Note that inside each circle is a number, and over the arrow is a letter. These symbols are used to reference

the list of activities and events that must accompany any PERT network. Note, too, that in this example the PERT events and activities are broadly defined. For some planning purposes, the entire process of the terrain study itself might be shown in a detailed PERT network which would depict all the relevant activities and events. The level of PERT activities has to be appropriate to the situation. It must be neither too detailed nor too general.

Figure 13.1

PERT Activity and Event Notation

① —— *a* ——▸ ②

PERT activity event listing

Event	Activity
① Start terrain study	*a* Make a detailed study of the terrain
② Complete terrain study	

There are several features about PERT networks that, while obvious, should nonetheless be mentioned. First, a PERT network is composed of events which precede or follow other events in time. In completing a network, one must work out the logical time sequence of events that applies. The second feature to note is that an event cannot be considered complete until all of the activities that lead to the event have been completed. In Figure 13.2, event 4 is not considered complete until both activity *c* and activity *d* have been completed. Note also that a loop in a PERT network will destroy the network. Shown in Figure 13.3 is a PERT diagram drawn with a loop in it from event 1 to 2 to 4 to 3 to 1 again. The effect of a loop is to cause continual cycling around the events with no chance of ever reaching the project completion. (Note that 4 cannot be completed until 2 is completed, but 2 cannot be completed until 4 is completed.) For this reason a loop is not permitted in a PERT diagram.

With only the simple concepts of events and activities arranged in time sequence, considerable advantage can be gained from preparing a PERT schedule. The planner or manager must list all the relevant activities and events and put them into a logical sequence along a time dimension. This accomplishes the function of thinking through a project. But to aid in decision making, some additional features must be added to the basic PERT network. It is usually of great importance to a manager that the project move along about as expected and be completed within the time limit allotted. A PERT network can be used to indicate places in the project where resources are in under- or over-supply, and hence where delay may occur. It may also indicate that resources might be found to lessen the likelihood of delay.

To aid in decisions concerning resource allocations, several time estimates must be made for the various activities. We require the following additional definitions:

Figure 13.2

A Hypothetical PERT Diagram

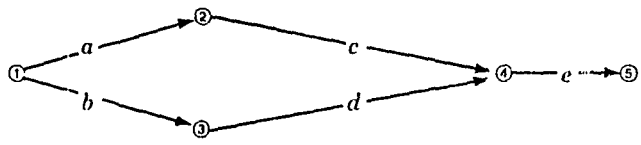
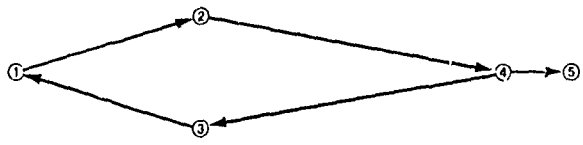


Figure 13.3

A Loop in a PERT Diagram



T_S is the *contractural obligation time*, the total time scheduled for the project.

t_e is the *average activity time*, if the activity were to be repeated many times.

T_E is the earliest possible time that an event can be accomplished (completed).

T_L is the latest allowable time that an event can be completed and the project still remain on schedule.

Since these definitions may not be immediately clear, each will be discussed in turn. The contractual obligation time, T_S, is merely the total time allowed until the project must be completed. If a new school building must be completed and ready for occupancy within 11 months, then 11 months is the appropriate value for T_S.

The average activity time, t_e, may be somewhat more complicated to determine. For each activity in the project, a separate t_e value must be estimated. Where a particular activity has been performed many times, such as in a production job, it may be fairly easy to estimate how long that activity will take on the average. Where there is more uncertainty, but still some experience in the past with the particular task, someone will have to estimate the average activity time from memory or from past records. When a job is new, a best guess may be all that is possible.

For calculating average activity time, regardless of the uncertainty involved, it is advisable to have people familiar with the activity provide three

time estimates. First, there is the most optimistic time possible; call this time a. Second, there is the most likely time: call this m. The third is the most pessimistic time; call this b. Given these three estimates, it is possible to calculate t_e. Equation (1) is a formula showing how t_e is determined from the values for a, m, and b.

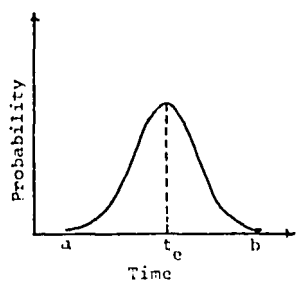
$$t_e = \frac{a + 4m + b}{6} \tag{1}$$

Figure 13.4 shows the relationship between t_e, a, m, and b under two circumstances. Note that t_e is the time at which 50 percent of the area in the distribution lies on either side of the line drawn to the curve. If the distribution is unimodal and symmetrical, t_e will coincide with m, the most likely time. If the distribution is skewed, as in Figure 13.4(b), then the most likely time will be different from the average time.

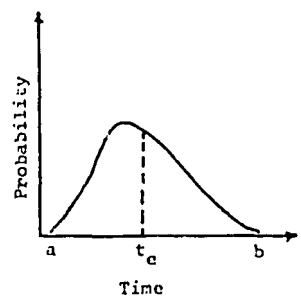
Figure 13.4

Some Hypothetical Distributions Showing the Average Activity Time (t_e)

(a) A Symmetrical Distribution



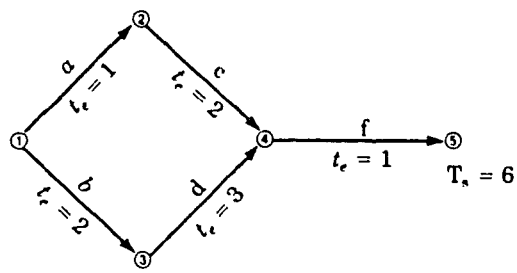
(b) A Skewed Distribution



2.1 *Calculation of T_E, The Earliest Possible Time*

Figure 13.5(a)

The PERT Network and Average Activity Times

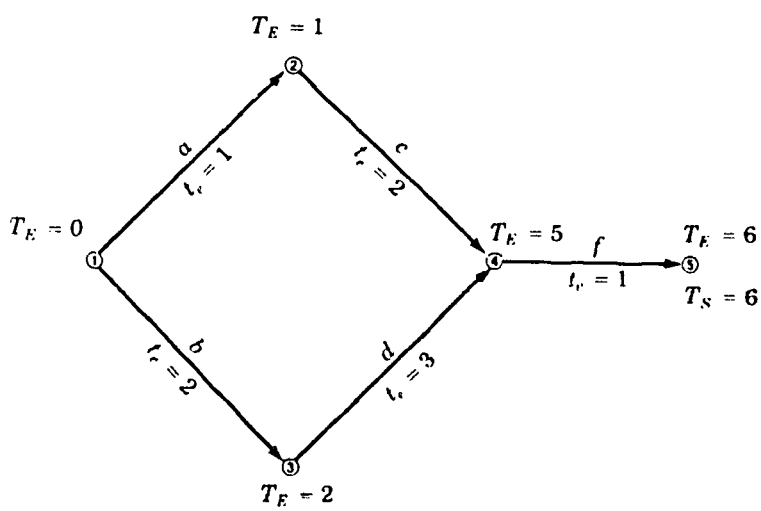


Activity	t_e (in days)
a	1
b	2
c	2
d	3
f	1

Suppose that we have calculated t_e values for each of the activities listed in a hypothetical PERT network shown in Figure 13.5(a). With this information it is possible to calculate both of the other times defined earlier: T_E, the earliest possible time that an event can be reached, and T_L, the latest allowable completion time.

Figure 13.5(b)

Calculation of T_E



Shown in Figure 13.5(b) are values calculated for T_E. For example, T_E listed over event 2 is one day. It takes on average one day to complete activity a, and since activity a is the only activity that must be completed before event 2 is reached, the earliest possible time (on average) that event 2 will be reached is one day. Similarly T_E for event 3 is two days, again employing the same reasoning. When we come to event 4, however, there are two activities that must be completed before the event is reached (they are activities c and d). The calculation of T_E is slightly more complicated in this situation. There are two logical options for T_E: first, it might be the sum of the length of the activities along the top path, from a through c, this being $1 + 2 = 3$ days; or, second, it might be the sum of the length of activities along the bottom path from b through d, this being $2 + 3 = 5$ days. Which of these two options is the earliest possible time that the event can be completed? Strangely enough (until we think about it), the correct choice is the *longer* of the two options. This is so because all activities leading to an event must be completed before an event is properly completed. In this case one set of activities leading to event 4 took three days; the other took five days. Since both have to be completed before event 4 is complete, 5 days is the shortest amount of time before the event can be finished. Note that this assumes that the time along the upper path through event 2 is being run concurrently with the time along the lower path through event 3. The final T_E, for the last event, is shown in Figure 13.5(b) to be six. If the earliest possible time we could complete event 4 is five days, and it takes one day on average to do activity f, then the earliest possible time we could complete event 5 would be $5 + 1 = 6$ days. Note that all of these calculations use the average figures t_e.

2.2 *Calculation of T_L, the Latest Allowable Time*

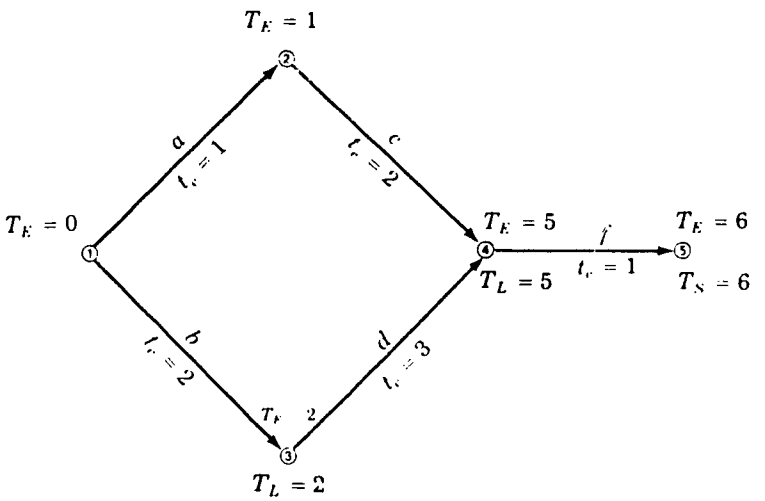
Calculations for T_L are made in a similar way with similar logic, but we begin from the last event in the PERT network and move back to the first event. T_L for the last event is just T_S, the contractural obligation date. It should be obvious that the latest possible time we can complete the last event and still have the project remain on schedule would be on the very day when the project was supposed to finish. T_L for event 4 is five days: it is T_L (event 5) $- t_e$ (activity f) $= 6 - 1 = 5$.

Similar reasoning can be used to establish that T_L for event 2 is 3 days $(5 - 2)$, and T_L for event 3 is 2 days $(5 - 3)$. The only question of choice of time paths arises where we have two or more arrows (activities) originating in the same event. This happens in Figure 13.5(c), when we go back to event 1. Here there will be two path options for T_L estimating. Moving along the upper path, where activity a takes one day, we get one possibility as $3 - 1 = 2$. Our second path option is moving along the lower path, where activity b takes 2 days, and we have $2 - 2 = 0$. The smaller of the competing values is selected. The smaller T_L value is always chosen. Notes at the end of the chapter explain why.

Smallest T_L, Slack Time and Critical Path

Figure 13.5(c)

Calculation of T_L



Always choose the smaller T_L value for an event, since that will be the latest time that the event can be completed and still allow the remainder of the project to be completed on time.

Values for T_E and T_L are used to calculate something called *slack time*. The upper path choice has slack time, $T_L - T_E = 3 - 1 = 2$. The lower path $2 - 2 = 0$ has no slack time. The lower path from 1 to 3 must be completed on schedule. It is critical. There is no slack, as in the path 1 to 2. From this the *critical path* is identified. The critical path is the one which has no slack time. It is the path of the latest time that can be followed to complete the project on time. It is the critical path that is of primary interest to decision makers. Along the critical path lie sources of potential bottlenecks in completing the project on time. The analysis suggests options for transferring resources or time from one activity to another.

> *Slack time* for an event is defined as the difference between the latest allowable time T_L and the earliest arrival time T_E, that is, slack time $= T_L - T_E$.

Where there is large slack time, it is possible that excess time or resources have been committed to the events involved. If there is negative slack, it is an indication of too tight a schedule. In such a situation, a decision maker may wish to transfer some resources from one set of activities with positive slack time to the ones causing the negative slack. A slack time of zero indicates the project is right on schedule. The less the slack, the more critical the event is to the project. From the start of the project to its completion, there is normally one path that stands out as being critical:

Figure 13.6

Calculation of Slack Time and Identification of the Critical Path for PERT Network in Figure 13.5.

Event	T_L	T_E	Slack Time = $T_L - T_E$
1	0	0	0
2	3	1	2
3	2	2	0
4	5	5	0
5	6	6	0

Critical Path: 1, 3, 4, 5 (where the slack time is 0, 0, 0, 0)

> The *critical path* in a PERT network is that path from start to completion that requires the most time. This is the same as saying that T_L is smaller, and there is no slack time, or no time to spare.

Any event which happens to be on the critical path can cause slippage in the final completion date. If an event is on the critical path and is reached 2 days later than expected, then the whole project is likely to be pushed back 2 days unless other events on the critical path are reached in times faster than the average time expected. To find the critical path in a PERT network we must identify that path with the minimum slack time. This is done in Figure 13.6 for the information in the PERT network in Figure 13.5.

As was already apparent from out previous calculations, perhaps, the critical path is the one going from event 1 through events 3, 4, and terminating in event 5. In a simple example like this one, it is readily apparent which path is the critical one but, in more complicated PERT networks, slack times will have to be computed before the critical path is determined. A manager faced with a PERT network like that in Figure 13.5 might assume that everything seems to indicate the project will finish on time. However, to help insure project completion at the specified time, a manager might wish to transfer resources to activities on the critical path. For example, activity *a* will require an average of one day if done with normal resources. If workers are transferred from this activity to activity *b*, it would lengthen the time needed to perform activity *a*, but decrease the time needed to perform activity *b*. This adds resources to those activities that would have the most immediate effect upon project delay, in effect helping to insure project completion on time. Obviously a PERT diagram cannot make this decision, but the information provided by the network is useful in making decisions about resource allocations of this type.

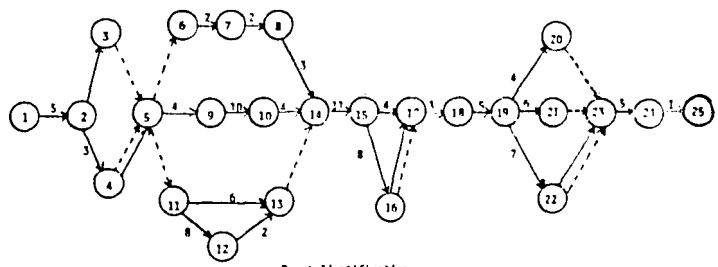
3.0 *Exercise*

Figure 13.7 shows a lengthier and somewhat more complex systems chart used in educational research and planning. The PERT sequence traces the

development of a research project based on a sample survey. Estimated time in days are placed along the paths. Find the critical path and trace it in with heavy lines. Check with Figure A13.3 at the end of the chapter to compare your critical path analysis with that of the planner.

Figure 13.7

A PERT Network



Event Identification

1. Start Project
2. Finish Objectives Statement
3. List Major Variables
4. Develop 8 Complete Hypotheses
5. Start Constructing Items
6. Start Defining Universe
7. Develop Sampling Scheme
8. Start Sample Selection
9. Start Tryout
10. Start Final Form
11. Start Interviewer Selection
12. Finish Administrative Procedures
13. Finish Schedules
14. Start Field Interview
15. Start Data Coding
16. Develop Model Data Tables
17. Start Tabulation
18. Start Statistical Analysis
19. Finish Tests
20. Finish Interpretation
21. Finish Tables
22. Finish Charts
23. Start Drafting Report
24. Complete Draft of Report
25. Present and Discuss Report

Chart is a Modification of chart in Desmond L. Cook "Program Evaluation and Review Techniques; Applications in Education", U.S. Office of Education, Monograph 17, Government Printing Office, Washington, D.C. 1966, p. 43.

4.0 *A Modification of the PERT Network*

Sometimes the planner's objective is to use scheduling to provide a comprehensive overview of a project. There is no need to calculate critical paths and resource allocations. Feedback mechanisms may operate to keep the project on track. In this situation it is often advantageous to modify the basic PERT network to indicate features in addition to events and activities. Typically, another feature that is of concern in projects are those points in time at which decisions must be made that affect the course of the project. If, for example, there is to be a review of a particular phase of the project, either internally or by external agencies or individuals, then one might wish to indicate this in a scheduling network.

A decision point in a project is usually noted with a diamond shape that takes the place of an event in a PERT diagram (see Figure 13.8).

Figure 13.8

Illustration of a PERT Network Modified to Include a Decision Point

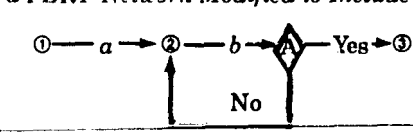


Figure 13.8 shows a simple network modified to include a decision point. Note that there are usually two exits from the decision point, one indicating *Yes* and the other indicating *No*. The *No* route traces back to some earlier event or activity of the project. Because this essentially introduces a loop into the traditional PERT network, it is not possible to calculate critical paths with this type of network. It is only used to identify the major events, activities, and decision points.

Appendix 13.1 shows a standard PERT network of a manpower planning sequence, as illustrated in Davis (1966). The identified steps in this PERT network are actually combinations of events and activities as defined previously. Note, too, that considerable detail can go into the preparation of any given diagram. Shown as a separate network is Step 7 in the original PERT. Called Subsystem #7, it uses a modified PERT format to illustrate the main activities, events, and decision points necessary in doing an establishment survey of existing industries. Lest one become carried away with ever-increasing refinements in scheduling networks, the reader is advised to heed the words of warning provided by Davis in the introduction to the schematization appearing here as Appendix 13.1.

APPENDIX 13.1

Two Modified PERT Networks of a Manpower Planning Sequence

Figure A13.1 and text schematize an overall manpower planning sequence. There are also specifications for staffing the planning sections to carry out the tasks schematized. Each one of the circled numbers in the overall diagram represents a subsystem which would have to be analyzed and broken into its component parts.

As an example, subsystem 7, Industrial Surveys and Analysis, is schematized and the activities and events are described. The schemata are offered as examples of how the planning process might be analyzed atomically. The schematization of all the component parts of the process is deliberately not given in this scheme. Planners often become so intrigued with models and schemata that they spend months working on pictures when they should be out looking at schools. For those planning staffs that have an underemployed draftsman, the preparation of such schema might offer considerable aesthetic satisfaction. A substantial literature on PERT analysis is available as a guide.

Overall Planning Sequence

Stage Descriptions

I. Situational Survey and Negotiations Pursuant to Study Design
II. Internal Management Planning
III. Systems Analysis and Data-Collection-Reduction
IV. Projection of Supply and Demand
V. System Design
VI. Feasibility Evaluation
VII. System Re-design

Note: Arrows show activities of staff, not flow of information. Communication among staff members must be complete and well-coordinated, but such lines would unnecessarily complicate the schematic.

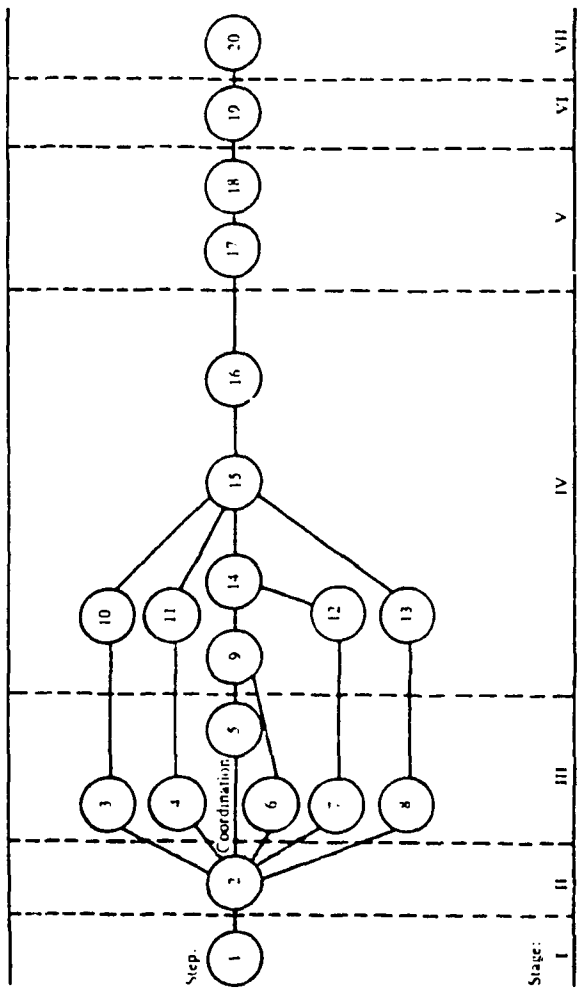

Step:
1
2
3
4
5
Coordination
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Stage:
I
II
III
IV
V
VI
VII

Figure A13.1

Notes on Staffing

a. Basic staff requirements and tasks are: Educational Planner and Project Director (1, 2, 5, 9, 14–20) plus coordination; Sociologist (3, 10); Demographer (4, 11); Industrial Survey Technician (7, 12, 14); Economist (6, 9, 14); and, Educational Systems Analyst (8, 13). All would cooperate in establishing service sector demand (Step 15) and total demand targets (Step 16).
b. The educational systems analyst should work with the project director from beginning to end; however, the sociologist, industrial survey technician, demographer and economist need only be available full-time during Stages III and IV, but should be available as consultants both in the preceding and final design stages. When a country is contemplating significant changes in its agricultural complex, an agricultural expert may be needed.
c. Since future measurement of the new system's output must be performed on a continuing basis by local officials, it would be advisable to include "counterparts" in each segment of the study, so that they may be thoroughly familiar with the operation of the system and can carry on without frequent technical supervision.

Step Descriptions

1. Establish study scope and sequence; survey existing data. *Note:* Scope will include targets set by home officials (over which the planner has no control) and economic development targets and specifics (which the planner must accept, at least until Stage VI is reached).
2. Determine staff requirements; recruit, organize and brief study staff.
3. Socio-cultural analysis to determine special conditions (e.g. religious restraints, literacy shortcomings, traditional family or village production patterns) which any future system will have to alter or circumvent.
4. Population study: Census tracts, birth and fertility data, life tables, migration, et cetera.
5. Data on employment in government sector and estimate of future needs, both state and local; *Note:* logical responsibility of project director since he is in closest touch with government officials; may require extra staffing.
6. Resource estimate: involves measures of national or regional product, sector or industry productivity, corporate and personal income; also, estimates of tax policies and revenues, as well as past practices in allocating resources to education; general analysis of existing economic development plans, including agricultural sector.
7. Industrial survey and analysis: establishment surveys to determine current status of workforce and future manpower needs; establish measures of efficiency in manpower utilization and performance; acquire data on current and planned in-plant or apprenticeship training programs.
8. Analysis of formal educational system (public and private): input-output relationships (e.g. supply of teachers and their distribution, as against output of graduates from various levels); efficiency measures (both those resulting from cost analysis and performance of graduates on the job); system structure and lines of authority and communication; current instructional content, techniques and sequences; hardware evaluation; legal bases for system; estimate of attitudes which might prejudice future system improvements (i.e. student, teacher and administrator).
9. Agricultural employment analysis, with reference to broad-scale development plans: rough worker projection in agricultural sector.

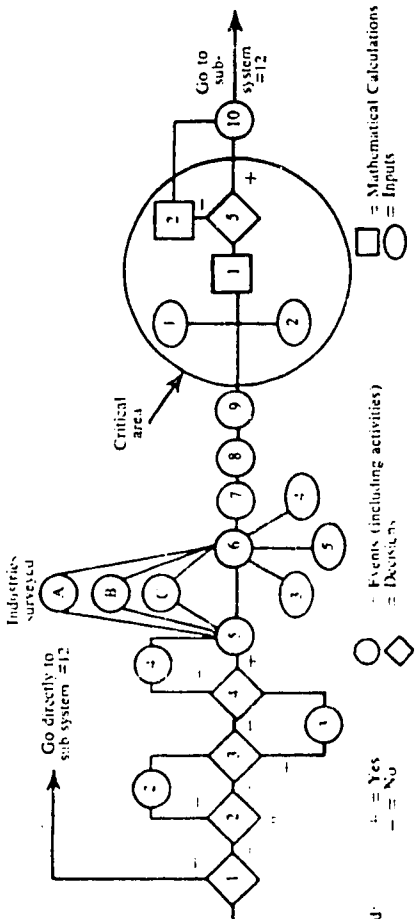
10. Set educational goals for non-workforce part of population, particularly women.
11. Perform necessary population projections.
12. Estimate effect of planned new industry on future workforce demand, by discrete steps to target year; add predicted need as ascertained from existing industries.
13. Project output of the formal educational system, all levels, public and private. *Note:* This is the output of the present system, if it continued to function unchanged until the target year.
14. Establish total future workforce requirements, in occupational terms, except for service sector; appropriate wastage factors should be used, as in 9 & 15.
15. Establish future workforce demand in service sector, by discrete steps to target year. *Note:* Those services connected with educational expansion and improvement can not be added in until end of step #16, and can not be made fairly exact until end of step #18.
16. Aggregate total workforce needed in target year, taking into account wastage; add in desired general characteristics of non-workforce; deduct projected output of present educational system; calculate gaps, in occupational and behavioral terms, which future system must fill. *Note:* Check percentages of economic sectors (e.g. service vs. production) against experience of similar countries.
17. Translate demand targets into educational terms (not necessarily years of schooling completed, et cetera). This partly depends on the prototype educational system which (from among many possible) is indicated by all of the preceding analysis. Therefore, final figures must await the actual system design.
18. Design optimal (ideal) system to fill gaps (as well as increase efficiency at current level of output), at lowest cost. *Note:* Sufficient cost analysis should be undertaken both to provide a sound basis for evaluation and to identify where and how much costs are increased (e.g. curriculum improvement, teacher training, laboratory equipment, et cetera). Thus, if cost-cutting is indicated in step #19, it can be done with full knowledge of how the quantity or quality of output will be affected in the re-designed system. Note that such factors will usually alter the assumptions and projections in step #13 and the final estimate of the "education gap" in step #17.
19. Test system designed in step #18 against estimate of resources available, both financial and human.
20. Re-optimize and re-design educational system to conform to financial, and other, realities.

Subsystem #7
Establishment Survey of Existing Industry
(Schematic)

Activities Leading to Circled Events

1. Start
2. Compile list of industries, classified by economic sector, ISIC and size. (Location may be also included if geographic factors warrant.)
3. Sample and Statistical Analysis Design

Figure A13.2



a Industry is defined here as emphasizing light and heavy production, but in actual practice the field staff will be able to gather data on such "industries" as retail businesses, hospitals, and so forth, although the master schematic shows others working in non-industrial sectors.

b. If complete industrial census data are available (◇ 7), the sequence from ◇ 7 up to (but not including) (6) will concern investigation of future needs, data on training programs, spot checks on census information, and bringing census data forward to base year x

4. Design questionnaires and personal interview forms
5. Conduct field survey
6. Classify work-force using following matrices:
   (a) Occ × Sector (b) Occ × Ed. Level (c) Occ × Age
7. Devise estimate of efficiency in large Occ × Ed. Level cells (may be productivity, if such a measure is available; otherwise, some management rating scheme)
8. Data processing
9. Profile of present industry, including efficiency of various sub-industry occupational or functional groupings
10. Report of projections for future work-force demand in existing industries, years x to n (discrete steps), as input for later calculations. Use IBM cards for final data.

DECISIONS (DIAMONDS)

1. Is industry presently in planning area?
2. Is listing of all local industry available, stating economic sector, ISIC coding and size?
3. Is number of industrial firms too large to handle in allotted time, if complete survey of all firms is performed?
4. Are personal interview and/or questionnaires available?
5. Was sampling plan used?

MATHEMATICAL CALCULATIONS (RECTANGLES)

1. Calculate gaps, using Occ × Economic Sector matrix. (*Note:* Hold off on Occ × Ed. Level data for later conversion, after general system design for occupational training is chosen.) Add wastage; subtract in-plant training.
2. Aggregate net gaps across all industries in survey or sample.
3. Perform statistical analysis to get final total.

INPUTS (ELLIPSES)

1. Future expansion plans of existing industry (from questionnaires and interviews).
2. Established "mix" for industries (elsewhere) not at stage projected for existing planning area industries in year n (for purposes of comparison).

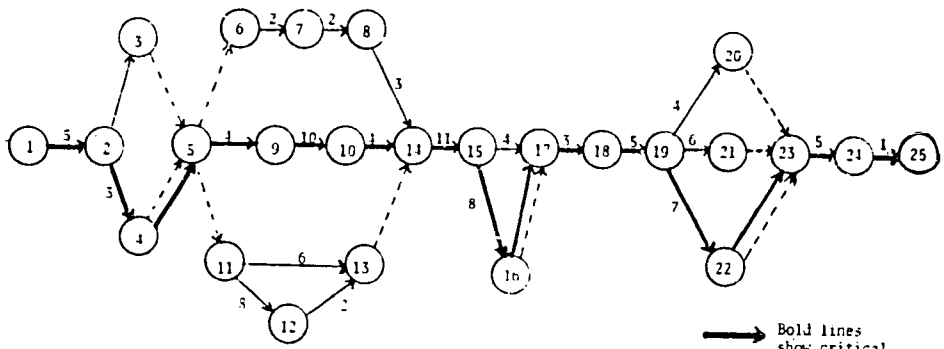
Important assumptions involved in any sampling scheme:

(a) Are occupational mix and efficiency in sample industries same as in total industry population of planning area? (steps 6 and 7)

(b) Are expansion plans (or some central tendency measure of same) of sample industries representative of total industry population of planning area? (ellipse 1)

Figure A13.3

Diagram ned Answer of Critical Path Exercise (Original shown in Figure 13.7: Compare)



Event Identification

1. Start Project
2. Finish Objectives Statement
3. List Major Variables
4. Develop & Complete Hypotheses
5. Start Constructing Items
6. Start Defining Universe
7. Develop Sampling Scheme
8. Start Sample Selection
9. Start Tryout
10. Start Final Form
11. Start Interviewer Selection
12. Finish Administrative Procedures
13. Finish Schedules
14. Start Field Interview
15. Start Data Coding
16. Develop Model Data Tables
17. Start Tabulation
18. Start Statistical Analysis
19. Finish Tests
20. Finish Interpretation
21. Finish Tables
22. Finish Charts
23. Start Drafting Report
24. Complete Draft of Report
25. Present and Discuss Report

Chart is a modification of chart in Desmond L. Cook Program Evaluation and Review Techniques; Applications in Education. U.S. Office of Education. Monograph 17. (Washington, D.C.: U.S. Government Printing Office, 1966) p. 43.

CHAPTER 14

Project Analysis: Benefit-Cost and Cost-Effectiveness

Philip Zodhiates

1.0 *Introduction*

The rationale for project appraisal techniques such as benefit-cost and cost-effectiveness analyses is economic efficiency, the aim being to ensure that scarce resources are put to their most valuable use. Cost-benefit and cost-effectiveness analyses can be viewed as the application of profitability analysis—practiced for many years in the private sector—to publicly funded projects where the focus is not on the individual person or firm, but on society as a whole. But there are other differences as well. A private firm normally looks at its profit and loss at the end of a production period, whereas benefit-cost analysis attempts to evaluate a project before it is undertaken, to decide whether or not it is worth adopting. We will use benefit-cost as a generic term that includes the analytic procedures of net present value, internal rate of return, and benefit/cost ratio. The terminology sometimes changes around to cost-benefit analysis when we are referring to general procedures for comparing costs and returns on a project. In some cases, either usage may occur, and the choice is arbitrary.

Systematic project evaluation has become particularly important for planners when a project is being designed and alternatives are being considered. The project analyst looks at one or more alternative projects, and after a systematic enumeration of all costs and all benefits—expressed in monetary or non-monetary terms, readily quantifiable or difficult to measure—he determines which alternative produces the greatest benefits. His task, essentially, is to predict for each alternative project the inputs that will be employed and the outputs (sometimes outcomes) that will result.

Benefit-cost analysis is used when project costs and benefits can be identified and assigned monetary values. It is based on the simple but reasonable idea that projects should be funded only when benefits exceed costs, or, at the very minimum, when benefits at least equal costs. The importance of this criterion for decision making does not depend on the claim that it should be the only criterion for investment—after all, political considerations often take precedence—but on the fact that when resources are scarce the central problem of decision makers is maximizing the returns to investment; or, looking at the opposite side of the coin, minimizing the costs.

In educational planning, benefit-cost approaches have been applied in two major contexts. The first is a general policy planning context in which rates of return are computed for general levels of education, or types of educational

programs. Rate-of-return studies have been comprehensively reviewed in Chapter 5, Volume I. This review covered comparisons based on net present value, internal rate of return, and cost-benefit ratios, with investments assessed on both a private and social basis. In this kind of application the analyst attempts to assess the return on investment to a level of education by comparing the net earnings of graduates at one level with the net earnings of graduates at the next higher level of education. The difference, discounted to present value or expressed as an internal rate, is then interpreted as the return on the investment to the additional level of education. The sweep here is a broad one, and presumably policy makers use these rate-of-return comparisons to guide investment in an entire level or type of education. In reality the approach has been far more prominent in the academic literature on economics of education than it has in policy planning.

The second context in which benefit-cost approaches have been used is in project analysis and planning. This is the context which frames the work in the two volumes which have been cited as companion pieces to this series:

— Educational Testing Service, *A Manual for the Analysis of Costs* and *Outcomes in Nonformal Education,* Princeton, N.J.: International Office, ETC, 1979.

— Jamison, Dean, Steven Klees, and Steven Wells, *Educational Media: Guidelines for Planning and Evaluation.* Beverly Hills, Cal: Sage, 178.

Material in this chapter can be supplemented by the two books cited above. A brief section of the first book is used as a reading selection at the end of this chapter, but the entire book is useful as a reference work for planners. Cost-benefit analysis applied in project analysis and planning is the context that will be stressed in this chapter. This application has practical significance for planners, although the utilization of conventional cost-benefit approaches is not universal among planners in developing countries despite strong advocacy from the international assistance agencies and development banks. Roemer and Stern (1975) make the topic readable for practitioners.

Applications in both contexts rest on the same basic framework of assumptions, which have been reviewed by Harberger (1972) and in Chapter 5, Volume I. Benefit-cost analysis of returns to education rests on the assumption that lifetime earnings differentials between individuals are close approximations to the differences in their contributions to national income. Related to this is the claim that differences in earnings are largely attributable to differences in educational attainment, rather than to differences in native ability and family background. These ideas were also reviewed in Chapter 5, Volume I.

The evidence in favor of this set of assumptions is based on a strong and consistent positive relationship between education and earnings. Moreover, if adjustments are made for differences in education—instead of just counting numbers of workers in the labor force—a much better explanation can be constructed for the growth of goods and services in developing countries. Edward Dennison, among others, has offered this as evidence that education leads to higher productivity (Denison 1960, 1964).

A counter-explanation for the positive relationship between education and earnings is that those who receive more education tend to be advantaged in other ways—family background, social contacts, opportunities. Critics of the basic assumption also point to the credentialing effect of education, that is, people receive a higher income not because they are more productive but because they have access to higher paying jobs by virtue of their educational credentials.

The validity of the productivity assumption has been challenged by numerous authors; see for example Woodhall (1970), Blaug (1967), Psacharopoulos (1973), and Berg (1970).

At present the debate centers not so much on whether education increases productivity but on how much, as well as on the unresolved question of how accurately earnings reflect productivity. This debate has great relevance for the validity of benefit-cost analyses in education because economic benefits are almost always construed as the difference in earnings, over the years, between people with different levels of education.

In project evaluation one issue is whether or not the proportion of returns attributed to education is, for example, 50, 70, or 100 percent of the total income differential. Typical is the example in the appendix at the end of this chapter, in which all of the increased earning which carpenters received after training is attributed to the training. A second issue is that at the pre-project stage, evidence from the past must be used to determine how much of an increase in output can be expected from enrollment in the project under consideration. The error involved in equating earnings with productivity is thus compounded by having to rely on past earnings trends based on cross-sectional data. Even at the post-project stage the effect of an educational project on productivity is extremely difficult to measure because it is difficult to determine how much of the increase in output can be attributed to the project under consideration. The cumulative impact of these problems has the effect of making benefit-cost analysis a very rough tool indeed for decision makers.

There is also the matter of the discount rate, probably the most important variable in benefit-cost analysis since even small changes in the discount rate frequently have a significant impact on the results.

A second category of economic benefits poses lesser problems for the project analyst, namely, internal efficiency, which is measured by the reduction in unit cost per student enrolled, or per graduate. Greater internal efficiency enables the educational process to produce more graduates for the same amount of inputs or to provide the same amount of education with fewer inputs. The resources saved represent the benefits to the economy as a whole. As an example of this type of analysis carried out at the national level is Blaug's (1968) study of internal efficiency in British schools.

The evaluation of internal efficiency, however, may also take account of non-monetary outcomes, by means of a cost-effectiveness analysis which is undertaken when costs and benefits cannot both be expressed in terms of monetary values. Non-monetary benefits of increased productivity within a project can be educational effects in the form of improved achievement scores

or decreased repeater and dropout rates. See the appendix to Chapter 2 for a model of these effects.

Project appraisal is most successful and hence most useful in measuring a project's internal efficiency. By utilizing a multidimensional approach that includes cost-benefit and a variety of cost-effectiveness analyses—one for each clearly defined project objective—evaluation can serve the needs of planners, as well as the needs of project participants, for feedback when improvements are being considered.

Because education normally serves multiple goals, only one of which is to raise productivity, and hence the earning capacity of individuals, both benefit-cost and cost-effectiveness techniques are necessary for evaluating educational projects. The remainder of this paper takes up the concept of discounting which is at the heart of benefit-cost analysis. It discusses three criteria associated with the benefit-cost analysis framework: net present value, internal rate of return, and benefit/cost ratio. The discussion of cost-effectiveness in section 4.0 is followed by a brief account of the concept of value, a central issue in the use of decision tools such as benefit-cost and cost-effectiveness which are essentially prescriptive and value-laden.

2.0 *The Notion of Time: Interest Rates and Discounting*

The essence of investment is that something is given up today in order to gain some benefit in the future. The question facing decision makers and planners is whether, given the immediate costs as well as the stream of costs and benefits over the lifetime of the project, the contemplated investment would be profitable, or in the case where several options exist, whether the project would be the most profitable of all available alternatives. The *time horizon* is a critical feature of projects.

Individuals, as well as society, are not indifferent to time. It matters a great deal, for example, whether one has $100 today or has to wait five years before he can make use of the $100. The idea is that $100 today is not equivalent to $100 five years from now because one could invest the money and earn interest. By using the appropriate interest rate, one can calculate the value of his investment at some future point, its *future value*. The equation used to calculate the future value of an investment is as follows:

$$FV = PV(1 + r)^t \tag{1}$$

where:

FV = Future value,
PV = Present value,
r = Interest rate,
t = Number of years of investment.

Suppose we want to calculate the worth of $100 invested five years at a 5 percent interest rate. Using equation (1),

$$\begin{aligned} FV &= \$100(1 + .05)^5 \\ &= \$100(1.05)^5 \\ &= \$127.60 \end{aligned}$$

We find that our investment would be worth $127.60 five years hence, at a 5 percent interest rate. Obviously, if we were to leave the $100 in a bank for ten years; at the same interest rate, it would be worth still more:

$$\begin{aligned} FV &= \$100(1.05)^{10} \\ &= \$161.10 \end{aligned}$$

Working forward, from the present investment to its future worth, however, has several drawbacks for planning purposes. One of the problems is that future value is conceptually remote for decision makers interested in knowing whether an investment is worth making today. Planners and decision makers need a mechanism whereby estimated future returns can be evaluated at their present worth, that is, at the time the investment decision is being made.

Discounting future returns to their present value is, in essence, the obverse side of caculating the future value of a current investment. In discounting, the interest rate becomes the rate by means of which we discount future value, now called the *discount rate*. The relationship between future value and present value is given below:

$$FV = PV(1 + r)^t, \text{ where } r = \text{interest rate or discount rate.} \qquad (1)$$

Dividing both sides by $(1 + r)$, we get the equation for present value:

$$PV = \frac{FV}{(1 + r)^t} \qquad (2)$$

If, for example, we estimate that we will receive a payment of $100 in five years, and we know the interest rate to be 5 percent, we can calculate its present value:

$$\begin{aligned} PV &= \frac{\$100}{(1.05)^5} \\ &= \$78.37 \end{aligned}$$

Now suppose that instead of five years, we have to wait ten years before we can use the $100. Present value then becomes:

$$\begin{aligned} PV &= \frac{\$100}{(1.05)^{10}} \\ &= \$61.39 \end{aligned}$$

Note: Analysts do not have to do the calculations. The answer can be looked up in a Present Value Table, as in Table A 14.2 in the appendix at the end of this chapter.

The more distant the payments (whether benefits or costs), the smaller is

their present value because discounting increases as we move further into the future.

It may be useful to consider some of the implications of discounting. If we owed money, for example, we would prefer to pay later than sooner, because the later we pay, the smaller will be the present value of the amount paid. If we were owed money, the opposite would be true. Similarly, planners would prefer a project with early benefits and deferred expenditures to one where the reverse holds.

2.1 *Education Projects*

The fact is, however, that educational projects tend to incur costs early on, while returns in the form of additional earnings due to the project occur in the future. Unless the stream of costs and benefits is discounted, the evaluation of an educational project will tend to grossly overestimate the project's net returns. This is illustrated in the following example. Suppose we have a project X that takes one year to build at an initial cost of $500,000, and then yields a declining stream of benefits over a five-year period. The complete stream of payments is shown below

Table 14.1

Stream of Payments (All Figures in Thousands of Dollars)

Project/Year	0	1	2	3	4	5
X	− 500	+ 200	+ 150	+ 100	+ 50	+ 25

Suppose we know that the appropriate discount rate is 5 percent. Project X will immediately yield a net benefit of − 500 (actually a cost), and the present value of this is simply − 500. At the end of the first year, there is a positive yield of + 200 with a present value of $^{200}/_{1.05}$ = 190.48. The present value of the second-year flow of + 150 is $^{150}/_{(1.05)^2}$ = 135.99, and so on. The total present value of X is

$$PV_X = -500 + \frac{200}{1.05} + \frac{150}{(1.05)^2} + \frac{100}{(1.05)^3} + \frac{50}{(1.05)^4} + \frac{25}{(1.05)^5} \qquad (3)$$

$$= -500 + 190.48 + 135.99 + 86.36 + 41.12 + 19.59$$

$$= -26.45 \text{ or a net loss of \$26,460}$$

If the appropriate discount rate is indeed 5 percent, project X turns out to be a rather poor investment. However, had we not discounted, that is, had we made our calculations with a discount rate equal to zero, we would have arrived at the mistaken conclusion that project X was in fact profitable. With $r = 0$, the total stream of payments comes to − 500 + 525, which is a net gain of $25,000. The use of a discount rate and the value we assign to it clearly make an important difference to project evaluation results.

3.0 *Criteria Used in Benefit-Cost Analysis*

3.0.1 *Net Present Value*

The Net Present Value approach reduces a stream of costs and benefits to a single number in which costs and benefits that are projected to occur in the future are discounted. The NPV equation, which is the general statement of the calculations above in (3), can be expressed as

$$NPV = B_0 - C_0 + \frac{B_1 - C_1}{1 + r} + \frac{B_2 - C_2}{(1 + r)^2} + \frac{B_3 - C_3}{(1 + r)^3} \ldots + \frac{B_n - C_n}{(1 + r)^n} \quad (4)$$

where $B_0 - C_0$ represents net benefits at the initial investment period, $B_1 - C_1$ indicates net benefits at the end of the next year, and $B_n - C_n$ represents the net benefits for the last year of the project's life. In the case of an educational project, for example, the net benefit would be the additional income of graduates due to extra schooling minus all the costs of the additional education—such as students' foregone earnings, teachers' salaries, building and maintenance costs, expenditures on books and other instructional materials—all discounted to present value.

The NPV criterion prescribes choosing a project with a positive NPV, and in the case of several alternatives, choosing the project or projects with the highest NPV. This decision rule is examined below with the use of some examples.

(a) Choosing one of a number of mutually exclusive alternative projects.

Suppose a group of planners have come up with six alternative proposals for starting a secondary school, ranging from buying some old but dispersed buildings to purchasing some land and constructing a new school. For this example we assume that funding and other inputs are not a problem; and that all payments have already been discounted. The costs and benefits of the six alternatives are summarized below in Table 14.2. Project D promises the largest net benefit, $750,000, and should therefore be chosen.

Table 14.2

Alternative Projects (All figures are in thousands of dollars)

Secondary school alternatives	Discounted costs	Discounted benefits	Net present value
A	200	700	500
B	100	500	400
C	300	475	175
D	500	1250	750
E	500	750	250
F	200	600	400

(b) Choosing among a number of alternative projects, given a resource constraint.

Now suppose that the six choices are not mutually exclusive, but instead represent different vocational education projects, ranging from carpentry to a computer technicians programs, and that the decision makers are bounded by a resource constraint of $500,000. For simplicity, we again assume that all costs and benefits have been considered, and discounted over time. Again, the calculations would involve finding out whether or not appropriate instructors are available, computing the cost of salaries for staff and teachers as well as the cost of equipment and materials, and, most importantly, researching the regional economy's demand for particular skills. The NPV criterion tells us to choose those projects which maximize net benefit for an expenditure of $500,000. The easiest way to proceed is to calculate the net benefit per unit of cost, rank the six projects according to this index, and select projects from the top of the list down, until the $500,000 is expended. This selection procedure is shown in Table 14.3.

Table 14.3

Benefit for Unit of Cost (All Figures in Thousands of Dollars)

Vocational Education Projects	Discounted Costs	Discounted Benefits	Benefit per unit of cost	Cumulative cost, all projects
B	100	500	5.0	100
A	200	700	3.5	300
F	200	600	3.0	500
				constraint*
D	500	1250	2.5	1000
C	300	475	1.6	1300
E	500	750	1.5	1800

Projects B, A, and F will be chosen, thereby exhausting the available funds while at the same time maximizing the net benefits. With B, A, and F total net benefits, $(500 - 100) + (700 - 200) + (600 - 200) = 1300$, or $1,300,000. Project D, which was the best choice when funds were unlimited, produces only $750,000 worth of benefits.

3.0.2 *The Internal Rate of Return*

Benefit-cost analysis in education often takes the form of calculating the internal rate of return (IROR) of aproject, which is the discount rate that makes the net present value of a project equal to zero. In other words, the IROR is the i, or interest rate, that satisfies

$$\sum_{t=0}^{T} \frac{B_t}{(1+i)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+i)^t} = 0 \tag{5}$$

where T represents the total life of the project; Σ, the sum over costs and benefits; t, the year at which each cost and benefit occurs; and i, the discount rate, which equates the sum of all costs and the sum of all benefits.

The advantage of the IROR approach over other discounting techniques is that it is a conceptually easy technique to comprehend because it closely parallels the kinds of profitability calculations practiced in private firms, that is, it is equivalent to the method used to estimate the yield of a private investment. Its advantage over the NPV approach is that IROR does not have to rely on any assumptions or outside estimates of the appropriate discount rate. The interest rate is generated within the project itself based on project data.

The decision criterion associated with IROR is to undertake a project if its IROR is greater than the appropriate interest rate provided by the market. When there are several alternatives, the project with the highest internal rate of return should be chosen. If, for example, the market interest rate is 5 percent while a project's IROR is calculated at 10 percent, the decision maker is justified, on economic grounds, in allocating resources to the project. The criterion is based on the reasonable assumption that a project should be undertaken if it offers a rate of return greater than the rate at which money can be borrowed.

Obviously, one cannot totally ignore the market interest rate because, at the end of the analysis, one always has to compare the project's internal rate of return with the interest rate provided by the market. But as long as the project's IROR is substantially different from the appropriate market interest rate, a rough estimate of the latter is sufficient, whereas in the NPV approach a great deal of time and effort might be necessary at the outset to estimate an accurate discount rate. Testing the rate with later analysis might also be necessary.

The IROR approach involves a trial-and-error procedure in which we try out a number of discount rates until we arrive at the rate which equates a project's costs and benefits. Suppose, for the sake of simplicity, that a proposed project Y has an initial cost of $100,000, and a declining stream of net benefits over the next five years, at the end of which the project comes to an end.

Table 14.4

Stream of Project Costs and Benefits (All Figures in Thousands)

Project/Year	0	1	2	3	4	5
Y	−100	+50	+40	+30	+20	+10

In this case the project's cost does not have to be discounted because it occurs in the initial year. The stream of benefits, however, must be reduced to their present value. What is the IROR of project Y? In our process of trial and error, suppose we begin by trying out a discount rate of 15 percent. The choice is arbitrary, but not without some basis. Usually, the analyst starts with a rate just below or just above some rough estimate of the prevailing rate outside.

Present value of cost (PV_c) = \$100,000

Present value of benefits (PV_B)

$$PV_B(i = 0.15) = \frac{50}{1.15} + \frac{40}{(1.15)^2} + \frac{30}{(1.15)^3} + \frac{20}{(1.15)^4} + \frac{10}{(1.15)^5}$$
$$= 43.48 + 30.23 + 19.72 + 11.44 + 4.97$$
$$= 109.84 \text{ or } \$109{,}840$$

Since 109.84—100 does not equal zero, we know that the project's IROR must be higher than 15 percent. Next, suppose we try a discount rate of 20 percent. Now

$$PV_B(i = 0.20) = \frac{50}{1.20} + \frac{40}{(1.20)^2} + \frac{30}{(1.20)^3} + \frac{20}{(1.20)^4} + \frac{10}{(1.20)^5} = 100.48$$

Since 100.48 − 100 is almost zero, we know that the project's IROR is approximately 20 percent. If our rough estimate of the market discount rate is say, 10 percent, we can be sure that project Y is worth undertaking.

Most of the time the IROR is a valid decision criterion, but there are some serious problems with it which have recently been discussed in the program evaluation literature. See Sassone and Schaffer (1978) and Stokey and Zeckhauser (1978) for a lucid summary of criticisms leveled against IROR. In considering mutually exclusive projects, the IROR criterion has sometimes been found to prescribe the wrong decision: this happens when the project with the highest internal rate of return is not the one with the greatest net present value. Suppose we have to choose between two competing projects, Y (from the previous example) and Z, whose stream of payments is given below.

Table 14.5

Two Streams of Payments (All Figures in Thousands of Dollars)

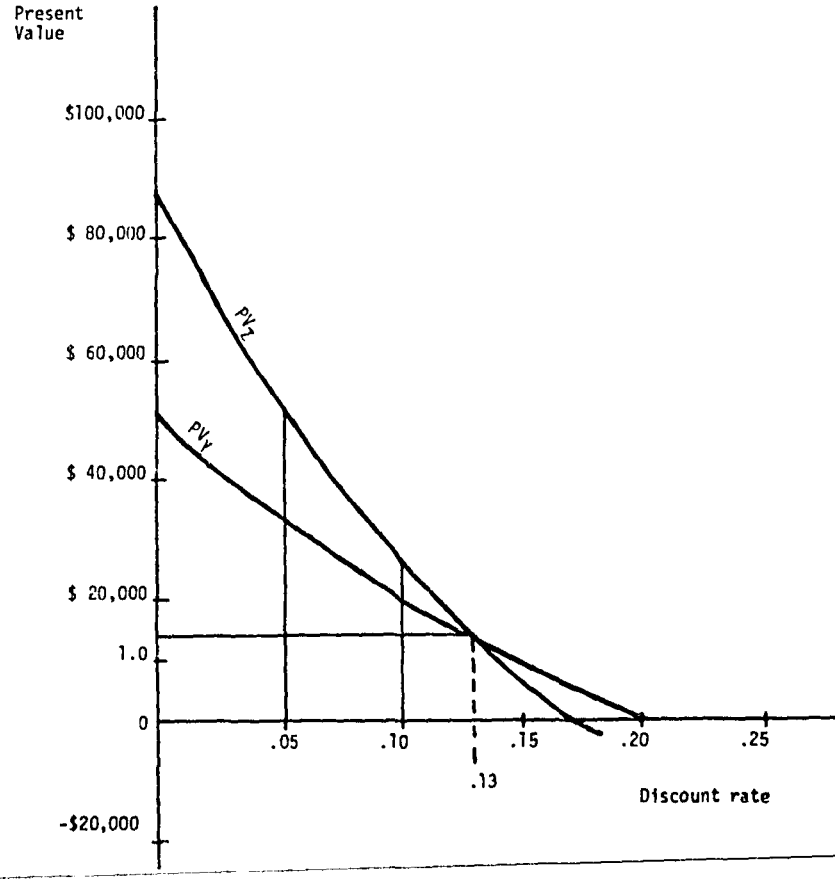
Project/Year	0	1	2	3	4	5
Y	−100	+50	+40	+30	+20	+10
Z	−100	−50	+60	+60	+60	+60

We already know that the internal rate of return of Y is about 20 percent. By using a similar series of successive approximations we can arrive at the internal rate of return of project Z, which turns out to be about 16.5 percent. According to the IROR criterion, we should choose project Y. But if we were to undertake a net present value calculation, this decision would be incorrect for all discount rates between zero and 13 percent. If the appropriate discount

rate was anything less than 13 percent, it would be Z, not Y, that had the higher net present value. Only if the appropriate discount rate was greater than 13 percent but less than 20 percent would the two criteria—internal rate of return and net present value—agree that project Y should be chosen. Figure 14.1 shows the present value of the two projects at different discount rates; the IROR of each project is given at the points of intersection of lines PV_Y and PV_Z with the horizontal axis. It would clearly be a mistake to pick project Y, if the appropriate discount rate was below 13 percent, despite the fact that it has a higher internal rate of return.

Figure 14.1

Comparison of PV Comparisons for Two Projects at Various Rates (0 to 20)



The IROR criterion is also unreliable when a project's net costs do not all come at the beginning. Suppose we have a project J with the following stream of payments:

Table 14.6

Stream of Project Payments (All Figures in Thousands)

Project/Year	1	2	3	4	5
J	−210	−100	+300	+200	−400

In computing project J's internal rate of return, we find that costs and benefits can be made equal at two different discount rates, around 5 percent and 25 percent.

(a) With $i = 0.05$

$$\text{Costs} \qquad\qquad \text{Benefits}$$

$$\frac{210}{1.05} + \frac{400}{(1.05)^5} = \frac{100}{(1.05)^2} + \frac{300}{(1.05)^3} + \frac{200}{(1.05)^4}$$

$$200 + 313.48 = 90.66 + 259.07 + 164.47$$

$$513.48 = 514.20$$

(b) With $i = 0.25$

$$\text{Costs} \qquad\qquad \text{Benefits}$$

$$\frac{210}{1.25} + \frac{400}{(1.25)^5} = \frac{100}{(1.25)^2} + \frac{300}{(1.25)^3} + \frac{200}{(1.25)^4}$$

$$168.00 + 131.07 = 64.00 + 153.60 + 81.92$$

$$299.07 = 299.52$$

If the appropriate discount rate is between 5 and 25 percent, the IROR criterion is of no help at all. Owing to these problems, most project analysts now counsel using the net present criterion whenever the appropriate discount rate can be determined.

3.03 *The Benefit/Cost Ratio*

Although the benefit/cost ratio criterion has been popular in the past—largely due to its simplicity—it is now considered unsatisfactory. The decision rule associated with it is to choose a project if its benefit/cost ratio (that is, its total benefits divided by its total costs) is greater than 1, and to reject it if the ratio is less than 1. With competing projects the criterion prescribes the project with the largest benefit/cost ratio. In many situations the benefit/cost ratio will lead to the same choice as the net present value and internal rate of return criteria. But, as with IROR, there are circumstances in which it can mislead us into selecting the wrong project. A principal deficiency of the

benefit/cost ratio is that it tends to prescribe projects with the largest returns per unit of cost rather than projects with the greatest net benefits. Suppose there is no budget constraint, and we have two projects, A and B, whose streams of payments have been discounted to their present worth.

Table 14.7

Net Present Benefits of Two Projects

Project	Benefits	Costs	Net Benefits	Benefit/Cost Ratio
A	$100,000	$10,000	$90,000	10
B	$1,000,000	$250,000	$750,000	4

In this instance, project A has a higher benefit/cost ratio, and according to the benefit/cost ratio criterion, should be selected. But B produces larger net benefits: since funding is not a problem, project B should be undertaken.

Moreover, the benefit/cost ratio depends on whether we define something as a cost or a benefit. A public utility, for example, may cost $1 million, generate $4 million of benefits, but cause environmental damage of $2 million. Depending on whether that damage is regarded as a positive cost or a negative benefit, the benefit/cost ratio is 2.0 or 1.33. If the environmental damage is added to the costs the ratio = $4 million/($2 million + $1 million) = 1.33. If the damage is subtracted from the benefits: ($4 million − $2 million)/$1 million = 2.0. The net present value criterion is not vulnerable to this ambiguity.

Nevertheless, the benefit/cost ratio remains a useful criterion when there is a capital constraint and there are a number of independent projects from which to choose. As in the example presented in Table 14.3, it serves to rank projects according to their (discounted) benefits per dollar of (discounted) costs. When the benefit/cost ratio of each project is computed, we then choose the project with the highest ratio until all our investment funds have been exhausted.

The current trend in project appraisal is away from the internal rate of return and the benefit/cost ratio, and toward the adoption of net present value as the preferred criterion for decision making. There are, however, some counter-indications: most evaluators of educational projects, and the World Bank in its project appraisals, continue to utilize IROR. The retention of the IROR criterion is unproblematic as long as a situation similar to that presented in Figure 14.1 does not hold, and as long as a project has front-loaded costs followed by an uninterrupted stream of net benefits. But, in general, because it is applicable in all circumstances in which the appropriate discount rate can be determined, the proper criterion to use is net present value. This is illustrated in the problem at the end of the chapter.

4.0 *Cost-Effectiveness Analysis*

Not all educational outcomes can be expressed in monetary terms. Often, project planners are interested not only in the effect that a particular education program will have on the participants' future earnings, but also on purely educational outcomes, such as the number of participants who successfully graduate, the number who repeat, the number who drop out, or the proportion of students that successfully passed a reading test. Whenever an educational project has objectives that cannot be measured in monetary terms—and this is almost always the case—the project evaluation must take the form of a cost-effectiveness analysis, a version of benefit-cost analysis. Cost-effectiveness is characterized by the measurement of costs and benefits in different units, a strategy which allows us to undertake an evaluation without the use of a common metric.

This sort of analysis is applicable when the costs of alternative projects are identical and therefore only benefits need be compared; or when benefits are identical and therefore only costs need be evaluated. In order to do cost-effectiveness analysis it is essential that project objectives be specific and clearly stated—that is, measurement of project outcomes and comparison of project costs are possible only when project objectives are made explicit and defined unambiguously. With projects that have multiple objectives, cost-effectiveness analysis becomes multidimensional, each objective requiring separate appraisal. The evaluation of a project that has succeeded in attaining certain objectives while failing to reach others depends on the decision maker's set of priorities, his "preference function." The planner's task may be to help the decision maker to make his objectives explicit, to help him rank goals according to his order of preference, and to evaluate the project's success in meeting each of the relevant objectives.

The technique of cost-effectiveness analysis may be illustrated by the following simplified example. Suppose there are two alternative methods available for teaching adult literacy in a rural community. Both methods involve setting up evening classes at the local elementary school. Method A is a six-month program that costs $100 per participant. According to previous experience with a similar project, A has a 90 percent success rate. Success in this instance is measured by the proportion of participants who pass a literacy test at the end of the project. Method B is an abbreviated three-month program that costs only $40 per participant, but has only a 50 percent success rate. The Ministry of Education has allocated $10,000 for an adult literacy program in the community. Five hundred adults are believed to need literacy training.

Neither method could be afforded if the goal was to cover all of the 500 illiterate adults in the community. Even the cheaper alternative would require an expenditure of $20,000. The question is which program will achieve more for the $10,000 the Ministry has available to spend on adult literacy. A simple calculation shows that Method A can cover 100 adults ($10,000/$100 = 100 people); on the average, 90 of the participants will have achieved literacy by the end of the program. Project B can cover 250 adults ($10,000/$40 = 250 people) of which 125 are expected to become literate. Since alternative B will produce a greater number of literate adults, it will be

the preferred choice, all other effects, including the attitudes of the 125 who fail, being equal.

The calculations and the criterion of choice are both quite similar to the benefit-cost technique which prescribes selecting the project with the greatest net benefit. In cost-effectiveness analysis, the decision rule is simply a variant of the benefit-cost rule: select the alternative that produces the maximum effectiveness. Method A produces .9 literate adults for every $100 spent, with an effectiveness of .009 (.9/$100 = .009) successful participants per dollar. Method B produces .5 literate adults for every $40 spent, with an effectiveness of .0125 (.5/$40 = .0125) successful participants per dollar. Table 14.8 sets up the decision problem under discussion.

Table 14.8

Cost-Effectiveness Decision Rule

Method	No. of illiterate adults needing program	Cost per person	No. of adults who can be covered	Probability of success	Effectiveness: participants successful passing test per $ spent
A	500	$100	100	.9	.009
B	500	$ 40	250	.5	.0125

It is possible that decision makers involved in this situation may have objectives in addition to the literacy goal already considered. They may, for example, also intend to affect the child-rearing or family-planning practices of the community. Each of these objectives will have to be clearly defined, and each will require a separate cost-effectiveness analysis. In general, cost-effectiveness analysis is a useful technique for project evaluation as long as we know what we want to achieve, or what we are allowed to spend.

5.0 *The Concept of Value*

Clearly, benefit-cost and cost effectiveness analyses are not very exact techniques. A further weakness, for some people, is that they are prescriptive tools which must rely heavily on normative judgements. Far from being weakened by this fact, cost-benefit and cost-effectiveness are powerful precisely because they utilize the value orientation of the relevant decision makers by making these values explicit, and by forcing decision makers to rank them. As tools for rational decision making, cost-benefit analysis and cost-effectiveness analysis encourage a systematic and thorough appraisal of all costs and benefits, though they may not always succeed in giving precise answers.

The issue of value permeates every aspect of project evaluation, from the consideration of what costs and benefits should be attributed to a project to the assignment of weights to each input and output. When the appraisal of a

project takes the form of an economic analysis, the central problems revolve around the difficulty of identifying and measuring all social costs and benefits. The problem becomes even thornier when we try to deal with the non-economic effects of an education project. If a principal objective is to reduce inequality among social clases in a community, what weight should we attach to educating a working-class student as opposed to one from the upper classes? Equally important, who should make this valuation? Some would object to any attempt at quantifying these kinds of objectives, and, particularly, to the assignment of numbers to value questions. The fact is, however, that everyone confronted with conflicting needs and scarce resources with which to meet them is forced to set priorities, and to rank his objectives in order of importance, at least in an implicit or intuitive way. The quantification of non-economic outcomes is merely the attempt to make these valuations explicit and to systematize how we think about them.

Many problems remain unresolved, most notably the questions surrounding the productivity assumption. Similarly, cost benefit and cost-effectiveness have not made much progress in coming to grips with education's other external effects such as its consumption value, as well as other social and cultural contributions of education. Nevertheless, cost-benefit analysis has the virture of posing the issue of costs and benefits sharply, thus encouraging efforts to improve the measurement of educational benefits. It also has the virtue of linking up with social demand by permitting comparisons of private benefits which influence parents and students with social benefits which affect government decisions.

Finally, despite the recent attacks on rational approaches to planning and the evident shortcomings of project appraisal techniques, the use of decision tools such as cost-benefit and cost-effectiveness analyses is growing. The reality of scarce resources and the need to make efficient use of them, coupled with growing apprehension about the misuse and misallocation of public funds, have served to increase the use of program evaluation techniques and to encourage efforts at improving them. More than ever before, decision makers are calling for evaluation at all stages of a project's life: in its planning and design, in the course of its operation, and at its termination.

APPENDIX 14.1

Net Present Value Analysis of a Village Nonformal Education Project

Example: Setting

The central government would provide training materials and a master carpenter to a village for two years to train five local carpenters' apprentices. The village would provide a suitable building to serve as a meeting place, heat during the winter months, and would have to pay $150 per year toward the teacher's salary. The village could pass on part of the cost to the participants by charging up to $50 per year to each. The village could also require participants to provide their own tools.

The village leaders calculate that a suitable building will cost $100 per year to rent and $50 per year to heat. They survey the village and find five carpenters' apprentices who are qualified and willing to attend the program. By chance, the apprentices all happen to be 28 years of age!

The main difference between this example and a case of an individual deciding to attend lies in the perspective of the decision maker. The central government must assess the advantages of investing in the program from the perspective of society as a whole. The basic questions concerning the investment are the same as those asked by the individual—but from the perspective of society.

(1) What additional costs does *society* incur from the project?

(2) What additional benefits will *society* receive from the project?

In an evaluation of this project, government analysts begin by listing the *amount* and *timing* of *all additional costs and benefits* which can be associated with the program. The concepts of *social cost* and *social benefit* are more complex than those for the individual. Social cost is the value of all resources used by the project, regardless of the sources from which funds and contributions come. Similarly, social benefits are the value of all the effects of the project.

2. *Determining a Time Horizon*

The first question for governmental analysts is the period of time over which they expect their decision to affect the economy. In the case of an individual, his entire working life would be the appropriate time horizon. In the present example of village training for carpentry we will make things easy by using the same time horizon, 32 years, for all five participants.

It should be noted, however, that the effects of this village program in nonformal education may well extend beyond the working lives of the indi-

vidual participants. For example, with increased incomes the families of the new carpenters may have more children at school for longer periods of time, with even more income resulting in the future. But the amount of these benefits to the next generation is difficult to know, and they will be discounted heavily because the time horizon is so many years ahead. Consequently, we note these benefits in our analysis of the village carpentry program but we have not assigned them values in our calculations.

Table A14.1 shows the various cost and benefit items in the nonformal education program for village carpentry. Explanation for each item follows:

3. *Cost and Benefit Analysis*

(1) *Teacher's Salary*
$650 at t_1 and t_2

A teacher is hired at $650 per year to give the five carpenters' helpers the skills required for master carpenters' work. Although $150 of the teacher's salary is in the village project budget, and $500 of the teacher's salary is paid by the central government, the total salary of $650 is the appropriate cost figure for the analysis. This figure reflects the value of the teacher's labor. Because the master carpenter is employed as a teacher, the economy has lost the goods and services he would otherwise produce, and those are valued at $650 per year.

(2) *Tools*
$200 at t_1

Five sets of tools are required for program participants at the beginning of the program, at $40 per set.

(3) *Building Rental and Heat*
$150 at t_1 and t_2

A suitable building has been found for the village project costing $150 a year for rent and heat. The fact that the village council, rather than the central government, is paying this cost makes no difference. All costs, regardless of source, must be included in Table A14.1.

We should point out that even if the village owned the building, and did not have to pay rent, there may still be an economic cost if other activities are displaced from the building as a result of the NFE program. In this case, the cost that should be listed in Table A14.1 would be the value of the building to the activity that is displaced—for instance, the rent they have to pay in a comparable place.

Another complication which sometimes arises in economic analysis of nonformal education has to do with shared facilities. For example, the village carpentry program might use a governmental school after school hours. If the NFE program creates additional costs by using the school or displaces other after-school programs, some reasonable share of facility costs should be entered in Table A14.1. The idea is to capture *all* costs of the program, whether they appear in the program budget or not.

(4) *Opportunity Costs of Participants' Time*
$2500 at t_1 and t_2

Table 14.1

A Governmental Investment Decision With Discounted Present Values

(1) Year in Project Time Horizon	(2) Current Value of Costs	(3) Current Value of Benefits	(4) Discounted Value of Costs @ 5%	(5) Discounted Value of Benefits @ 5%
t_1	$650 200 150 2,500 = 3500		$3,332[a]	
t_2	650 150 2,500 = 3300		2,993[b]	
t_3		$ 500		$431.90
t_4		500		411.35
t_5		500		391.75
t_6		500		373.10
t_7		500		355.35
t_8		500		338.40
t_9		500		322.30
t_{10}		500		306.95
t_{11}		500		292.35
t_{12}		500		278.40
t_{13}		500		265.25
t_{14}		500		252.55
t_{15}		500		240.50
t_{16}		500		229.05
t_{17}		500		218.15
t_{18}		500		207.75
t_{19}		500		197.85
t_{20}		500		188.45
t_{21}		500		179.45
t_{22}		500		170.90
t_{23}		500		162.80
t_{24}		500		155.05
t_{25}		500		147.65
t_{26}		500		140.60
t_{27}		500		133.90
t_{28}		500		127.55
t_{29}		500		121.45
t_{30}		500		115.70
t_{31}		500		110.20
t_{32}		500		104.95
Totals	$6,800	$15,000	$6,325	$6,971.60

[a] $\frac{\$3500}{(1.05)}$ from Table 10 = .9524 X 3500 = $3,332

[b] $\frac{\$3300}{(1.05)^2}$ from Table 10 = .9070 X 3300 = $2993

As in the case of the individual carpenter's helper, we are assuming that the five participants in the village program are giving up their jobs as carpenters' apprentices and, consequently, are giving up their earnings of $500 per year each.

This can also be viewed as a cost to society because, if the five individuals did not enroll in the NFE program, they would have spent the two years doing carpentry for various villagers and village projects. The apprentices would

have received payment for their labor, and the village would have received the products of their labor. When the apprentices go into nonformal education full-time, the village loses their production. The value of this lost production is the cost to the economy of the time the participants spend in training.

Economic theory suggests that in a competitive labor market which operates freely, wages indicate the value of a worker's contribution to production. So, for instance, the value of the five apprentices' lost production would amount to $2500 per year. But in some situations an analyst would have reason to think that wages are not a good measure of lost or foregone production. Indeed, in some situations there may be no wage scales readily available to gauge how much production is lost when participants enter nonformal education.

In these circumstances, economic analysts come up with a *shadow price*, to take the place of a wage figure, in order to indicate the approximate value of production which is lost. By shadow price we mean an estimate of someone's productive contribution to society when that cannot be judged from wages. Because these are estimates, procedure should be used cautiously, and reasons for using shadow prices rather than wages should be documented.

(5) *Increased Earnings*

$500 @$t_3$, t_4, t_5 . . . . . t_{32}

The total benefit to the economy from the village carpentry program is the value of the additional productivity of the participants as a result of the program. The projected increased earnings are used as an indicator of this additional production. In this example, we estimate that the newly trained carpenters will each earn $100 more annually, and the group will earn $500 more annually for 30 years following the training project.

In Table A14.1, column 3, this $500 is entered each year from t_3 to t_{32}, which is the working life of the trained carpenters after they complete the training program.

In column 5, this $500 is discounted each year of the working life by the familiar equation (2) from the text:

$$PV = \frac{FV}{(1 + r)^t}$$

For t_3, this equals $\$500/(1 + r)^t$ at 5% and t = 3: $\$500/(1.05)^3 = \$431.90$ (in table)

For t_4, the present value would be $411.35, and so on through each year of the project.

The analyst need not do the arithmetic above. He can simply consult a present value table at the appropriate interest rate and time period. We have referred in the text to large sets of tables of compound interest prepared by Stanford Research Institute and the World Bank. Table A14.2 is an excerpt from one of these large sets of tables, and it shows present value calculations for years 1 to 35, and then years 40, 60, and 80. It tabulates only the values of the interest rates 3%, 5%, 8%, 10%, 12%, and 15%. In the problem, the rate is 5%. The present values, year by year, of this interest rate are shown in Table A14.2.

Table A14.2

Present Value (PV) of a $1 Payment t Years in the Future Discounted at r

t	r = .03	.05	.08	.10	.12	.15
1	0.9709	0.9524	0.9259	0.9091	0.8929	0.8696
2	0.9426	0.9070	0.8573	0.8264	0.7972	0.7561
3	0.9151	0.8638	0.7938	0.7513	0.7118	0.6575
4	0.8885	0.8227	0.7350	0.6830	0.6355	0.5718
5	0.8626	0.7835	0.6806	0.6209	0.5674	0.4972
6	0.8675	0.7462	0.6302	0.5645	0.5066	0.4323
7	0.8131	0.7107	0.5835	0.5132	0.4523	0.3759
8	0.7894	0.6768	0.5403	0.4665	0.4039	0.3269
9	0.7664	0.6446	0.5002	0.4241	0.3606	0.2843
10	0.7441	0.6139	0.4632	0.3855	0.3220	0.2472
11	0.7224	0.5847	0.4289	0.3505	0.2875	0.2149
12	0.7014	0.5668	0.4289	0.3505	0.2875	0.2149
13	0.6810	0.5305	0.3677	0.2897	0.2292	0.1625
14	0.6611	0.5051	0.3405	0.2633	0.2046	0.1413
15	0.6419	0.4810	0.3152	0.2394	0.1827	0.1229
16	0.6232	0.4581	0.2919	0.2176	0.1631	0.1069
17	0.6050	0.4363	0.2703	0.1978	0.1456	0.0929
18	0.5874	0.4155	0.2502	0.1799	0.1300	0.0808
19	0.5703	0.3957	0.2317	0.1635	0.1161	0.0703
20	0.5537	0.3769	0.2145	0.1486	0.1037	0.0611
21	0.5675	0.3589	0.1987	0.1351	0.0926	0.0531
22	0.5219	0.3418	0.1839	0.1228	0.0826	0.0462
23	0.5067	0.3256	0.1703	0.1117	0.0738	0.0402
24	0.4919	0.3101	0.1577	0.1015	0.0659	0.0349
25	0.4776	0.2953	0.1460	0.0923	0.0588	0.0304
26	0.4637	0.2812	0.1352	0.0839	0.0525	0.0264
27	0.4502	0.2676	0.1252	0.0763	0.0469	0.0230
28	0.4371	0.2551	0.1159	0.0693	0.0419	0.0200
29	0.4243	0.2429	0.1073	0.0630	0.0374	0.0174
30	0.4120	0.2314	0.0994	0.0573	0.0334	0.0151
31	0.4000	0.2204	0.0920	0.0521	0.0298	0.0131
32	0.3883	0.2099	0.0852	0.0474	0.0266	0.0114
33	0.3770	0.1999	0.0789	0.0431	0.0238	0.0099
34	0.3660	0.1904	0.0730	0.0391	0.0212	0.0086
35	0.3554	0.1813	0.0676	0.0356	0.0189	0.0075
40	0.3066	0.1420	0.0460	0.0221	0.0107	0.0037
60	0.1697	0.0535	0.0099	0.0033	0.0011	0.0002
80	0.0940	0.0202	0.0021	0.0005	0.0001	0.0000

Using Table A14.2, we can easily get the values in column 5 of Table A14.1. The value in Table A14.2 shows the present value of $1 invested at 5% for various years. For 5% at three years the value is .8638. To get the value in column 5 of Table A14.1, we simply multiply this by the number of dollars, which is 500, and the answer is:

$$t_3 = \$500 \times .8638 = \$431.90$$
$$t_4 = \$500 \times .8227 = \$411.35$$
$$t_{32} = \$500 \times .2099 = \$104.95$$

The discounted values in the cost column (column 2) and in the benefits

column (column 5) are added up to give the bottom-line values of Table A14.1. Note that the costs and benefits are discounted in the same way, using the same table, the same interest and the appropriate year.

4. *Summarizing*

As we saw earlier, when examining the investment decision by an individual, cost-and-benefit information needs to be summarized. Table A14.1 first states all costs and benefits in current dollars. Then Table A14.1 givs the same information at a common point in time, that is, the discounted present value of each item using a 5 percent discount rate.

From Table A14.1 we learn that the discounted present value of benefits in the village program is greater than the discounted present value of costs. This nonformal education project is a good social investment—from a long-term economic standpoint.

Source: *A Manual for the Analysis of Costs and Outcomes in Nonformal Education*. International Office, Educational Testing Service, Princeton, N. J.

CHAPTER 15

Heuristic Methods for Planning

Delphi Method: reviewed by Russell Davis
Compass Method: developed by Barclay Hudson

1.0 *Introduction*

This volume on planning methods has been weighted toward models, systematic analysis methods, and set procedures for problem solving. These approaches yield computable solutions, and thus they are called *algorithms*. There are many planning tasks that are best approached with the more open-ended search procedures called heuristic methods or models. Heuristic methods are not confined to standard formats or set procedures, and are therefore well suited to improving problem definition, accommodating dialectical processes, and tracing broad trends into distant futures. The latter task is called futurology. All three of these tasks—problem definition, accommodation of dialectical processes, and futurology—are important in planning.

The planner must define his problem by identifying, observing, and relating its relevant variables before he can develop models or apply analysis. Premature closure on problem specification means a partial, invalid, or irrelevant solution. Heuristics can serve by stimulating research or discovery. Through open-ended search, new variables can be added and new relationships defined and measured.

Planners must often attempt to analyze and model a social process to which participants bring ideas and counter-ideas, values and counter-values. The process may become a dialectical one, in which there is a confrontation of oppositions, sometimes leading to domination of one position over the other, sometimes to cycles of alternative influence, and sometimes to a higher synthesis. The planning process must accommodate the dialectical process, and in conflict situations heuristic methods stimulate the articulation of competing views. We will be examining a method for stimulating a dialectical process called *Compass*, an approach developed by Hudson (1979) to aid policy assessment and planning.

The planner deals with the future. Chapter 7 stated that Friedman (1973) segments this future into three domains. First, there is the *near future*, which is the domain of the systems planner. Planners study the near future with projections and forecasts. These methodologies have been covered. Secondly, there is the *historical future*, which is the domain of ideological thought. Here policy planners must cope with the dialectical process. Finally, there is the *ahistorical future*, which is the domain of utopian thought and futurology. In our view the planner must deal with all three domains, and in any given

situation his major preoccupation may be either the *near future,* the *historical future,* or the *ahistorical future,* or all three in some mixture. The day-to-day work of the planner may be truly grounded in methods for analyzing the *near future,* but concern with more distant future will constantly intrude, and for futurology, heuristic methods often serve better than systematic forecasts.

1.1 *The Objectives and Content of This Section*

The objectives of this section are:

— To provide general background knowledge on the heuristic methods which are used in planning to improve problem definition, accommodate dialectical processes, and provide a framework for futurology.

— To describe briefly a number of heuristic methods used in planning. There will be no attempt to offer detailed descriptions and elaborations on these methods. Much less will there be detailed instruction on how to apply these methods, as in the case of instructional units on population projection and manpower analysis. One reason for this is that there is not all that much to the methodologies, and hence step-by-step technical presentation is not required. Some of the methodologies have been improved upon by experts who have brought in techniques from mathematics and statistics; but these elaborations are not necessary for planners who wish to use heuristic methods. The contrary point is argued here. Heuristic techniques are useful for compact policy assessment where their virtues are speed, economy, and, above all, the fact that they are simple to understand and apply.

— To describe and elaborate two heuristic methods as examples of useful forms for compact policy assessment. The first is Barclay Hudson's Compass, a simple workshop-based heuristic method which is used by social planners to define issues and problems and accommodate dialectical processes. This is a typical heuristic method in that there are few formal and technical features to the methodology. A second heuristic method is Delphi. This is an older technique, considerably more elaborated with borrowings from statistics and the social sciences. There are several variants of Delphi, the simplest of which is the Conventional Delphi, or Delphi Exercise (pencil and paper).

We will look at a Delphi exercise used for clarifying planners' ideas about future developments in the field of education and development. We will briefly describe Real-Time, or Conference, Delphi, which is a form of Delphi Exercise. The Real-Time Delphi is usually based on a computer operating in interactive mode. There is also the Policy Delphi, where exploration of issues and discussion and development of policy options are encouraged. Unlike the Delphi Exercise, the Policy Delphi does not aim at consensus, but is very similar to the heuristic method called Compass.

The material of this chapter includes:

— A brief description of the Delphi Exercise and the Policy Delphi;

— A description of a second heuristic method called Compass;
— A comparison of Compass and Delphi;
— A Glossary, which briefly describes other heuristic methods;
— An Appendix, which shows a questionnaire used in a Delphi Exercise on education and development futures.

2.0 *Delphi*

Delphi is a heuristic methodology designed to structure the opinions of an informed group in order to analyze and clarify policy, planning, and futures issues. A knowledgeable group is asked to give its opinion on possible future development of important issues. These opinions are pooled and analyzed, and over time some form of group consensus is sought. This is the Conventional Delphi or Delphi Exercise, and the procedure as described by Linstone and Turoff (1975) is:

— A questionnaire on the issues or problems under study is designed by a monitor or control team, which is the group running the exercise (see Appendix 15.1 for an example of such a questionnaire.)
— The questionaire is sent to a large group of respondents who have knowledge of the issue or problem under study.
— The respondents state their opinions in answer to the questionnaire and return their answers to the monitor team.
— The monitor team summarizes the answers of the respondent group on the first round of the questionnaire and feeds this information back to the respondents, along with a revised questionnaire for the next round.
— Individual members of the respondent group have the opportunity to change their original opinions and make them converge toward the group average. Methods for creating convergence and consensus will be shown in the following section. To gain consensus, the monitor team shows individual respondents how far they diverge from the group average on opinions. Over successive rounds there is an attempt to move divergent respondents toward the group average. (Note: This is true of the Delphi Exercise where consensus is sought, but not required of the Policy Delphi.)
— The respondent group again fills out the second-round questionnaire and sends it back to the monitor team, which summarizes the answers and gives the group a chance to reevaluate their replies. The monitor team prepares a new-round questionnaire.
— The procedure goes on iteratively for three or more rounds, and the monitor team analyzes the way individual members' opinions converge toward some average or consensus.

In a newer form called the Delphi Conference, or Real-Time Delphi, the monitoring and circulation of successive rounds of the summaries are done by computer, which compiles the group results and feeds them back to the individual respondents.

2.1.1 *The Policy Delphi*

The Policy Delphi differs in purpose and use from either the Delphi Exercise or Delphi Conference. The Delphi Exercise and the Delphi Conference are designed to move toward group consensus, and hence those methods can use pooled opinions to trace future policy implications, technological developments, plan outcomes, or future developments. The Policy Delphi, in contrast, is designed to generate strong opposing views on major policy issues, and hence it is useful primarily for exploring issues and accommodating dialectical processes in support of alternate policies. The Policy Delphi is similar to Compass in purpose and use. The Delphi Exercise is different; it is used mainly in forecasting. All forms of Delphi are heuristic methods for open-ended exploration and definition of issues.

2.1.2 *A Delphi Exercise example*

An example of a simple Delphi Exercise is given in Appendix 15.1 at the end of this chapter. The methodology centered on successive rounds of a questionnaire designed to get the expert opinions of educational planners on future happenings in education and development. The questionnaire, which was submitted to education planners and officials, was designed to identify future developments in education that would affect planners and policy makers.

The purpose of the exercise was to introduce educational planners to the topic of futurology, to introduce heuristic methods and the Delphi technique, to identify important emerging issues in education and development that planners should be aware of in developing their plans, and, lastly, to provide guidance for developing forward-looking curricula on issues in education. The questionnaire was given to planners and policy makers who were experts in the fields of education and development. The planners estimated present and future possibilities. The estimates were summarized and reported back to participants. In three rounds of exchange, some consensus on the future of education emerged, as well as some firm differences.

2.1.3 *The general stages of a Delphi Exercise*

Delphi exercises similar to the one shown in Appendix 15.1 usually go through several stages. Linstone and Turoff (1975) list four stages in the process, whether or not the exercise is a paper-and-pencil questionnaire or real-time interaction with a computer:

(1) Exploration of the theme of the exercise: During this time the respondents contribute their own versions of information on the topic, or their attitudes toward the issue. This is an essential test of the validity of the exercise and an important criterion for judging whether the respondents are truly participating, or merely passive observers. The exercise in Appendix 15.1 worked reasonably well at this stage when it was submitted to educational leaders, policy makers, and some planners in developing countries. It

did not work when it was submitted to teachers and planning technicians. They simply waited for the experts in the monitor team to give them more information.

(2) Clarification and understanding of the meaning of the issue from the viewpoint of the members of the respondent group: The Delphi Exercise questionnaire in Appendix 15.1 provoked two kinds of disagreement and resistance among the respondents. First, there was disagreement about the terminology and format of the questionnaire. Respondents wanted to know what the framers of the questionnaire had in mind when they asked for judgement on the importance of an issue. They also wanted to know what it meant to rank a possible future event from *bad* to *good*. There was a second kind of disagreement that centered on the meaning of the words used in the questionnaire items. For example, some educators wanted to know what the designers meant by *economic development*, as it was used in the first item of the questionnaire. The monitors defined this in terms of growth in GNP. Early versions of the second item used *cultural patrimony*, and many did not know what this meant. It was changed simply to *culture*. Linstone and Turoff (1975) recommend exploring significant disagreements on meanings in later phases of the exercise. Experience with the exercise in Appendix 15.1 indicated that sophisticated participants will refuse to continue with the exercise until all meanings are clear and all items revised.

(3) Exploration and resolution of disagreements would be the third stage of an exercise if the questionnaire itself were generally acceptable. If the questionnaire is not accepted, then it must be redesigned and the exercise started again from the outset.

(4) The fourth phase is a final assessment after response data have been analyzed and fed back to the respondents, and the opinions of the respondents have begun to converge.

Statistical measures of central tendency and dispersion can be used to guide respondents toward convergence by reducing extreme spread and moving *outliers* (respondents whose opinions diverge markedly from the group) closer to the group average. The simplest technique is the use of the median as a measure of central tendency, and the inter-quartile and the semi-quartile range as measures of spread. We can best illustrate this by referring to the Delphi Exercise in Appendix 15.1.

2.2 *Convergence in Delphi*

The third column of the questionnaire in Appendix 15.1 asks the respondents to indicate when they believe some change may take place. The date will be within the period of years from 1980–2020.

1980 1990 2000 2010 2020

Suppose that 50 percent of the respondents report in the first round that they think the event will occur on or before the year 2000, and 50 percent think it will occur after. Then the group median is at 2000:

median

1985 1990 2000 2010 2020

This can be fed back to individual respondents in the second round, and they can see how far their estimate diverges from the group's. Respondents may also be asked to give reasons for their estimates. This may lead *outlier* respondents to move closer to the group median. Hence, Delphi is often described as an exercise which seeks consensus or convergence in a group. Suppose also that 25 percent of the group think that the event will occur on or before 1990 and 25 percent think that it will occur after 2010. This marks out the inter-quartile range, i.e. the range in which the middle 50 percent of respondents say the event will occur (see figure).

25% 50% 75%

median

1985 1990 2000 2010 2020

inter-quartile range

If a respondent has indicated in his estimate that the year will be after 2010 for example, the monitor group can show how much this estimate deviates from the group inter-quartile range. The respondent may again be asked to explain why he feels his estimate is right when it deviates from the pooled estimates of other respondents. After three or four rounds, estimates may converge, or they may congeal at an extreme. Convergence is a strength of Delphi if consensus is sought. It may also be a weakenss if false consensus is forced. Some *outliers* may persistently refuse to move their estimates toward the consensus value. This can also be important information, especially when it is accompanied by a reasoned rationale for the disagreement.

More refined statistical techniques can be applied to Delphi results to measure convergence, or to guide respondents toward convergence, but the methodology is essentially simple. High precision in statistics is not warranted. In general, we should simply note that the Delphi Exercise, but not the Policy Delphi, attempts to move respondents toward consensus on successive rounds by:

— Indicating where the group estimate lies and where the individual estimate lies in respect to the group;

— Asking individuals whose estimate depart widely from the group estimate to justify their divergent estimates;

— Developing group convergence and consensus over the rounds of the exercise or revealing reasons for persistent divergence;

Turoff (1975) discribes a very different process for the Policy Delphi. He lists the phases:

— Formulating what the issues for discussion are.

— Laying out the policy options, given the issues.
— Determining initial positions as to the important issues, and identifying disagreements.
— Exploring the reasons for the disagreements and clarifying underlying assumptions and views.
— Getting group evaluations of the underlying reasons for support of positions.
— Reevaluating of the policy options on the basis of an assessment of the underlying evidence.

These steps do not suggest a process that is inexorably leading toward convergence and concensus, and this is precisely the point in which the Policy Delphi differs from the Delphi Exercise. The Policy Delphi brings underlying differences on issues to the surface and thereby lays out policy options for dialectical exploration. There is no attempt to move toward definitive solutions, decisions, or even single views of the future. Hence, the Policy Delphi is used for exploration of social issues, definition of social problems, and consideration of alternative policy options. It is a valuable technique in the repertoire of heuristic methods available to planners.

3.0 *Compass: An Approach to Compact Policy Assessment*

Compass is a fast and inexpensive procedure for exploring policy issues, summarizing the pros and cons of a policy proposal, or organizing divergent evaluations of the outcomes from completed projects. Compass is essentially a workshop form and, unlike the Delphi Exercise but similar to the Policy Delphi, it is designed so that participants will be in direct, competitive dialogue. In fact, opposition and struggle are essential to the dialectical process which Compass is designed to stimulate. Participants in the workshop may be limited to a small team of subject experts, or the procedure may be adapted to open public hearings or participatory planning in community settings.

The two major structural roles in Compass are *project manager* and *moderator*. The project manager is in charge. He controls resources and staff and usually is a responsible person or decision maker in an organizational setting. The moderator manages the Compass sessions and the social interchange.

3.1 *Stages in the Operation*

Compass operates in two stages. The first consists of a brief workshop, from which findings issue in a brief interim report for critical feedback. The entire process spans about 24 hours. The second stage is optional, consisting of follow-up investigation into the tentative conclusions and key issues raised in the first report. This can range from a day to two weeks.

COMPASS opens when the moderator provides participants with a brief statement of the scenario (forecast, policy proposal, design plan . . .) to be

discussed. The workshop begins with a canvass of informed opinions on possible outcomes from the existing issue or program proposal. Program impacts are listed in a graphic display, noting especially the emerging points of disagreement and uncertainty. The procedure is structured, but in ways quite different from Delphi methods or ordinary public hearings. The pace is faster, and the decision options are better defined. A central feature of the process is the maintenance of a graphic record of summary issues. The opposing views and the pros and cons of issues are summarized graphically by the moderator. The objective is to maintain a graphic display of salient points of view at all times. The fairness with which views are written and displayed is critical. A large (3′ × 5′) strip of butcher paper is useful to record and display the development of an extensive discussion and to keep major developments in view. It can be removed and saved as a record, or it can be cut up and sorted when a summary report on the session is written and edited. Detailed rationales for positions are kept off the record at this stage. Supporting arguments and evidence are kept to a minimum. The objective at this stage is mainly to raise or scan issues, not to try to resolve them.

The process of issue-scanning in the first workshop may take an hour, or possibly several. It can go through several iterations, focusing on a series of policy alternatives, or later involve specialized groups of participants for deeper analysis of issues raised in earlier rounds.

In preparing the report for this stage, the record from the graphic display is presented intact. It is also reworked into an agenda for follow-up research on points of uncertainty and disagreement. The graphic display serves several purposes during the workshop. It keeps the overall shape of issues in view, preventing polarization of opinion around isolated points. It also provides participants' continued access to earlier points, encouraging second thoughts about earlier assumptions and often leading to important insights. The graphic record keeps discussion concise: it helps prevent wasted repetition of statements, it reassures people that they have been heard, and it reminds them that whatever they have to say must ultimately be reduced to a single key phrase or illustrative example.

The second stage of Compass consists of follow-up actions which may take several directions. One is short-term intensive research into critical issues raised in the workshop. In selecting priorities for investigation, the issues are screened according to several criteria:

- Issues of fact, value and cause-effect are separated out—an important step insofar as these need to be resolved by distinct methods of scientific, political, and historical inquiry.
- Genuine points of contention are separated from matters of simple misunderstanding Most attention is given to issues reflecting the expressed concerns of important groups affected by decisions, whose support for alternative policies hinges on the results of further investigation.
- High priority is given to the clarification of issues that bear directly on the relative merits of specific policy options being considered.

— Special attention is focused on issues which can be resolved on the basis of existing knowledge or with results from short-term follow-up investigation. Issues requiring more elaborate research and original data-gathering are considered only secondary targets of effort.

The Compass approach can be applied to a range of specialized problems—for example, policy interpretations of forecasting, or analysis of social impacts in connection with environmental impact reporting. Another application of Compass is in drafting of funding proposals for policy research or evaluation of experimental programs, where key issues and appropriate research methods need to be spelled out as concretely as possible in advance of the main effort.

4.0 *Mechanics of Running a Compass*

We will take a typical project and describe the functions of the two persons with major roles and responsibilities. The *project manager* may be a policy decision maker, a corporate troubleshooter, the principal investigator of a research project, a task force coordinator for an interjurisdictional planning effort, or perhaps a funding agency officer.

The *moderator* can be a member of the organization or part of the in-house staff, but some of the moderator's functions are best carried out by an outsider, especially in helping tacit assumptions to surface. It might be difficult for an organization's own members to expose these assumptions.

In order to run a Compass session to define specific tasks in a large project, the *project manager* has these responsibilities:

— He must commit a small but definite budget of time and staff resources to the Compass effort—perhaps 1 to 5 percent of the total. This means asking staff to devote a few hours or days to a very intensive and quite unorthodox form of policy research. If outside participants are to be included, a list of names must be prepared and invitations made.

— He needs to authorize consideration of a very concrete policy proposal—something that might conceivably constitute an end product of the overall research effort. The proposal might be hypothetical, or a genuine best guess. It might be the leader's own idea, or might be derived from speculative thinking encouraged among the research staff. It might be a suggestion offered by the moderator, based on exposure to background materials on the project, or general knowledge of the field.

— The project manager needs both the authority and mental flexibility to modify research priorities and reassign tasks based on results of the Compass session. Otherwise the effort is relatively pointless.

The *moderator* has three functions:

— First he must help crystallize a proposal—for discussion—for example, to expand or close out a program, to adopt a new line of

policy, to revise a physical plan in a specific way, to revise a forecast toward a specific target. The proposal can be a straw man, or a serious working hypothesis, or it may represent the outcome of an earlier study needing critical review. (Experience suggests that the moderator can often suggest a concrete proposal for debate more easily than a project manager: the moderator is not so inhibited about making naive and premature suggestions, nor so defensive about freewheeling criticism of proposals offered.) The moderator must also consult with the project manager to set the specific question. For example: "The issue is whether to adapt Plan A with modification B. What are the pros and cons?" Or, "Let's assume the worst—that population will grow 30 percent faster than predicted. Do we stick with Plan A anyway?"

— The moderator manages the Compass session itself. He can keep it shortened to half an hour for a simple canvass of pros and cons. Generally, however, the session takes the good part of a morning or afternoon, allowing participants to review the results and identify key points of agreement and disagreement. They may also want to push further on one or more new lines of thinking opened up in the course of debate. Pros and cons are summarized on the graphic display which has been described.

— The moderator edits the graphic display into a 7 to 10-page preliminary report on findings, delivered with 12-36 hours, depending on his/her stamina, available logistic support, and editorial assistance. Editing mainly consists of (a) clustering pros and cons around points of consensus or debate, identifying the grounds of disagreement (factual uncertainty? value conflicts? cause-effect assumptions?); (b) highlighting key issues based on a subjective sense-of-the-meeting or straw vote at the session's conclusion; and (c) specifying short-term lines of attack on those issues which seem objectively resolvable, and directly bearing on practical policy choices.

— The moderator is responsible for surveying reactions to the preliminary draft. He may prepare a revised version incorporating refinements, dissenting opinions, and relevant supporting data.

— The moderator should also be prepared to work with the project manager and staff to set up compact forms of follow-up investigation into key issues, including design of task force roles, collaboration with outside agencies, and comparative case review of historical precedents for policies under consideration.

4.1 *Products and Outcomes of COMPASS*

- First, there is the workshop graphic display, serving as immediate overview of issues raised (1-2 hours).
- Second, there is an immediate follow-up report, providing opportunity for immediate feedback and revisions (12-36 hours). In subsequent drafts, minority opinions and technical appendices may be added for support on positions expressed.
- Third, Compass provides a written agenda for high-yield research, focusing on remaining areas of uncertainty and disagreement that directly affect policy. It defines special areas of expertise and appropriate combinations of techniques needed to triangulate on findings.

- Fourth, results can be written up to dovetail into traditional management and planning formats, such as technical reports, legislative analyses, or implementation guidelines.
- Finally, Compass provides a structured but open-ended procedure for communication and mutual understanding among members of a highly diversified group jointly concerned with solving a shared concrete problem or exploring a specific scenario.

5.0 *A Comparison of Compass and Delphi*

Delphi makes a good baseline for comparing the Compass approach. Both are examples of compact policy assessment. (Appendix 15.2 describes Compact Policy Assessment and other heuristic approaches).

5.1 *Similarities between Compass and Delphi*

Major similarities between Delphi and Compass are as follows:

- Both are designed to *address complex problems,* and both aim at a systematic display of important policy issues.
- Each provides its own *fairly simple procedural formula* for canvassing informed opinion about social processes, policy impacts, and the feasibility and desirability of new policy actions. When the methods are applied, the formulas can have many variations, which will depend on the moderator's sensitivity to group processes, as well as on the project director's objectives and the organizational setting of the discussion. In this sense, both constitute an art as much as a science, a communication process rather than a decision algorithm.
- Both offer capacity to develop *results based on judgment* in circumstances where judgment plays an important role: (a) as a surrogate for unobtainable data; (b) as a context for liberating intuitions and imagination in the discussion; and (c) in dealing with attitudes, feelings, and subjective interpretations.
- Both deal with issues that cannot be resolved by recourse to objective almanac-type facts, but only by a process of *refereed advocacy* or systematic confrontation between rival views.
- Both methods emphasize the value of *fruitful tension* between opposing views. Neither looks for truth solely in consensus. Differences of opinion are treated as signposts for exploring alternative futures, gaining fresh perspective on social processes, and pointing out new requirements for policy design.
- Both seek to *economize on information-processing* by minimizing discussion in areas of general consensus. Only where divergent opinions are at stake do they give freer rein to explicit marshalling of arguments and evidence to support advocacy positions on each side of the issue.
- Delphi and Compass share the same *pitfalls* associated with any form of compact policy assessment. Problems of bias can arise in the selection of participants; in the personalities of the persons who are monitoring the Delphi process or moderating the Compass process; in peremptory deflection

of minority opinions; or in falling into a particular language, logic, or conceptual paradigm for defining policy issues. It is easy to overspecify any method, denying the need to adapt it to particular problem-solving situations. It is also easy to overlook the demanding nature of each method, misusing it by ignoring the finesse that comes from experience.

5.2 *Differences Between Compass and Delphi*

Compass is distinct from Delphi in a number of respects, some substantial, some merely reflecting differences in emphasis. Starting with the most important:

- *Compactness.* Compass is basically a half-day procedure resulting in an immediate, concise report with optional stages of follow-up. Delphi is considerably more elaborate.
- *Definition of issues.* Delphi often focuses on dimensions of a situation that can be depicted by some scalar response, as, for example, rating scales or dates. In contrast, the policy issues raised in Compass are open-ended. A single question is used to catalyze responses—"Are you for Policy X or against it—and why?" The aim is to promote discussion, dialectical process, and even confrontation.
- Compass begins with *a concrete scenario*—a context specific enough for participants to have a solid base for expressing judgments. In contrast, Delphi inquiries usually refer to general propositions or conceptual qualities abstracted from a larger social context.

Compass was initiated in part as a response to the limitations on the rational comprehensive tradition of urban planning, and draws on alternative traditions, including advocacy planning, incremental planning, and transactive planning (see Hudson, 1977a, 1977b, 1978).

6.0 *Conclusion*

The use of heuristic methods in policy analysis and planning has been discussed. An overview of heuristic methods used for exploring current and future social issues has been offered. Two methods, Delphi and Compass, have been described in some detail. This study should indicate that there is no extensive technical methodology essential to either approach. Experts have elaborated the methods, especially Delphi, with techniques borrowed from mathematics and statistics, but these refinements are not essential to mastering and applying the methods. Readings are suggested in the Bibliography for those who wish to cover heuristic methods and futurology in greater depth.

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APPENDIX 15.1

Delphi Exploration of Educational Futures

Introduction to Exercise

You are asked to make some judgments. In the first column, if you judge that the statement is of no importance, place a check mark and go to the next statement. If you simply can't understand or judge the statement, place a check in the second column and go on to the next statement. If you judge the event in the third column impossible, circle zero and go on to the next item. If you judge that the event is possible (occur before 2020) circle a number in ascending order of possibility. In the next column, indicate the date for this possible event to occur sometime. In the final column, circle your judgment as to whether the event will be *bad*—lower numbers on scale; or *good*—higher numbers on scale. If you judge that the event has taken place, or condition now exists, mark *Now* in the *Year Event* column.

Change statement	No importance	Can't judge	Possibility: Impossible (0) … Almost certain (6)	Year event will occur sometime	For better or worse: Bad (1) … Good (6)
I. Education and Development					
1. The major goal of education will be to promote economic development.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
2. The major goal of education will be to preserve the culture of the country	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
3. Education will be designed to attain and maintain economic and social equity.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
4. The primary objective of education will be to foster social adjustment of individuals.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6

Change statement	No importance	Can't judge	Possibility: Impossible (0) – Almost certain (6)	Year event will occur sometime	For better or worse: Bad (1) – Good (6)
5. Basic skills and acquisition of cognitive learning will be the main objectives of schools.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
6. Ethical development will be the first objective.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
7. Intellectual development will be the only important objective of instruction.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
II. International Exchange					
1. International assistance agencies (UNESCO) will aid non-formal education only.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
2. Agencies will provide assistance for work related and vocational-professional education only.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
3. Agencies will provide assistance for training only within firms and production context, i.e., no assistance to schools and training centers.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
4. Capital assistance (World Bank Loans) for school facilities and equipment will end.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
5. Provision of satellite supporting technology and software, will dominate educational assistance.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
6. World Education Center will be established.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6

Change statement	No importance	Can't Judge	Possibility: Impossible (0) – Almost certain (6)	Year event will occur sometime	For better or worse: Bad (1) – Good (6)
III. Instructional Technology					
1. School systems will have only a few teachers to monitor and reinforce computer aided instruction and provide counseling. For example, a team of three monitor-discussants would handle all six grades of a 200 pupil elementary school.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
2. Bound books will be a rarity and most instructional material will be in expendable form similar to computer print-outs.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
3. All elementary schools, even in poor countries, will be linked to ITV (Instructional TV) and computers.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
4. Satellite and transmission facilities to support ITV will be under international authority.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
5. The major professional role in education will be two: A. Designers and producers of computer and ITV software. B. Counsellors and Discussion leaders	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
6. The major paraprofessionals will be: A. Technicians to run and maintain computer and ITV equipment. B. Program librarians and instructional resource technicians.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6

Change statement	No importance	Can't Judge	Possibility: Impossible (0) – Almost certain (6)	Year event will occur sometime	For better or worse: Bad (1) – Good (6)
IV. Organization of Instruction					
1. In most countries, instruction will be completely flexible with no fixed hours days or calendars	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
2. Instruction will be brought into homes rather than delivered in centers called "schools."	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
3. Schooling, or formal instruction, will be delivered in small, flexible increments throughout the life times of learners.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
4. Work training, either at vocational or professional levels, will be taken out of schools and carried out in work sites.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
5. Many schools or learning centers will be cooperatives owned and managed by parents or students.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
6. Post-secondary schools will be governed by boards of trustees on which students form a majority.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
V. Instructional Topics					
1. Conservation of resources will be a major instructional topic in schools the world over.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
2. Avoiding consumption and waste will be a major topic.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
3. Social cooperation and avoidance of competition will be a major topic.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6

Change Statement	No importance	Can't judge	Possibility Impossible (0) – Almost certain (6)	Year event will occur sometime	For better or worse Bad (1) – Good (6)
4. International peace and cooperation will be a major topic.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
6. Socialism will be the major form of political and economic organization fostered through education.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
7. Religion and belief in Divine being will be central in all curricula.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
8. Ethical practice will be a central topic in schools throughout the world.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
9. A composite of theology and ethics from all major world religions will be synthesized and become a central teaching-learning topic.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
10. Children will be taught to access and use computers from early ages (5-7) on.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
11. Reading skill will not be required of all students in schools	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
12. A world language will be taught and used by all students from early ages on.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
13. Learners will be required to master at least two languages before the age of 15.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
14. Learners will be required to master mathematics through intermediate calculus before the age of 15.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
15. Instructional programs will be developed and made available for training other intelligent animals besides man.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6

Change statement	No importance	Can't judge	Possibility Impossible (0) Almost certain (6)	Year event will occur sometime	For better or worse Bad (1) Good (6)
16. After the age of 10, children will regularly be released for work periods of increasing length during the school day.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
17. Children will learn at a rate and level that is almost double the present average.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
VI. Education and Societal Value Change					
1. A significant decrease in traditionalism.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
2. A significant decline in authoritarianism.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
3. A significant decline in materialism.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
4. A significant decline in acceptance of bureaucratic corruption.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
5. A significant increase in participation in societal decision making.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
6. A significant increase in the value of creativity and self-expression.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
7. A significant increase in the respect and value placed on manual work.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
8. A significant increase in respect and value placed on agriculture and rural pursuits.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
9. Significant rise in status of women.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
10. Significant increase in value of time as resource.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6
11. Significant increase in sense of efficacy.	___	___	0 1 2 3 4 5 6		1 2 3 4 5 6

Change statement	No Importance	Can't Judge	Possibility Impossible (0)	Almost certain (6)	Year event will occur sometime	For better or worse Bad (1)	Good (6)
12. Significant decrease in fatalism.	___	___	0 1 2 3 4 5 6			1 2 3 4 5 6	
13. Significant increase in respect for religious authority.	___	___	0 1 2 3 4 5 6			1 2 3 4 5 6	
14. Significant increase in cooperative work.	___	___	0 1 2 3 4 5 6			1 2 3 4 5 6	
15. Significant decrease in preoccupation with self.	___	___	0 1 2 3 4 5 6			1 2 3 4 5 6	
16. Significant increase in need of self-actualization and satisfaction.	___	___	0 1 2 3 4 5 6			1 2 3 4 5 6	
17. Significant gain in satisfaction with work.	___	___	0 1 2 3 4 5 6			1 2 3 4 5 6	

APPENDIX 15.2

Glossary of Selected Heuristic Methodologies for Issue Exploration, Problem Analysis, Planning and Forecasting

Barclay Hudson and Russell Davis

Compass. A specialized tool of Compact Policy Assessment. A brief structured conference of diverse participants, guided by a moderator, to elicit pros and cons on a policy proposal. Key points of debate are recorded on a graphic display for an immediate decision or investigative follow-up. Debate may be oriented to formulate new policies, or alternatively to evaluate ongoing programs, validate research findings, or design information systems for future monitoring of uncertainties.

Compact Policy Assessment. Any of various procedures for intensive, short-term formative evaluation of programs and proposals, stressing (a) diversity of analytical methods and data sources (using informed judgment as well as quantitative information previously available); (b) early specification of concrete action possibilities (even if hypothetical); (c) use of composite (cross-disciplinary and cross-jurisdictional) task force investigation teams detached from their normal institutional setting; (d) succinct iterative reporting for incorporation of critical reactions by diverse interested parties, and (e) explicit recognition of irresolvable issues, to maintain focus on productive investigation.

Cross Impact Analysis. One common problem in Delphi is to get at the underlying relationships among possible future events. Cross-impact analysis provides a framework to trace change(s) through the system, and to probe the effect of interactions among elements of a system. As a systematic means of studying interactions among events or developments, and in specifying how one event will influence the timing, likelihood, and mode of impact of other events, a *cross-impact matrix* is used. It lists events (or fields of development) on both horizontal and vertical axes, with cross-impacts estimated in the individual cells. The technique has multiple uses: to highlight critical linkages underlying problematic forecasts; to define "relevance trees" helpful to contingency planning; to provide the theoretical structure of relationships underlying computer games and simulations. Specification of interrelating consequences may be quite informal and intuitive or highly systematic, drawing on Delphi, or perhaps quasi-experimental research.

Delphi. A group process for pooling informed intuitive judgment, typically applied to predictions about the future, and designed to preserve independence of judgment among a panel of experts. Delphi technique is designed as a sequence of exchanges between a monitor team and individual respondents. It is conducted by questionnaires, interspersed with information and opinion

feedback based on a computed consensus. Questions inquire into the reasons for expressed opinions, and a collection of such reasons is then presented to each respondent in the group, together with a suggestion to reconsider and possibly revise earlier estimates, Helmer (1960). Responses are compiled from several rounds of questionnaires, interspersed with feedback results assembled numerically on a distribution scale. Successive iterations move toward consensus, or at least a congealing of multiple positions defining alternative futures. Delphi can also be carried out through computer conferencing, replacing paper-and-pencil responses with electronic recording, and tabulation of judgments.

Goals Achievement Matrix. A planning tool which lists diverse objectives (aesthetic, environmental, political, as well as economic) on the horizontal axis, with diversely affected interest groups (including suppliers as well as consumers) on the vertical axis. As originally formulated by Morris Hill, the GAM assigns numerical weights to the various rows and columns, allowing computation of an aggregated welfare function, and thus numerical comparison among different plan proposals. In other versions (such as Nathaniel Lichfield's Planning Balance Sheet), intangibles and incommensurables are left in prose form, separated out from monetary and other quantifiable aggregates. In all cases, GAM gives special attention to multiplicity of outcomes and diversity of affected groups. Lichfield's version stresses design modification of plans under evaluation. (See Lichfield 1970, and Hill 1973)

Logical Framework, or Log Frame developed by Practical Concepts, Inc. (Washington, D.C.) is a 4 × 4 matrix summarizing critical elements of project design. The rows of the matrix cover the project *goals, purposes, outputs,* and *inputs.* This establishes a hierarchy of means-ends relationships much in the spirit of Management by Objectives (MBO) and Planning-Programming-Budgeting systems (PPBS). The column headings address each of these means-ends relationships on four levels: narrative summary; objectively verifiable indicators; means of verification; and important assumptions.

Figure A15.1

The Logical Framework Matrix

	Narrative	Objectively verifiable indicators	Means of verification	Assumptions
Goals				
Purposes				
Outputs				
Inputs				

Since its initial development for the U.S. Agency for International Development in 1970, the Log Frame has been more diversely applied to federal and local government, corporate management, and overseas development programs. The Log Frame applies to both project design as a statement of expectations and to project evaluation, in specifying criteria for success, responsibilities for follow-up, and baseline data needs. In practice planners often develop their own frameworks which may be similar, though not identical to the Logical Framework. The Logical Framework is useful, however, as a point of departure for developing a framework which fits the situation. In actual application of the Log Frame, planners in USAID sometimes leave out one of the row or column headings, for example in doing sub-projects which may have common goals as part of an overall project.

Pattern Language. Developed by Christopher Alexander and others at the Center for Environmental Structure, Berkeley, pattern language is a design tool for social and physical planning. Several hundred "patterns" have been explored. Each is expressed as a graphic symbol and defines a cultural need, or stereotypical solution, to a recurrent problem. Examples of "patterns" include a window, a road network, a cellular residential area, a small work group, a university, trees, death rites. Each pattern has an associated set of normative design hypotheses, and specifies strong (supportive or destructive) relations with subsets of other patterns. (cf. cross-impact analysis.) Pattern language serves to formalize and simplify recurrent problems encountered in social planning and establishes "relevance trees," or system hierarchies, and side effects that need to be taken into account for each design element. (See Alexander 1964)

Prediction, Forecast, and Projection. A prediction is a statement that an event will occur, or a condition will prevail, at some future time. Predictions, forecasts and projections are often confused, but analysts and planners distinguish them:

— A projection is a consistent set of alternative statements about future events or conditions, and the alternative statements rest on alternative assumptions which are stated but not evaluated for their likelihood.

— A forecast is a consistent set of alternative statements which rest on assumptions that are assessed for their likelihood.

— A prediction is a single statement that an event will occur or a condition will prevail.

Projections are correct by definition, except for clerical or arithmetical error in the statement, because projections indicate what will take place if the underlying assumptions should turn out to be correct. A projection is often confused with an extrapolation which is the extension of a trend line on the assumption of a continuing pattern of change.

Scenario. A description of a sequence of related future events. A scenario may begin with a future opportunity or threat, and then imagine the range and sequence of developments that might follow. Highly formalized scenario building can employ computer simulations (like the Club of Rome work on

World Dynamics), Delphi, cross-impact analysis, or rigorous algorithms such as econometric models. Alternatively, it may consist of imaginative storytelling by gifted individuals. H.G. Wells, Arthur C. Clarke, and George Orwell built scenarios into novels. A scenario is more than just a set of forecasts about some future time. It is a picture of an internally consistent situation, which, in turn, is the plausible outcome of a sequence of events. There is no rigorous test for plausibility. "The scenario thus occupies a position somewhere between a collection of forecasts whose interrelationships have not been examined, and a mathematical model whose internal consistency is rigorously demonstrable." (Martin 1972).

Sensitivity Analysis. Measurement of the rate of change of an outcome resulting from manipulating changes in values assigned to variables and parameters. The manipulation helps establish which assumptions are critical and which can be left as rough estimates. Sensitivity analysis also suggests the level of benefits that might result from efforts to modify a situation. Sensitivity analysis helps planners recognize that there is no unique, no one best set of assumptions. It also helps identify which assumptions have most effect on results, deserving greatest attention for critical analysis and validation. (As applied to mathematical modelling, sensitivity analysis can be interpreted as a partial derivative, relating changes in the objective function to changes in selected parameters.) Analytical variations on the "base case" can take several forms: *contingency analysis* (referring to changes in environmental conditions or change in the criteria for evaluating outcomes); *a fortiori analysis* (where two or more policy alternatives are compared, and all uncertainties are resolved in favor of the "weaker" options, to see whether they can plausibly challenge the "dominant solution" by a combination of favorable actions and circumstances); and *trade-off analysis* (where alternatives are compared by calculating the "switching values" where one strategy becomes preferable to another.)

Simulation and Pseudo-Experimentation. A model of a situation in the real world is constructed which may be either mathematical or physical. Each element from the real situation is simulated (represented) by a mathematical symbol or physical object. The relevant properties and relations of other elements are represented by corresponding simulated properties and relations. Instead of formulating hypotheses and predictions directly about the real world, it is possible to do the same thing about the model. Any results obtained from an analysis of the model, to the extent that it truly simulates the real world, can then later be translated back into the corresponding statements about the world. This has the advantage of pseudo-experimentation. A particular case of simulation is built on role-playing by the intrinsic experts and is known as operational gaming. A special case of this is war gaming. A simulation model may properly be said to be "gaming" a real life situation if the latter concerns decision makers in a context involving conflicting interests.

Synectics. A theory and methodology of problem-solving, based on integration of diverse individuals in a setting designed to draw out nonrational, free-associative psychological mechanisms of creative thinking. Developed by the Cambridge Synectics group in the 1950s, synectics reflects basic

psychological theory combined with applied research on problem-solving both in business and academic settings. It relies on helping participants to take "psychological chances" to abandon familiar ways of looking at problems. Major use is made of analogies and metaphors to achieve a sense of "making the familiar strange, and making the strange familiar." The strength of the method derives from careful study of the psychological processes of creativity and the pragmatic testing of that theory in solving real problems. The outcome is a sustained dialogue between highly concrete and highly abstract references for problem-solving (Gordon 1956).

The Futures-Creating Paradigm of the Resource Center for Planned Change. This paradigm is designed to assist planners in developing a systematic perspective of future change, beginning with broad societal trends and value shifts, followed by a translation of these changes to institutional plans, policies and programs. The paradigm is structured into 10 stages: 1) Societal Trend Areas; 2) Societal Value Shifts; 3) A Matrix for Trend Areas; 4) A Matrix for Values Shifts; 5) Institutional Objectives; 6) Testing Compatability (of objectives and policies); 7) A Futures Scenario; 8) A History of Alternative Futures; 9) Foresight (systematic examination of impacts and results); 10) Feasibility (assessment of constraints and evaluation). A detailed handbook, with examples, explains the stages thoroughly. For example, Phase 1, Societal Trends, develops in twelve areas covering population, environment, energy, science and technology, lifestyle, participation . . . The original paradigm was developed for AASCU (American Association for Colleges and Universities) by John Osman. The manual, copyright to AASCU, can be used to guide a participatory process of university planning and compact policy assessment. American Association of Colleges and Universities, *Futures Creating Paradigm: A Guide to Long Range Planning from the Future for the Future,* AASCU Resource Center for Planned Change, 1978.

CHAPTER 16

Area Planning and School Mapping Background to the Methodology

Russell G. Davis and Ernesto Schiefelbein

1.0 *Introduction to Area Planning and School Mapping*

The final part of this volume deals with the topic of educational planning for regions and local areas within a country. The topic is covered in this and the following chapter.

Chapter 16 presents a background to the methodology of planning for areas below the national level. There is no attempt to develop a theoretical framework or systematic rationale. In educational planning there is no special theory of area planning. There is, however, a sound reason for dealing with area planning as something apart from national planning. There are situations where area planning is called for; and there are approaches and methods commonly applied in area planning. Distinct types of information are used for local as opposed to national planning. Also distinctive methods are used in area planning and school mapping. Chapter 16 covers these information sources and the methodology applied in area planning and school mapping.

Chapter 17 applies the approaches, methods, information, and formulations of Chapter 16 to an actual case of educational planning. The case exercise describes the application of school mapping approaches and methods to educational planning for the Chilean school reform during the period 1964-1970. Other features of the reform are described in Volume I.

The objective of Chapter 16 is to provide instruction on the methodology of area planning. The objective of Chapter 17 is to teach how these methods apply in a real situation. The purpose of this segment, the two chapters together, is to teach planners *how to plan for areas below the national level.* The weight of coverage in this book reflects the fact that there is more concentration on national level planning in the developing countries than there is on area planning within the country. This is changing slowly. School systems in less developed countries (LDC's) are highly centralized, and planning reflects this fact. Analysis is performed on both national (aggregated) and local (disaggregated) data, but usually the work is done in a central ministry or planning office. This may not be a desirable form of organization or planning, but it is a common pattern.

Although data for planning at the national level are gathered at local levels, they are usually processed and analyzed only at the national level; and the analysis is often fitted into a national planning model or target structure.

The national model does not preclude differentiated goals and services for the sub-areas or regions of the country, but very often these goals are set in accordance with national targets and norms. To plan for the various areas requires local area information, including maps of the areas. The topics of School Mapping, School Location Planning, and Educational Planning for Areas address the problem of creating information bases and situational maps for areas within a country.

1.1 *The Purposes of Educational Planning for Areas*

The basic purposes of educational planning for areas are:

— To assess the outreach, or coverage, and distribution of educational services to populations in areas within a nation state.

— To compare the coverage between and among the areas, usually on the basis of the percentages of the relevant population receiving services.

— To compare the coverage of the areas with national norms, standards, or plan targets.

— To inventory facilities and resources allocated to programs in the areas:

— To diagnose, on the basis of the assessment and comparison of coverage and resources allocated, the differences among areas:

— *To plan the provision of educational services so as to expand coverage, to enhance equity in the coverage, and to improve the efficiency and effectiveness of educational services in the areas.* This last is basic.

1.2 *Brief Comment on Planning Terminology*

In these notes, the terms school mapping, school location planning, and educational planning for areas mean virtually the same thing. Each term has its limitations: *school mapping* suggests that the objective of the planning is to develop maps or graphical representations of the spatial distribution of schools and school services. (The maps in a school-mapping exercise may also show a variety of demographic, economic, and social, as well as educational, distribution characteristics for planning purposes.) Though maps may aid educational planning for specific areas, the development of maps is not the end purpose of educational planning. Nor is *school location planning* the main purpose of educational planning in spatial terms within a country. Its main purpose is to expand and improve educational services and outcomes, and to improve the distribution of these services and outcomes within national, regional, or local domains. The term *educational planning for areas* expresses this general purpose better, and also is more suited to suggest the steps to be taken in educational planning below the national level. The term *area* is imprecise, but it is fairly widely used by demographers to refer to data and projections that cover a subnational area—for example, a region, province, state, district, or locality within a nation.

1.3 *Requirements for Educational Planning in Areas*

There are two requirements for carrying out planning for areas within countries: the first is to have a coherent approach and analysis methodology; and the second is to apply this methodology to good data and information dealing with education in the regions and localities within the nation. We will begin with a brief discussion of data requirements.

2.0 *Data and Information Requirements for Area Planning: Assessment of Coverage and Inputs.*

School enrollments are the primary data for area planning of education. Planning may also cover nonformal education programs, in which case the enrollments in such programs are also relevant but, in general, educational planning for areas deals with enrollments in the formal, graded schools of a nation. Enrollments are first compiled by levels and grades in the system. Enrollments within grades will also be classified by age and sex of the students. Enrollments classifed by age and sex are important for assessing or compiling indices of coverage, e.g. percentage of age/sex group enrolled in grades and levels of the system. Hence, demographic data, the population classified by age and sex, are also basic for area planning.

Indicators, the percentage of an age/sex group enrolled in schools of a given area, can be compared with national norms or targets to assess plan attainment for a given area. This assessment provides a basis for monitoring equality in plan attainment and for planning increased coverage. Standard forms for collecting and tabulating enrollment, and sometimes population data, are used in the statistics and planning offices of almost all ministries of education. UNESCO missions over the years have succeeded in standardizing formats used in data collection and reporting procedures in the developing countries. The information requirements are similar to those specified by Brolin (UNESCO) and Chesswas (IIEP). McGinn (USAID/Harvard Project Paper 25, 1979) describes and evaluates these formats.

Area assessments also provide a basis for the comparison of one area with another. This permits evaluating equality of coverage, at least in quantitative terms, among regions. It also provides one basis for planning the improvement of equality in coverage.

Inventories of programs and educational inputs also yield basic data for area planning, as the case in Chapter 17 will illustrate. School facilities, i.e. the buildings, furnishings, and equipment, are inventoried, evaluated for used and unused capacity and maintenance condition, and the building locations mapped. The formats for collecting information on school facilities are standardized in most ministry statistics, planning or school construction offices. A typical form is shown in Appendix 16.1 of this chapter.

In poor countries, the provision of facilities once had such real and symbolic importance that the inventory and mapping of school facilities became a dominant concern of planners at the national level. School mapping was born out of this concern. Teachers and supporting staff are also surveyed and are characterized by training and experience. Results are reported by schools,

locales, districts, or whatever the area unit being studied. Other educational inputs, e.g., instructional materials and supporting services, administration, supervision, and specialized education services, are also assessed.

The assessment of eductional inputs allows comparison among regions on the basis of national norms. This permits one more step toward the assessment of equity, since the program activities and inputs can be taken as one indicator of the provision of quality services among areas.

2.1 *Data and Information Requirements for Area Planning: Assessment of Outputs*

In rudimentary form, an assessment of educational outputs is based on the assessment of enrollments and educational attainment by grades and levels. First, there is the assessment of the structure of enrollments by grades in any given year. This yields a static picture of enrollments. Second, there is the assessment of changes in enrollments over time. This shows the changes in enrollment from grade to grade and year to year, and yields a picture of the dynamics of enrollments,or enrollment flows. Though the emphasis in school mapping is on the spatial distribution of enrollments, the temporal characteristics, or changes in enrollments over time, are fundamental in any planning exercise. It is important to assess the history of such changes in the past, and it is necessary in planning to estimate, or project, how enrollments will change in the future. Trend analysis of past changes provides the basis for projections into the future.

The flow of enrollments can be used as an indicator of system performance. Let us briefly review Chapter 5. Enrollment flow is governed by three rates, promotion p, repetition r, and dropout d. From the enrollment in any given grade in any given year, a certain number will be promoted to the following grade for the following year (p); or repeat in the same grade in the following year (r); or drop out (d) of the school system. If the enrollment were 100, and 60 were promoted, 30 repeated, and 10 dropped out, p would equal .60; r would equal .30; and d would equal .10. As proportions the p, r, and d add to 1. The rates p, r, and d are called *flow rates*. The flow rates in the schools of a given area can be used as a measure of efficiency in the system because the rates are indicators of system performance. Promotion rates will determine the number who ultimately complete a grade or level.

Assessment of flows may indicate a problem in the functioning of the system. (See Chapter 6 for analysis methods.) But an assessment must go further and deeper if it is to tell the program implementers how to intervene to change the system to improve learning. The output measures must be related to specific input characteristics in the classroom situation and the process of instruction. Teaching/learning activity must be analyzed in order to guide intervention and remediation. Policy analysis, when applied at the highly aggregate level of the total system, may be inadequate to guide policies, program decisions, and actual intervention into the instructional process. Analysis at the local level is one step toward closing the gap between national level policy planning and research into teaching/learning.

On the basis of the flow coefficients (p, r, and d), various indicators of output or efficiency can be computed and used to compare the schools in different areas. Two examples of these indicators are:

(i) Fraction of enrollees who eventually graduate:

$$\frac{P_1 P_2 P_3}{(1 - r_1)(1 - r_2)(1 - r_3)} \tag{1}$$

(ii) Expected time in system of those who graduate:

$$\frac{1}{(1 - r_1)} + \frac{1}{(1 - r_2)} + \frac{1}{(1 - r_3)} \tag{2}$$

We will give a brief numerical example of equations (1) and (2). Assume that we have a three-grade system with these flow rates:

	Grades		
Rates	1	2	3
p	.72	.88	.95
r	.18	.08	.02
d	.10	.04	.03

Applying equation (1), we would have:

$$\frac{(.72)(.88)(.95)}{(.82)(.92)(.98)} = \frac{.60}{.74} = .81$$

Eventually, in a system with these flow characteristics, about 81 percent of those who entered would graduate. The reader who is interested in doing the exercise can check this by entering a cohort of 100 into the first grade, multiplying by the flow rates and checking it through a six-year cycle until all of the cohort graduate. The fraction will be about .81.

Using the flow rates shown above, equation (2) would be:

$$\frac{1}{.82} + \frac{1}{.92} + \frac{1}{.98} = 3.33$$

Given the repetition in the system, the average time spent in the three-grade system would be about 3 1/3 years. Repetition adds 1/3 of a year.

Input/output ratio:

$$\frac{\text{number of student years}}{\text{number graduates} \times \text{number years in level}} \tag{3}$$

Example: In a rural six-grade elementary school, 400 pupil years are required to produce 50 graduates. (The 400 pupil years include repeaters and dropouts). The input/output ratio would be:

$$\frac{400}{6 \times 50} = 1.33$$

(If the 400 pupil years were divided by 50, the number of graduates, the result would indicate that on the average it takes 8 years of schooling to produce a graduate of this 6-year program.)

Coefficient of efficiency: This is the reciprocal of the input/output ratio. In the example above it would be $^{300}/_{400} = .75$ (4)

Percentage pupil years' excess: $$\frac{\text{student years} - \text{legal years}}{\text{student years}} \quad (5)$$

In the example, this would be: $^{400 - 300}/_{400} = .25$

The excess measure can be further analyzed to determine whether the excess places are caused by dropping out or repeating.

There are other quantitative indicators of school system performance that can be used for comparing the schools in one area with those in another. Durstine discusses these in a useful paper entitled "Performance of the Indonesian School System: A Review of Some Quantitative Measures" (Jakarta: UNESCO Project INS/71/537, 1978).

The quantitative indicators assume that the number of years spent in school, and the attainment of graduation, reflect some significant output of the education system. Because learning is presumed to be the output of instruction, there is an assumption that the indicators measure, or represent, learning. Learning is more directly, though not completely, measured, however, by testing the achievement of students. Test results can be used to assess the output of the system in a given area. Test results compiled in one area can be compared to national test norms as standards. Or the results of one area can be compared with another.

2.2 *The Assessment of School Outcomes by Areas: Educational Effects*

There is also one step beyond the measuring of learning output, and that is the assessment of the purported *outcomes* of schooling. Schooling is presumed to produce education, and education is presumed to contribute, through learning, to enhanced worker productivity and better workforce performance. This chain of presumptions is almost never directly measured, but it may be indirectly assessed by relating differences in educational attainment to earnings. Chapter 2, Appendix 2.1, showed models for analyzing school effects.

A complete assessment of the effectiveness of the outcomes of schooling in the various areas of a country would demonstrate that (1) resources were provided, and enrollments and educational attainment levels reached; (2) the schooling resulted in learning; (3) the learning resulted in improved economic, social, and cultural outcomes. (See Chapter 2, Appendix 2.1, model).

2.3 *Other Approaches to Area Planning: Needs Assessment by Areas*

The assessment of school system performance and comparison of input,

output, and outcome indicators for areas within a country represents one basic set of analytic approaches to school mapping and educational planning for areas. Another major activity of area planning is the assessment of needs. Area planning and school mapping are also concerned with the assessment of the needs of populations for educational services of different kinds and quantities.

3.0 *Systematic Information Formats for Area Planning*

The information requirements for area planning go beyond the data requirements specified in formats for school location planning and analysis of internal efficiency of schooling. Area planning and school mapping often cover broader planning purposes, which include assessment of the needs of area populations for schools and other social services, and assessment of external efficiency, effectiveness, or relevance of education, i.e. how education and training fit economic and social goals. This work requires a considerable variety of demographic information, but the population structure by sex and age groups still provides the base data for all planning.

Data on economic activity, income, prices, costs, and manpower requirements for the area, may also be needed for area planning. Social and cultural data on ethnic membership and the cultural and linguistic status of the area populations might also be relevant. The basic maps for area planning will show the spatial arrangements of populations, enrollments, and school facilities; but other economic, geographic, social, and cultural data may also be mapped. (Exhibit 16.1 shows a school district map of students characterized by race. Exhibits in the next chapter show highways and rivers.)

A great many data forms and schemes have been devised for collecting, arraying, and analyzing the information for area planning and school mapping. These schemes are reviewed by McGinn (USAID/Harvard Project Paper 25, 1979). McGinn discusses an information scheme for local area planning. This scheme builds up information by beginning in the classroom and going up to national level. The scheme specifies the data necessary for needs assessment and for assessing the external efficiency, effectiveness, or relevance of local area education programs.

3.1 *The International Institute for Educational Planning Cases on School Mapping*

The International Institute for Educational Planning, in its school map project, also provides extensive coverage of the information requirements, analysis procedures, and planning techniques used in school mapping and area planning. The UNESCO/IIEP series provides a set of 12 case studies for different countries, a collection so complete and detailed that there is no need to repeat much of that work in these chapters on area planning. (A selection of these school mapping cases is listed in the bibliography at the end of this paper.) The methodologies of school mapping are simple enough so that a reasonably careful reading of Hallak's book (1976) should acquaint readers with the commonly used methods. Some of these methods will be examined in

later sections of this chapter, where standard formulas for determining area population densities, and the resulting population need for schools, are examined.

3.2 *The World Bank Approach: School Location Planning*

The World Bank has also prepared staff papers on the topic of school location planning, which is similar in approach to school mapping and area planning. A recent World Bank paper (1979) describes typical situations in which school location planning is used:

(a) A country with 50 percent of the total age group accommodated in primary schools, and with 10 percent of the age group enrolled varying in different regions of the country, plans to expand coverage to 75 percent of the age group in a five-year period and to 100 percent within ten years. The question is how to allocate resources to reach targets and minimize inter-regional differences through the rational location of school facilities. (See Appendix 16.2 for simple schema of problem.)

Maldistribution of enrollment by areas is common in developing countries, but rarely does the approach to attaining targets and minimizing area disparities follow the rational approaches advocated by planners. Political, geographic, economic, and cultural forces make the implementation of area programs follow a lumpy and uneven path. Still, the planner may attempt to rationalize this, as shown in the example in Appendix 16.2. The example is not typical, however.

(b) A country plans to alter the structure of its educational system from 6-2-4 to 4-4-4, and to expand enrollments in the basic cycle, which is grades 1-4. This will require changing some six-year schools to four, and the planner's task is to organize this change in as orderly and efficient way as possible. The objective would be to insure maximum access to the basic cycle and maximal opportunity to continue on into the middle and upper cycles.

Again, reality would be considerably more complicated than this simple example suggests. The shift in pattern from 6-2-4 to 4-4-4 represents a basic change in system structure and not just some changed numbers. In this case the secondary-school level would stay about the same with grades 9-12, but there would be a very big change at primary and middle-school levels. This would require an entire shift in educational philosophy. A middle-school level is being created. In effect, the new four-year primary school would be a basic school and probably a rural feeder school. Feeder schools would have to be planned and located to provide continuation to the new middle school, which would be a nuclear school receiving students from several four-year basic schools. The new age groupings would also require attention, as would articulation in the curriculum between grades 4 and 5 and grades 8 and 9. A middle-school curriculum would have to be created. Limited space does not permit full treatment of the pedagogical and managerial problems that would arise in this example. The number crunching is the easy part.

(c) The efficiency of schools, as reflected in unit costs, can be influenced by large disparities in teacher-pupil ratios because of thin populations in rural and isolated areas. The planner's problem is to raise ratios in low-ratio areas,

and to reduce variability without reducing access. This may be accomplished by restructuring schools, for example, adopting the 6-3-3 pattern (six grades attended by three teachers in three classrooms in double session); or by grouping schools into feeder and nuclear units. Other options are to furnish transportation or to build boarding schools.

Area planning may also lead to more efficient utilization of school space. Planners may redefine catchment areas, those areas from which a school's attendance is drawn, in order to provide primary school graduates with a better opportunity to continue on to middle schools. This would raise efficiency by reducing the numbers who are forced out of the system because there is no school beyond primary level. The next chapter shows how catchment areas were mapped in a rural area of Chile.

Hallak (1976) states that the two fundamental activities of school mapping are establishing catchment or attendance areas served by school units and setting norms (e.g. school size) for diagnosing local needs and assessing service and coverage.

A World Bank paper (1978) lists the four major school planning activities in centralized ministries:

— Setting national norms for the size and costs of schools and classes and setting construction standards. Note that setting national norms does not mean that one standard size, or number or ratio would be imposed on schools in all areas of a country. The norms might well provide different standards for different areas, depending on climate, transportation routes, population density, and even local building materials.

— Ensuring the collection of reliable data for diagnosis of inadequacies in the provision of school services.

— Establishing plan targets based on projections of the population and its social and economic characteristics,and assessing the extent to which these targets are reached.

— Allocation of resources among competing areas. (Anyone who knows the reality of education in developing countries (or elsewhere) recognizes that strong political influence from outside ministries of education usually determines how school resources are allocated.

The national central authority commonly sets these kinds of norms for the system:

— Norms that govern the structure of the system, i.e. the levels, grades and program types.

— Norms related to school size or class size (measured in enrollment capacity).

— Norms that relate to the internal efficiency of the schools. These norms are revealed by the enrollment flow indicators and efficiency ratios discussed.

— Space per student and teacher-pupil ratios are also inportant governing norms that should be related to class size. Requirements for special programs also affect all input norms, including space, teachers, equipment, and books.

— Construction and facility specifications and norms.
— Unit cost norms for capital and recurrent costs.

The first two kinds of norms impose standards that apply for all areas of a country. The structure of the system is usually the same nationwide, but there may be some differences in programs for local areas. Minimal internal efficiency standards may be established as norms for the country, but this does not mean they can be enforced. Differences are usually tolerated. The final three norm types apply to facility and input standards. These may vary for different areas of the country.

4.0 *Additional Comment on Area Planning Approaches*

In some nations the standards and norms vary widely for different areas. Area planners may use different norms for different areas. The object of planning might be precisely the opposite of insuring uniform patterns across different areas of the country.

More significantly, the entire approach to mapping and area planning might be different. Instead of dealing from the national area downward, the analysis might begin at local level and build up to the national level through aggregation rather than disaggregation (McGinn 1979; Hudson, Davis 1977).

4.1 *Spatial and Temporal Planning*

Most area planning material also deals with static or cross-sectional analysis, and there is less stress on comparisons over time. This is done deliberately in order to emphasize the spatial comparisons, but planning by nature deals with inter-temporal analysis and comparisons. To map comparisons of changes in different areas over time is not simple, and the usual procedure is to show a separate map for each time period that the area characteristics are depicted. Ideally, temporal and spatial analysis must be combined.

4.2 *Additional Charts for Planning Educational Expansion*

In Chapter 6, data were displayed in tables rather than in maps. In many situations tables are easier to understand than maps. Some planners may work more efficiently with tables or even graphs rather than with maps. But for certain types of problems, such as deciding where to locate future schools, or for determining where population will tend to migrate in the future, maps represent an invaluable aid. Superimposing transparent map overlays on different demographic, economic, geographic, and educational information will reveal relationships among variables.

A simple system for classifying maps may be useful for deciding when to work with maps. A simple way to start is to divide maps between those describing the distant or near past (including present) and those depicting the future, or showing potential use of resources. A second way is to separate maps based on objective data from those built up on the opinions of people

reputed as expert in a given field. Expert opinion may be used to guess about future industries or activities to be started in the near future in a given area. Maps dealing with the current situation cover:

migration flows
urbanization indexes
population density
rates of population growth by micro-regions
division of land by political subdivisions
density of different types of herds
economic production of main crops
density of tractors and other agricultural machinery
isochrons of access to urban centers (points requiring same travel time)
isochrons of access to highways
highways and trails
transmission of electric energy (primary system)
transportation systems
health and sanitary conditions
TV coverage

Maps dealing with potential development may include:

hidrographic basins
geological formation
potential usage of soil
mineral prospecting
climatological variables
botanical and zoological data

When actual use of soil is clearly inefficient in comparison with potential usage, future development of the area may be planned. Future economic development will have implications for future economic demands on the educational system. Charts with the location of probable projects (including hydroelectric projects) may help in planning educational projects. Maps provide an easy way to keep track of data for making decisions when a complex of economic, cultural, social, and physical variables are involved. In this situation, the newly emerging field of computer graphics provides invaluable tools for dealing with multiple variables that differ according to time and location.

4.3 *Computer Graphics as an Aid to School Mapping of Spatial and Temporal Characteristics*

To show several different areas, characterized on several different variables, and over several different time periods is a challenging task for information processing, analysis, and display. For this work the computer has become an increasingly necessary adjunct and support resource. Most planners are familiar with the use of the computer for analysis and display of numerical information in conventional form. Volume IV in this series describes the methods for preparing data for the computer, analyzing it, and displaying it. Lewis (1979) deals with the tabulation and display of data in

conventional tables and graphs, and the application of statistical measures of central tendency and distribution. There are other methods for analyzing and displaying data, and among such methods are those based on computer graphics programs. Computer graphics is a field that has developed because it can handle the problem of showing several different areas, characterized on several different variables, over different time periods.

A center for developments in computer graphics is the Harvard University Laboratory for Computer Graphics and Spatial Analysis. In *Lab Log*, a brochure and catalogue of the Laboratory (1977), the computer graphics programs which have been developed to handle the problem of data display maps for area planning are described. One of these program outputs, the ASPEX version 1.0, is illustrated in Appendix 16.3.

5.0 *Quasi-Objective Bases for Satisfying Expressed Local Needs*

Given a centralized system of decision-making and top-down planning, and the popular demand for formal schooling delivered in conventional classrooms and schools, planners have developed a few quasi-objective approaches to satisfying education needs across the areas of a national domain. One such method is used to determine the threshold population required for the establishment of a school facility. This, and several other rough, rule-of-thumb normative measures attempt to provide some basis of objectivity in planning for the provision of educational services to areas within a country.

5.1 *Establishing the Threshold Population Density*

There is a minimum total population necessary for establishing a school in an area, given the graded structure of the school system, a standard class size (these yield a standard school size), the percentage of the population in the enrollment-age covered by the school, and a target enrollment percentage. Given a school structure of four grades, a standard class size of 45 pupils, 10 percent of the total population in the normal age group for the four grades, and a target for coverage of 80 percent of this age group, then the simple calculation is:

$$\frac{4 \times 45}{(.10) \times (.80)} = 2250 \qquad (6)$$

This suggests that the area to be served by the school should have a total population of 2250. The formulation is simple enough and is useful for providing a rule of thumb for assessing *need* for facilities on a very crude basis, i.e. the estimated population to be served. Here *educational needs* are those educational services that are lacking, are perceived as lacking and desired by local populations, and within the norms and delivery capability of the nation and local area.

The estimate is very rough, however, and could lead to poor results, unless the area to be served is clearly defined and mapped and the population characteristics already known. The denominator of the ratio hides a de-

mographic crudity. If the total population and age structure in the area are not known, the application of a national age-group percentage (in this example, 10 percent), without some demographic warranty, would be fairly risky. Census data might not be available and current for the area of interest. In this situation, the analyst might run a rough count of population by age to check the assumed age structure.

If local area censuses or surveys are run, it is worth including other items beside head-counts in the survey to make the need assessment more useful. Other data might include the pattern of school attendance, reasons for nonattendance, and the kind of schooling local people want, if that can be articulated. Without this, the application of a target percentage (in the example, 80 percent) may not mean much. Some children may be unable or unwilling to attend unless supporting services are provided.

The pattern of attendance in any given area is influenced by a number of demographic, social, cultural, geographic, climactic, and economic variables. Those familiar with a given area in a country can visualize the kinds of variables which affect attendance in that particular area. For each area there will be slightly different influences on attendance at school, and no general list will serve.

The numerator of the ratio in equation (6) does not present any data problems because it is set wholly by conventional and administrative norms in the first place. Research might be necessary to establish and validate this conventional setting, but such research is rarely carried out. The graded structure of the system may have many alternatives, and, for a given area, different patterns of grades might be appropriate. The first or basic level of an education system could have any number of grades, but the common range is between four and eight, with an average of six. School systems do experiment with different patterns, and planners sometimes have to trace the possible outcomes of changing these patterns. In the school mapping case from the Chilean Educational Reform, the "Basic Education" level was changed from six to eight grades, and planners used school mapping to plan these changes at the local level.

Whatever the norm for the system as a whole, schools in rural areas may have several different grade groupings, and both complete and incomplete primary schools. There are unitary, or single-class schools, with any number of grades from one to six. There are feeder schools of three, four, or five grades which feed into a nuclear school for the higher grades. Peru, many years ago, and Honduras more recently, have used varied patterns of feeder and nuclear schools; and similar trials have been quite widespread in developing countries. The grade grouping and structure may depend on the number of sessions. Chapter 7 in Volume I and Chapter 5 in this volume discuss the advantages of the 6-3-3 pattern for serving rural areas with low population densities. In this pattern, six grades are served by three teachers operating in three classrooms, perhaps covering grades 1, 3, and 5 in the morning session and 2, 4, and 6 in the afternoon.

The number of sessions in the school will affect the enrollment threshold formula, and this figure should be incorporated into the formula. *Sessions* here means the number of times a full school program is offered in a day.

(School years may also be shortened, and two complete years offered within one calendar year.) If the school were operating on double sessions, this would change the population threshold. (As an exercise, how would the number of sessions enter into equation (6) to change the population threshold?). The point to be made here is that there is a great deal more to area planning than the manipulation of a few numbers in a simple formula. Still, the formula may serve for very general assessments of the coverage of educational services and the need for basic coverage with formal schools.

5.2 *Range, Distance, and Travel Time Measures*

Area planners also must deal with range, distance, and travel time. The formula for the area of a circle, πr^2, is used (where r is the average walking distance for students of varying age and grade levels) to compute the area covered by school services. If the norm for primary school children is a maximum distance of 3 km, then the school can cover an area of 28.28 km (3.142 × 9). Here, the norm of 3 km is purely set by convention, and in any given area this will be affected by terrain, roads, weather, and other forces. Any given area must be studied as a particular case, but the formula and the notion of *range* might have some general use for rough-scale planning at the national level.

The area served by the school, or the catchment area, may also be affected by major policy decisions to provide boarding facilities or transport to the students. School mapping studies in some countries have prepared tables of distances for areas, or regions, of the country, and for children in different age and grade levels. The IIEP research has established modal distances through case studies for various countries. These tables have some rough normative use, but in reality there is no substitute for a study of the local ground, because terrain features—rivers, mountains, and gorges—may be more important determinants of accessibility to students than the shape and size of an area shown on a map.

Range can be related to *population threshold* through population density per area, if that datum is known in developing countries. Hallak (1976) uses different combinations of the basic formula, $\pi r^2 d$, to determine the size of catchment areas that can be covered, given a set travel radius r for students, and the population density d. The threshold population of 2,250 computed in equation (6) would be found within an area of 3 km radius if the population density d were 80 people/km²:

$$\text{threshold population} = \pi r^2 d$$
$$2250 = 28.28 \times 80 \qquad (7)$$

Hallak states that a hexagonal shape, or cell, is better for school mapping because it is easier to fit surfaces together and to avoid overlapping or omission of areas. Hence the formula is $2.598r^2d$, rather than $3.142r^2d$. In an area with a density of 1 person/km² and a radius of 3 km, about 24 people would be found (2.598 × 9 × 1).

Hallak (1976) shows how school zones are covered, where the number of schools is derived by dividing the area by the population density times the radius of travel.

Table 16.1

Coverage of Enrollments for Zones: Density, Radius and Size of Area

Zones (1)	Pupils/km^2 (2)	Travel (distance) radius (3)	Area km^2 (4)	2.598 X radius^2 (5)	Pupils (6)	No. of schools[a] (7)
1	1	4	200	41.6	200	5
2	1.5	4	50	41.6	75	2
3	5	2	30	10.4	150	3
4	6	2.5	20	16.2	120	2

[a] To derive number of schools, divide col. 4 by col. 5. Note that schools will vary some in size, i.e. number of pupils enrolled

Table 16.1 is crude and aggregate planning analysis, but serves to give some orders of magnitude for planning when there are any data on population densities.

5.3 *Map Scale*

Range or radius can in turn be related to map scale. It is useful to know something about the size and detail of maps in area planning, and this introduces consideration of scale. Area planners work with scales that vary from 1:5,000 (a large-scale map) to 1:500,000 (a smaller scale map). The scale of the map can be related to the range to give some idea of the size of maps used for local area planning. To cover the same area shown in the lower map B in Exhibit 16.3, but using a larger scale of 1:5,000, would require a map 50 times larger, and for a scale of 1:50,000 the map would be 5 times larger. Either one would require a considerable wall space to display as a single area, but sections of a large map would be quite manageable in such scale.

Using a 5 km radius (for foot travel for secondary school students), the area could be mapped in considerable detail (1:10,000) with a map covering about a square meter of wall space. A primary school area with a walking radius of 3 km could be mapped in the same detail with either a scale 60 percent as large or a map 60 percent as large. A country with an area about 5 times that of the secondary school area would more likely be mapped at a scale of 1:50,000. (Note the widely different scales in the Chilean case, next).

The problem is that geographic variations within the area make standard walking distances and range measurements inapplicable in many areas. Two schools might have to be located within a kilometer of each other if separated by a river, mountain ridge, or other natural barrier. This seems obvious, but other barriers might be equally formidable. Cultural, ethnic, and linguistic barriers may be just as unbreakable as physical barriers. In Fiji, for example, it is not just a matter of providing a "school" in an area. Indians want an Indian school; but even within the Indian group, religious communities, Hindu and Muslim, want their own separate schools. One can imagine this problem translated back to India with its hundreds of ethnic and language groups, and dozens of religious groups. The writer once serviced a school in a

hovel in a Calcutta bustee in which three different language medium schools functioned in less than a 100 Mt^2 of floorspace. For an hour of the day the groups overlapped, and it was babel. Traditional patterns of communication and routes of trade, travel, and communication may alter patterns, and administrative divisions may separate areas, e.g. district, provincial, and state government boundaries.

6.0 *A Summary Comment*

In summary, though disaggregated spatial planning can be conducted by working from the center out, or the top down, it is the reality of the local area that is the final determinant of educational, or any other kind, of social outcomes. Furthermore, there is no set of formulas, mapping techniques, or analytic procedures which solve the problem of planning without thorough knowledge of local conditions. For this reason the World Bank paper and IIEP work on school mapping emphasize the importance of administrative relations in the planning of school location programs as well as the importance of data from the local level.

It is not simply a matter of mapping physical, economic, educational and demographic features of an area. Morphological mapping—the mapping of the influence of systems structures and organizational patterns on the process of educational policy and decision making—is also necessary for the planning and implementation of educational programs. This mapping is not as straightforward as physical mapping because it requires analysis and inferences about political, bureaucratic, and social structures and dynamics that may operate quite differently from the way they are portrayed in Ministry organization charts and school systems graphs. This topic is covered by DeHasse (USAID/Harvard Project Paper 22, 1979).

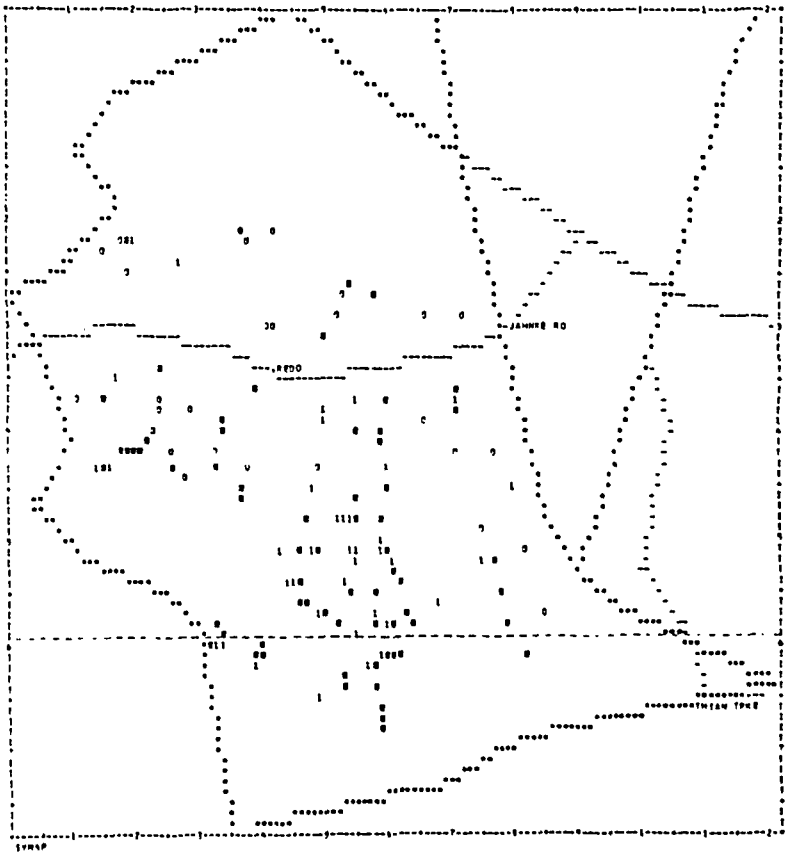
Here, we have attempted to offer a simple introduction to a rather broad and somewhat technical field of area planning, or school mapping. We have outlined the approach, discussed some of the data requirements, and given a few examples of systematic indicators and rule-of-thumb guidelines that are typically applied in area planning from a national, centralized education ministry. We have briefly introduced the topic of computer graphics, which represents one of the new technical aids for mapping and spatial analysis for planning. Other chapters in these volumes deal with the information formats for planning, morphological mapping, and systems and organizational analysis for planning.

The World Bank and the International Institute for Educational Planning have prepared methodological papers and case illustrations which provide further reading and reference materials. School mapping and area planning methods, in common with most planning methodologies, are best learned through experience in applying the methods to actual planning situations. Not every reader can go out to the field to work on school mapping. As a partial alternative to experience, we show some of the problems of field applications of mapping in the case which follows in the next chapter. This introductory paper on the approach, methodology and state of the art of

school mapping, the case which follows in Chapter 17, and the additional readings offered in Hallak (1976) and the IIEP cases (1973 to 1977) will serve to provide planners with sufficient background to begin work in area planning and school mapping. Only actual work experience, however, will provide eventual mastery of methodology.

Exhibit 16.1

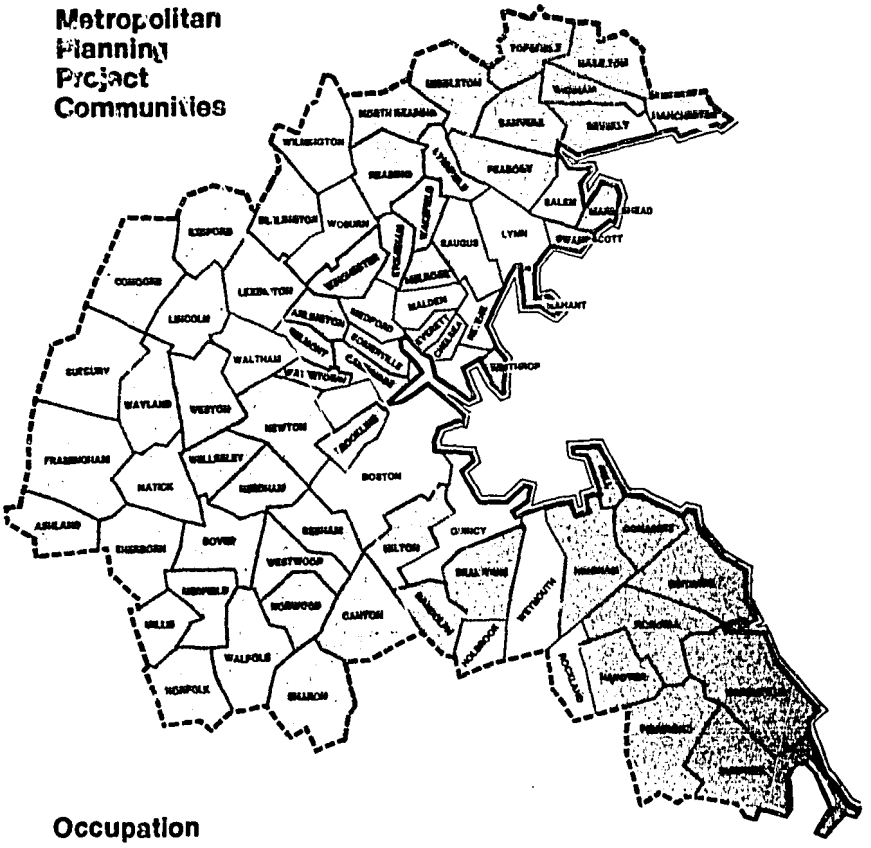
A Computer Map for Planning Racial Balance in an Urban School System



Source: Robert Rugg, and Dennis Marriott, "A Case Study of Computer Mapping System Use in Educational Planning." Paper presented to International Users' Conference on Computer Mapping Software and Data Bases, Harvard University, 1978.

Exhibit 16.2

Example of Socio-Economic Information Mapped for Planning Purposes



Occupation

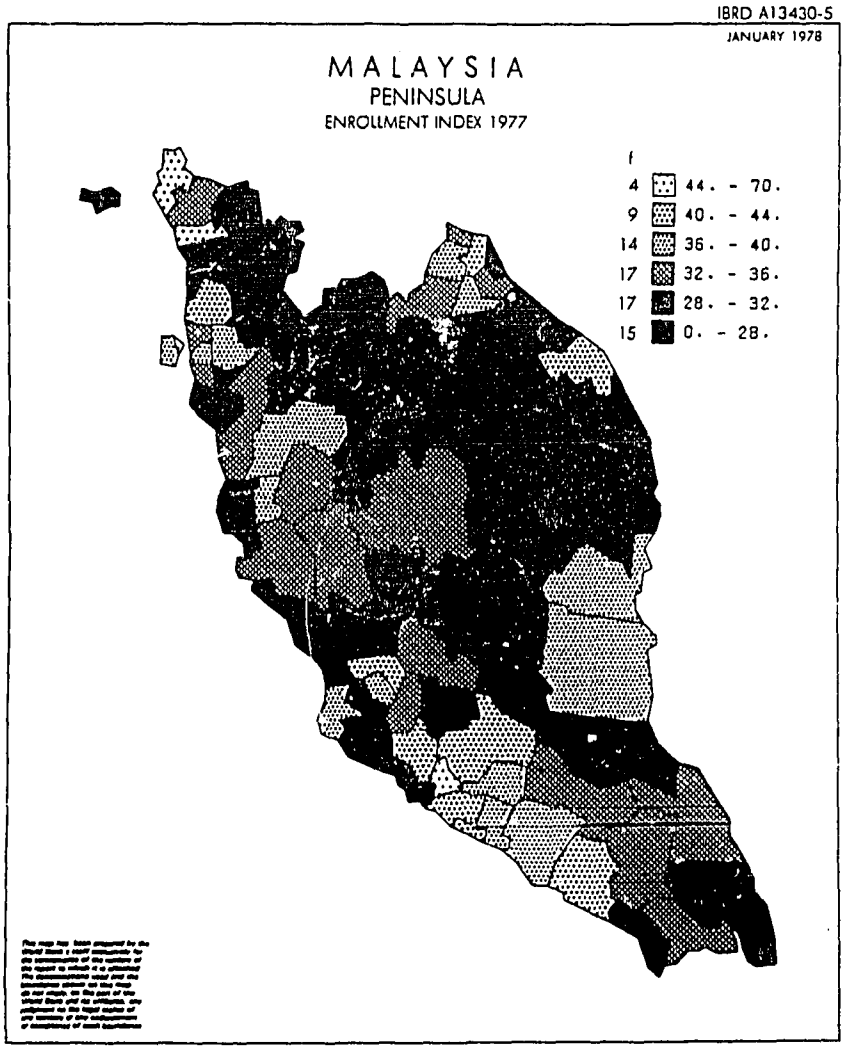
The Communities Shown in White are: Communities where less than 25% of the employed persons belong to the professional or managerial category.

Information Source: 1970 U.S. Census

Source of Map: Metro Ways to Understanding, The Metropolitan Planning Project, Winchester, Mass: 1974

Exhibit 16.3

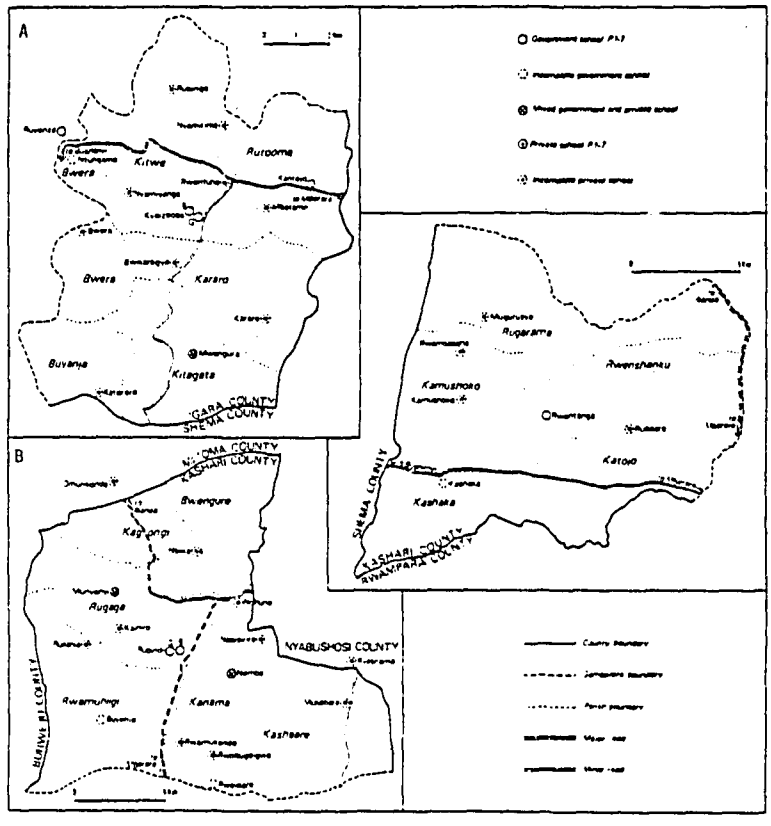
Computer Map of Educational Distribution



Source: World Bank (based on CALFORM program of Laboratory for Computer Graphics and Spatial Analysis, Harvard University).

Exhibit 16.4

Local Area School Maps

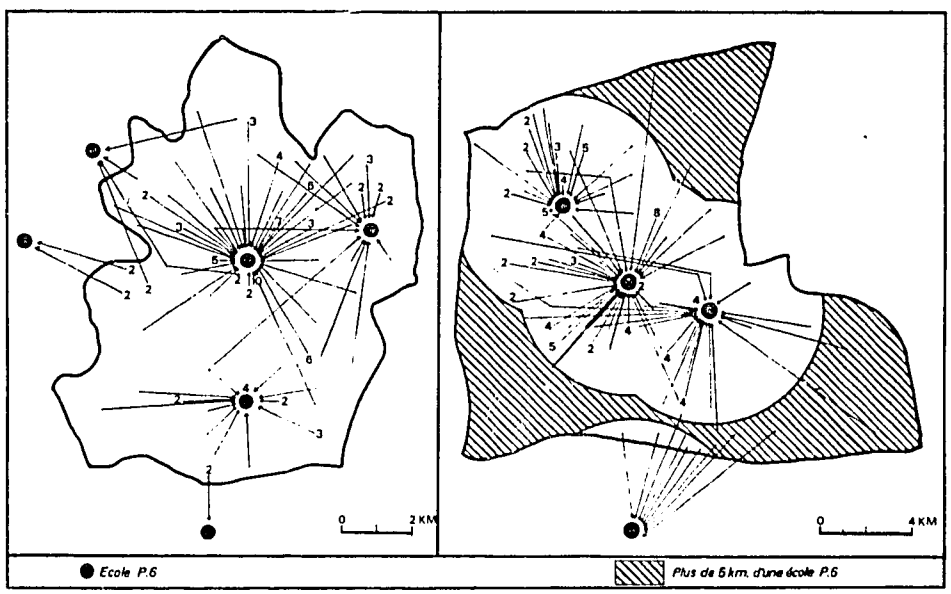


[a]As reproduced here, these are in small scale (1:250,000), but they could be shown in much larger scale (1:50,000 or even 1:10,000) on large assembled detailed maps that would fit on an office wall.

Source: World Bank Paper on School Location Planning.

Exhibit 16.5

Maps Showing Catchment Areas for Students According to Travel Distances
(These are for six-year primary schools in Uganda)



Cartes 19 et 20. Aires de recrutement des élèves des écoles P.6, Kyeizooba et Rubindi, Ouganda.

Source: Hallak (1976), p. 204.

UNESCO CASES in School Mapping: A Selection

Sri Lanka

Guruge, A. and K. D. Ariyadasa. *Planning the Location of Schools: Case Studies in Sri Lanka,* Paris: IIEP, 1976.

Uganda

Gould, W. T. *Planning the Location of Schools: Ankole District, Uganda.* Paris: UNESCO/IIEP, 1973.

Costa Rica

Hallak J. *e. al. Préparation de la Carte Scolaire dans la Region de San Ramón, Costa Rica,* 1975. Also version in Spanish. *Método de Preparacion del Mapa escolar: La Region de San Ramón, Costa Rica.*

Ireland

Hallak H., and J. McCabe. *Planning the Location of Schools: County Sligo, Ireland.* Paris: UNSCO/IIEP, 1973.

World Bank, "Guidelines for School Location Planning," Washington, D.C.: IBRD Staff Paper, 1978. There is also an earlier draft of the same paper by W. T. Gould dated February, 1977.

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McGinn, Noel. "Information Requirements for Educational Planning: A Review of Ten Conceptions." Cambridge, Mass: USAID/Harvard Project, Paper 25, 1979.

Harvard Papers in Thematic Cartography

Paper One: *Thematic Cartography: What Is It and What Is Different About It?* Howard T. Fisher

Paper Two: *Thematic Cartography: A Suggested Definition, With Comment Regarding Its Implications.* Howard T. Fisher.

Paper Three: *Qualitative Vs. Quantitative Cartography.*

Laboratory for Computer Graphics and Spatial Analysis. *Lab-Log.* Cambridge, Mass.: Graduate School of Design, Harvard University, 1977.

Rugg, Robert D. and Marriott, Dennis R. *A Case Study of Computer Mapping System Use in Educational Planning.* Cambridge, Mass.: Prepared for International Users' Conference on Computer Mapping Software and Data Bases, Harvard University, 1978.

APPENDIX 16.1

This is a typical building survey and inventory form used in area planning in developing countries. For any given country or area situation, the basic form must be modified to serve the special purposes of the study and the locale.

BUILDING SURVEY FORM

Serial Number _____

Date _____

Name of School _____ No. Students (a) enrolled _____
(b) attending this day _____

Location of school (e.g. name of town) _____ No. rooms _____

Grade levels taught _____ No. teachers _____

Name and position of respondent _____

Does your school have more than one session? If so, how many? _____

Note: Please answer every question. If a question is inapplicable, indicate so by "n/a". If you feel your answer needs explanation, please write on the reverse of this sheet.

I. Site

1. Accessibility—what % of students live within 3 k's of school? _____
2. Safety (a) are there any unfenced natural hazards adjacent? (e.g. river) _____
   (b) are there any unfenced man-made hazards adjacent? (e.g. highway) _____
3. Sanitation—are there health hazards adjacent? (swamps, dumps) _____

II. Lot

1. Drainage: no. of school days lost last year due to flooding _____
2. Is the lot reasonably level? _____
3. Size—give square meter measurement _____
4. Other—are there any other unsatisfactory conditions? _____ (explain on reverse)

III. Outside area

1. Is there a play area? _____ If so give square meter dimension _____
2. Is there a garden area? _____ If so give square meter dimension _____

5. windows _____
*6. sound proofing _____

B. Size
1. floor square meter _____
2. ceiling height _____
3. windows square meter _____
Are they adequate for illumination and ventilation_____. If not comment on reverse.

C. Facilities
1. storage square feet_____adequate_____
2. heating: type_____adequate_____
3. artificial illumination: type_____adequate_____
4. potable water: source_____
5. meal facilities: type_____adequate_____
6. sanitary facilities: type_____location_____
separate_____
*7. lab water supply: source_____adequate_____
*8. lab heat supply: source_____adequate_____

D. Equipment
1. blackboard—square mt._____
2. display board—square mt._____
3. bookshelves—number, mt._____
4. number student seats available _____
5. number student writing spaces_____
6. teachers desk_____and chair_____
*7. lab tables, number_____adequate_____
8. other lab or shop fixtures (specify)_____

E. Boarding School
Please use appropriate sections to describe dorms. Please supply the following as well:
1. number of beds_____
2. number of meals provided per day per student_____
(enclose last week menu)
3. location of cooking area_____
4. where do students eat _____

VIII. Summary
1. Indicate nature of school: (1) government owned _____
(check appropriate) (2) government rented_____
(3) loaned to government_____
(4) private school_____
_____

IV. Maintenance

1. Do you have regular maintenance repairs?_____
2. Do you have regular janitor service?_____

V. Administrative facilities

1. Are such facilities adequate?_____(if not, explain on reverse)

VI. Instructional facilities use

Name of school_____Location_____

No. of classrooms_____

Note: Use one of these forms for each and every classroom or laboratory in your school.

I Room Schedule

Hours	*Monday*	*Tuesday*	*Wednesday*	*Thursday*	*Friday*	*Saturday*	*Sunday*
	(1) Subj. Atten.						
7-8							
8-9							
9-10							
10-11							
11-12							
12-1							
1-2							
2-3							
3-4							
4-5							
5-6							
eve							

(1) For attendance figures use students in attendance in each class on each day last week.

VII. Structure

A. Materials

1. walls made of outside _____
   inside _____
2. floor made of _____
3. roof made of _____
4. ceiling _____

2. Age of structure
3. Rank facility overall:

Class 1 Priority:	Both building and site wholly inadequate must be replaced in different location_____
Class 2	Building wholly inadequate. Replace on same site_____
Class 3	Major remodeling and expansion required_____
Class 4	Major remodeling only_____
Class 5	Expansion only_____
Class 6	Some repairs necessary_____
Class 7	Currently adequate_____

SOURCE: Charleson, William, Davis, Russell G., and Williams, David, Harvard University Center for Studies in Education and Development

APPENDIX 16.2

Adjusting Differences in Coverage among Regions

Region	Actual percent covered (1)	Actual deviation (2)	Target deviations (3)	Target coverage (4)
A	80	0	0	80
B	40	-40	-6.66	73.33
C	50	-30	-5.00	75.00
D	30	-50	-8.33	71.67
Totals	50	-30	-5	75 (Target rate overall coverage)

Objective of Plan:

(a) Move from 50 to 70 percent coverage in country over five-year period.

(b) Do not reduce any area's proportional coverage, i.e. maintain 80 percent on Area A.

(c) Reduce deviations from coverage proportionately. This means that col. 3 is calculated by multiplying the actual deviations (col. 2) by the mean deviation, i.e. 5/30. Hence, in col. 3, 80% coverage is held constant, and the deviation is 0. For the second value, − 40 is multiplied by 5/30 which, equals − 6.66.

(d) Col. 4, which is the target rate among areas A to D, is obtained by subtracting the deviations in col. 3 from the maximum coverage rate; in this case, 80.

Note: The mean deviation is as follows:

Target deviation from highest percent (80) to target average (75). This equals 80% − 75% = 5%.

This must be apportioned to the actual average deviation, which is,

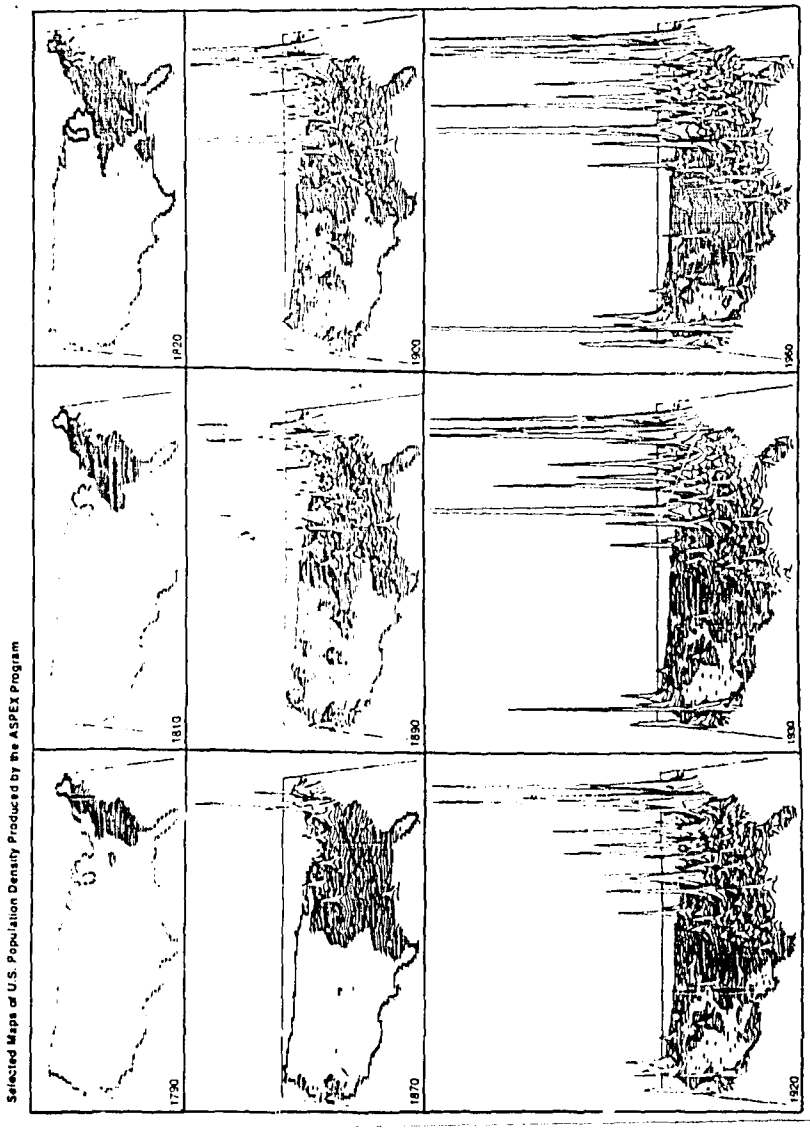
$$\frac{120}{4} = 30 \text{ (col. 3)}$$

Hence the mean deviation is 5/30.

See Hallak (1976) for further details on this method.

APPENDIX 16.3

Selected Maps of U.S. Population Density Produced by the ASPEX Program (Oblique perspective views of three dimensional surfaces)



Source: Harvard Center for Computer Graphics.

CHAPTER 17

School Mapping in an Educational Reform: Applying the Methods

Principal author, Ernesto Schiefelbein; Maria Clara Grossi assisted

1.0 *Introduction: National to Local Level Analysis*

Educational problems must be described and solutions proposed for different areas of a nation, or levels within a school system. National rates of repetition, for example, give a general idea of student flows, when compared with historic figures or international data. But the rates may be more meaningful when analyzed according to level of teacher training, or by student background. More and more specific data are introduced until the individual level of analysis is reached and a treatment is prescribed for a particular student. Planners may work at any point on the continuum from the global to the individual level of analysis. Here, we work from a national level, to a subnational area, to a local district level.

For any area, from national to local, to which planning is applied, the analysis may be carried out by the use of verbal statements, numerical tables, mathematical analysis, graphs or school maps. A map is a small-scale representation of the earth's surface on a plane. A chart is a special form of map on which additional information has been incorporated. The information provided by maps is specially fitted to analysis carried out along the geographical dimension. Information based on spatial distribution and geography can also be presented in tables. The geographical characteristics are shown by the row or column headings of the tables. This in fact is the most conventional way of presenting such information. Ministry of education data on school buildings, classrooms, teachers, and enrollments are usually given for the various states, provinces, or departments of a country. This information can be subjected to further statistical analysis to show significant differences by regions. An accompanying volume on data analysis will explain how analysis of variance can be applied to combinations of continuous and categorical data, for example, achievement test results arranged according to provinces of a country. Chi-square tests can be applied to data arranged in categorical form in both the rows and columns of a table; for example, enrollment in Complete versus Incomplete Schools can be tested for significant differences by province.

The exercise presented in this case works with tabulated data and maps. No further analysis is applied to the data. Data are arranged in tables, and the tabulated data are then transferred to maps which show the location and distributional features of the data more graphically than the tables can display them. A map may not show any more than a table shows; but the map shows what it shows more graphically. It is the presentation device best fitted

to display the spatial features of information. *This exercise was designed to show how to work back and forth between tables and maps.* This is a common task of ministry of education analysts and planners. The methods are illustrated with a case exercise. There will be additional comments on the limitations of maps when used in educational planning.

1.1 *Regional, National, Local, and School Levels*

School characteristics may be represented at several levels of geographical aggregation. In a UNESCO study of the feasibility of a regional educational TV system the analysis was carried out for the entire Latin American region; and for each of the participant countries UNESCO (1975) maps were used to diagnose the current situation and to portray the future. The map sets prepared for each country included population density in 1970 and 1990; a political map; population by areas of 80 km² for 1970 and 1990; and the national population distribution.

At the opposite level of disaggregation, in planning city schools, the plant layout of a given school, a classroom, or even a student classroom space can be shown in the most detailed and concrete types of maps for educational planning. In the accompanying text of the previous chapter the map in Exhibit 17.1 shows individual students (coded by ethnic characteristics) located according to their place of residence in the school district. This illustrates the point that maps as well as tables can display data from the aggregate level (the population of the world) down to the individual level.

Maps have long been used for portraying spatial characteristics of data used in physical, economic and social planning. As educational program planning in developing countries has had to deal more with problems below the national level, school mapping for area planning has grown in importance. Mapping responds to increased pressures for analyzing problems at the local level. Varied and detailed maps are becoming more necessary as school mapping activity increases (Hallak 1976). Furthermore, analyses of relations between antecedents and effects of schooling have detected significant relationships between educational outcomes and locational characteristics. Rural versus urban birthplace and/or residence, time or distance from home to school, access to TV broadcasting, size of community, or distance (time) from teachers' home to school, may all influence school achievement Note the effects of rural birthplace and rural residence on school achievement differences among school children in El Salvador. This is shown in the path model in the appendix of Chapter 2. In general, rural deprivation has affected the quality of educational inputs adversely; but rural children have performed better than urban students on some achievement tests (Robinson 1977). In El Salvador, preliminary analysis indicated that rural students had slightly higher achievement than urban students. This does not mean that there was not rural deprivation, because many rural students were forced out of schools before the testing. Rural "survivors" did perform better than unscreened urban students (1977).

2.0 *Priorities for Building New Schools: A Case Exercise in Chile*

Political and social pressures on school construction programs often introduce external and unplanned elements into the construction schedules of new schools. Schiefelbein and McGinn (1973) report experience in Chile which is common in developing countries. This chapter (based on Chilean experience) will describe attempts to provide an objective index for defining priorities for construction of schools in all areas of the country. Talca, one of the 25 provinces of Chile, has been selected as an example of the exercise; and a Talca country, the *communa* of San Clemente, will be studied in detailed fashion in a school mapping exercise.

The exercise was carried out in 1966. The previous census of population had been done in 1960 and published in 1965. There were population estimates available for 1970 by provinces. Table 17.1 presents the census data and basic estimates.

Table 17.1

Population of Urban Centers 1970 (Province of Talca)

Urban centers	Census 60 (1)	% Distrib. (2)	CELADE 60 (3)	Increase from 60-70 (4)	CELADE 1970 (5)
Casa Blanca	1,218	1.3	1,273	714	1,987
Central Cipreses	1,515	1.6	1,566	878	2,444
Central Isla	747	0.8	783	439	1,222
Cumpeo	1,006	1.1	1,077	604	1,077
Curepto	1,699	1.8	1,762	988	1,762
Gualleco	572	0.6	587	329	587
Lo Valdivia	462	0.5	489	275	489
Lontué	1,115	1.2	1,175	659	1,834
Maule	821	0.9	881	494	881
Molina	7,621	8.2	8,027	4 502	14,890
Pelarco	1,003	1.1	1,077	604	1,681
Pencahue	509	0.6	587	329	587
Sagrada Familia	739	0.8	783	439	783
San Clemente	2,507	2.7	2,643	1 482	4,125
San Rafael	1,156	1.3	1,273	714	1,987
Talca	68,148	73.6	72,049	40 407	114,596
Villa Prat	1,731	1.9	1,860	1 043	1,860
Pop. Urban	92,618		97,892		152,792
Pop. Rural	113,637		120,008		120,008
Total Province	206,255		217,900	54.900	272,800

Source: Population Centers by Province, Census of 1960, Dirección de Estadística y Censos; corrections, CELADE

2.1 *The Population Base: Table Formats*

Column 1 of Table 17.1 presents Census data for 1960 by urban population centers. The percentage distribution is computed in column 2. The Census percentages are multiplied by the corrected population estimates of the Latin American Demographic Center (CELADE) to obtain the figures in column 3. On the assumption that rural population remains constant due to migration from rural to urban areas, all the increment in population from 1960 to 1970 (54,900 inhabitants) is distributed in urban areas, using the population percentages of 1960 to obtain the increases in column 4. Final estimates for 1970 are shown in column 5.

Rural and total population by counties is estimated in Table 17.2. The Census population by counties in 1960 is presented in column 1; the distribution is computed in column 2, and multiplied by the total rural population estimated by CELADE (120,008) for 1970. This distributes the rural population by counties in column 3. Estimates by towns from Table 17.1 are added for each county and presented in column 4 of Table 17.2. Column 5 presents the addition of rural and urban estimations for 1970. San Clemente County is estimated to grow to a population of 27,856 in 1970.

Table 17.2

Rural and Urban Population of the Province of Talca for 1970

Counties	Rural			Urban	Total
	Census 60 (1)	Percent (2)	CELADE 70 (3)	CELADE 70 (4)	(5)
Talca	11,230	9.88	11,857	114,596	126,453
San Clemente	18,993	16.72	20,065	7,791	27,856
Polarco	12,205	10.74	12,889	3,668	16,557
Rio Claro	8,660	7.62	9,145	1,077	10,222
Pencahue	7,559	6.65	7,981	587	8,568
Maule	13,148	11.57	13,885	881	14,766
Total TALCA Department	71,795	63.18	75,822	128,600	204,422
Molina	19,757	17.39	20,869	18,711	39,580
Valdivia de Lontué	10,124	8.91	10,693	3,132	13,825
Total LONTUE Department	29,881	26.30	31,562	21,843	53,405
Curepto	11,961	10.52	12,624	2,349	14,973
Total CUREPTO Department	11,961	10.52	12,624	2,349	14,973
Total Province of TALCA	113,637	100.00	120,008	152,792	272,800

2.2 *Working from Tables to Maps*

The population figures may also be represented in maps. In order to do so the Census data must be further disaggregated. Table 17.3 presents data for San Clemente County from the two previous Censuses, by sex and district.

Table 17.3

San Clemente County by Districts

Districts	Census 1952			Census 1960			Density[a] of population	
	Men	Women	Total	Men	Women	Total	1952	1960
San Clemente	1,778	1,758	3,536	2,359	2,344	4,703	81.94	100.99
Ramadillas	1,051	958	2,009	1,475	1,318	2,793	80.00	111.23
Santa Elena	1,248	889	2,137	1,208	949	2,157	48.77	49.23
Peuno Negro	472	387	859	575	439	1,014	16.51	19.49
Bajos de Lircay	719	614	1,333	856	703	1,559	24.17	23.26
Vilches	2,644	1,953	4,597	749	626	1,375	2.20	0.65
Curillinque	701	229	930	2,706	2,283	4,989	0.81	3.90
Cerro Colorado	975	705	1,680	1,205	900	2,105	5.48	6.97
Mariposas	1,509	1,232	2,741	1,659	1,408	3,067	22.55	25.73
Total	11,097	8,725	19,822	17,792	10,970	23,762	5.11	6.13

Source: Ligia Herrera, "Tendencias del Poblamiento en Chile desde 1940 a 1960" Dirección de Estadísticas y Censos, Junio 1969.

[a]Density = inhabitants/km^2

Note: In estimating local populations, enrollments, and school needs, the planner must be constantly moving back and forth between tables, maps and overlays. He must also be moving back and forth between levels of system, using national data to guide and to check and control local data, and using local data to enrich and deepen national data. Mistakes are made when there is too much reliance on data tables at the expense of maps or graphics which give a clearer notion of spatial arrangements. It is, of course, equally dangerous to rely too much on graphics at the expense of data. The necessity of working back and forth between local and national level should be obvious.

Table 17.4 presents a further disaggregation. The first district, San Clemente, is broken down by villages, farms, and other population centers for 1960 and 1970.

Table 17.4

Subdistricts of San Clemente (District No. 1)

U/R	Centers	Symbols	Type	Houses	Men	Women	Total 1960	Total 1970
Rural	Alamo, El	(-)		35	140	121	261	276
R.	Alba, El	(-)		44	93	94	187	197
R.	Alba, El	(-)		9	36	25	61	64
R.	Brisas, Las	(-)		7	31	31	62	66
R.	Estrella, La	(-)		30	83	67	150	158
R.	Granja, La	(-)		21	88	74	162	171
R.	Hormiga, La	(-)		17	37	27	64	68
R.	Pellizco	(.)		4	15	14	29	31
R.	Pellizco	(ø)		5	12	12	24	25
R.	Peralillo	(ø)		2	7	4	11	12
R.	San Andrés	(ø)		8	20	15	35	37
R.	San Clemente	(3) white		51	155	156	311	328
Urban	San Clemente	(25)black		485	1,189	1,318	2,507	4,125
R.	San Diego	(2) white		39	127	111	238	251
R.	San Luis de Alino	(3) white		45	165	128	293	310
R.	San Mauricio	(-)		8	24	25	49	52
R.	Santa Emma	(-)		7	27	30	57	60
R.	Santa Rosa	(-)		19	53	54	107	113
R.	Tierruca, La	(-)		9	38	26	64	68
R.	Tilos, Los	(ø)		5	19	12	31	33
				850	2,359	2,344	4,703	6,445

Symbols:

(-) = Centers not located.

White means dispersed population, shown as small circle on map #2.

Black means concentrated population, shown as large black dot on map #2.

(.) = Centers considered concentrated, but with a population less than 45 people.

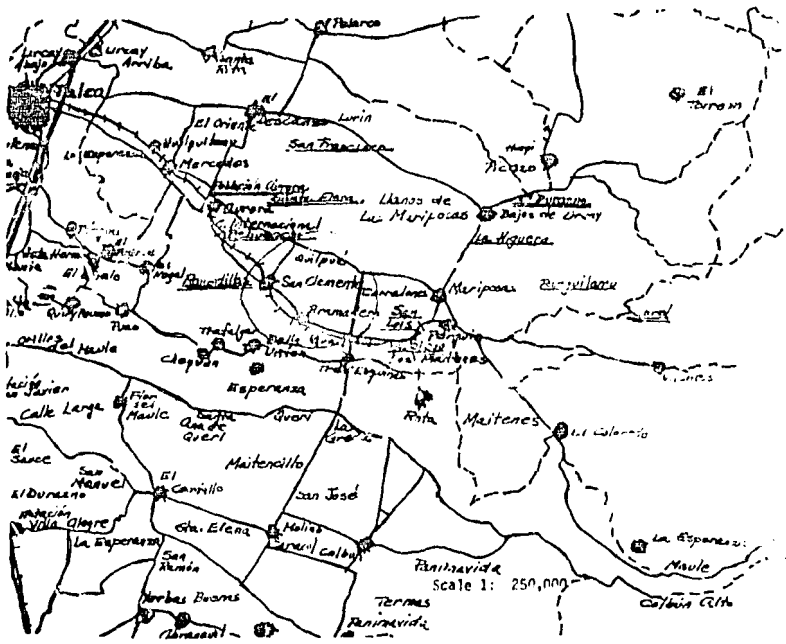
(ø) = Centers considered as dispersed, but with a population less than 45 people.

2.3 *Population and Area Maps*

Table 17.4 information was used along with the information on Map 17.1 to build a map showing the geographical distribution of the population in 1960. Map 17.1, prepared by the Bureau of the Census, includes the names of towns, highways, and railways. It is small in scale (1:250,000), but it is useful in the early part of a mapping exercise to have a small-scale map that sets the context for more detailed analysis later. San Clemente is in the center of Map 17.1, and various districts of San Clemente (Santa Elena, Ramadillas, etc.) are shown.

Map 17.1

The Area Around San Clemente



Data from Table 17.4 and information from Map 17.1 are now put together to make Maps 17.2 and 17.3.

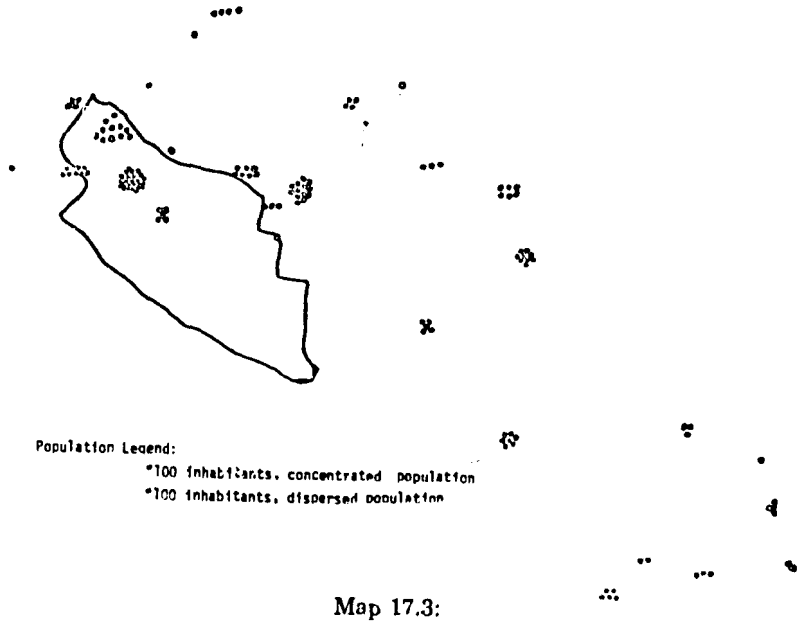
Map 17.2 shows the population of San Clemente in 1960, and is coded to show the size of the population (coded for size by number and type of dot). It is also coded to show *how* the population is dispersed. An empty dot shows a dispersed population living in small farms or Indian settlements scattered around a center. The information about San Clemente which is shown in Table 17.4 will be shown inside the line segment of Map 17.2. Note that some of the line segment cuts across certain groupings of population. This suggests some of the problems which will appear when the population is plotted onto the map. (For the whole county of San Clemente, 1600 inhabitants were not located, and this represents 5 percent of the population of the county.)

Map 17.3 presents similar information for the year 1970. No attempt was made to identify new towns or villages, but proportional increments were plotted, including an allowance for those (1600) not located in Map 17.2.

It would have been possible to plot dispersed population with other symbols (squares, for example) in the middle of each district, but only an approximate distribution of the population was considered necessary for the planning process illustrated in this case.

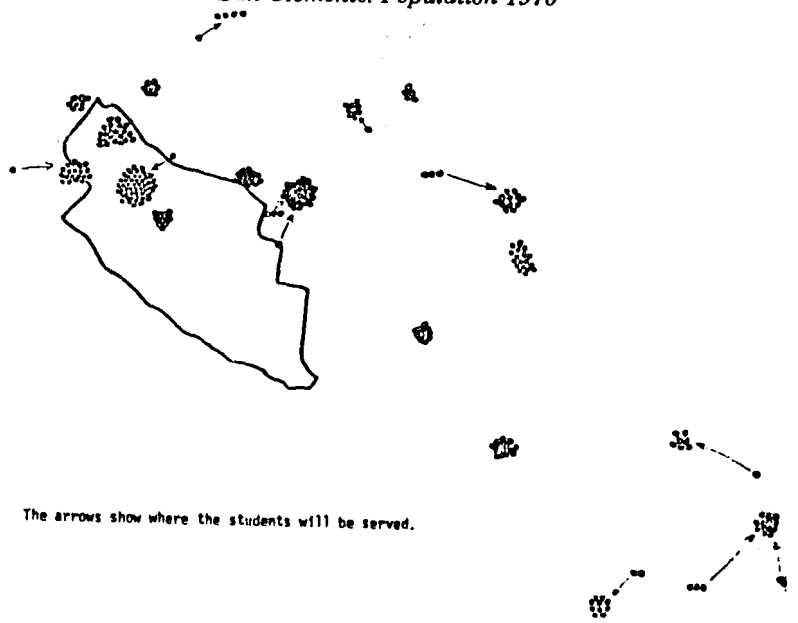
Map 17.2

San Clemente: Population 1960



Map 17.3:

San Clemente: Population 1970



3.0 *Area Demand for Educational Facilities*

Once the population was depicted on Map 17.3, the next step was to compute the projected demand for education in 1970, based on the national distribution by ages (see column 2, Table 17.5). National enrollment rates appear in the next column. The product of columns 2 and 3, is presented in column 4. Each figure represents the number of children of corresponding age who would be attending school in the Talca Province in 1970.

Table 17.5

Projection of Enrollment for 1970

Talca Province

Ages (1)	School age pop. (000) (area) (2)	Percent age group in school (nation) (3)	Population of school age enrolled(000) (4)
5	7.9	15.64	1.236
6	7.8	43.67	3.406
7	7.7	97.55	7.511
8	7.6	99.75	7.581
9	7.5	99.97	7.498
10	7.8	99.49	7.760
11	7.6	91.65	6.965
12	7.4	75.39	5.578
13	7.2	66.53	4.792
14	7.0	53.59	3.751
15	6.2	43.36	2.688
16	5.2	41.32	2.467
17	5.7	38.16	2.175
18	5.4	29.66	1.602
19	5.1	16.33	833
20	5.1	7.08	361
21	4.9	1.59	71
Total	113.1	53.63	66.397

Talca enrollment is broken down by grades according to national figures. The total number of students by grades is presented in Table 17.6. A total of 21.3 percent of the provincial population is projected to be enrolled in Basic Education level in 1970, and 2.5 percent in middle (secondary) education.

Table 17.6

Distribution by Grades of School Enrolled Population in 1970

Talca Province

	Basic Level Grades[a]								Sub-total
	1°	2°	3°	4°	5°	6°	7°	8°	
School-age population enrolled	9,190	8,593	8,275	8,640	8,256	6,160	4,615	3,402	58,131
Distribution in school by grades (%)	13.86	12.96	12.48	13.03	13.06	9.29	6.96	5.13	
Percentage of total population in "Basic" level									21.3

[a]As part of the Chilean Education Reform, the schools changed to 8-grade "basic" level.

Middle school and pre-university	"Middle School"			Sub-total	Pre-Univ.	Total
	9°	10°	11°		12°	
School-age population enrolled.	2,712	2,[illegible]	1,307	6,022	1,267	66,[illegible]
Distribution in school by grades (%)	4.09	3.59	2.77	10.45	1.[illegible]	
Percentage of total population enrolled.				2.5	0.5	24.3

The enrollment proportions and estimates previously carried out in Table 17.6 are distributed as a proportion of the 1970 population estimate in each of the counties of Talca Province in Table 17.7. This would give an estimate of 5,933 students attending at Basic Level by 1970 in San Clemente. (Map 17.4 shows the geographical distribution of this 1970 demand for Basic Education.)

Table 17.7

Population of School Age Enrolled in 1970[a]

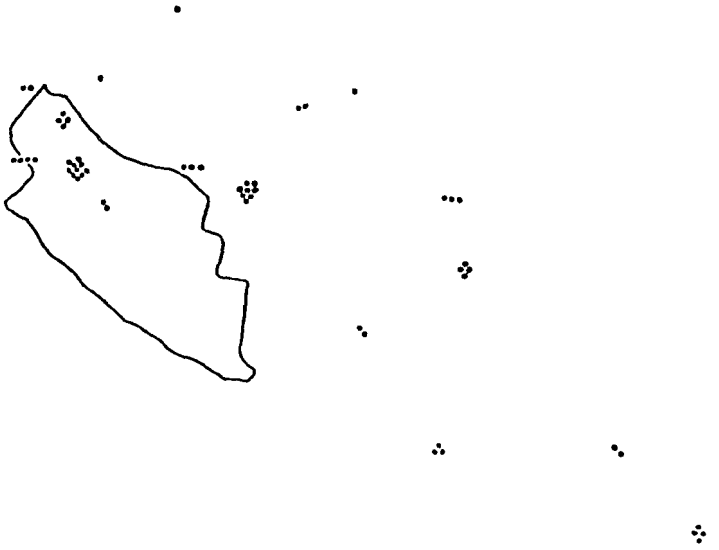
Counties	Urban		Rural		Total		
	Basic	Middle	Basic	Middle	Basic	Middle	Pre-Un
Talca	24,403	2,946	2,526	246	26,935	3,242	578
San Clemente	1,649	195	4,284	502	5,933	697	127
Pelarco	781	92	2,745	322	3,526	414	67
Río Claro	229	27	1,948	229	2,177	256	47
Pencahue	125	15	1,700	200	1,825	215	39
Maule	188	22	2,958	347	3,146	369	68
Depto. TALCA	27,391	3,297	16,151	1,896	43,542	5,193	935
Molina	3,985	488	4,452	522	8,437	1,010	180
Valdivia de Lontué	667	78	2,283	267	2,950	345	63
Depto. LONTUE	4,652	566	6,735	700	11,387	1,355	244
Curepto	500	65	2,702	316	3,202	381	63
Depto. CUREPTO	500	65	2,702	316	3,202	381	63
Total	32,543	3,928	25,588	3,001	58,131	6,929	1,247

[a]Distributes the enrollment by school level proportions (projected for 1970 in Table 17.6 by the Total population projected for counties and subdistricts previously projected (Table 2), e.g. 27,856 x .213 = 5993; 27,856 x .025 = 697

Map 17.4 shows the geographical distribution of the demand for Basic Education in 1970 in San Clemente.

Map 17.4

Estimated Demand for Basic Education in 1970



3.1 *School Facilities Inventory*

The organization in charge of school construction (SCEE) surveyed school buildings and inventoried available space in each school. The forms, filled out by the school principals and checked by the architects of SCEE, yielded the data of Table 17.8.

Table 17.8

Schools in San Clemente Survey

Prov. Talca Dpt. Talca County: San Clemente (11-1-2)

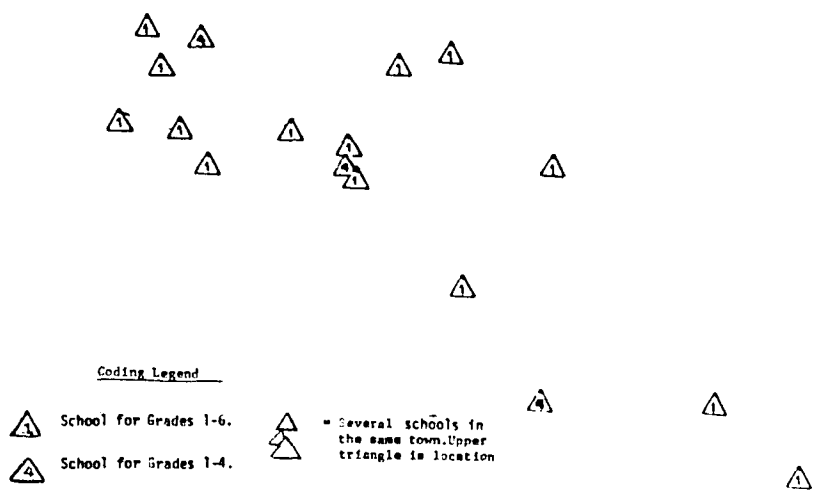
N° Clasific.	Address	Grades	Section	Enroll.	Teachers
01 - Primary Public Common					
-8 -Mx 2a.R.-	-Parc. Sta. Gladys-Perquín	1°/6°	6	217	5
-14 -Mx 2a.R.-	-Fdo. Bramadero	1°/6°	6	91	2
-20 -Mx 2a.R.-	-Fdo. El Durezno	1°/3°	3	100	2
-16 -Mx 2a.R.-	-Los Cipreses	1°/6°	15	719	14
-21 -Mx 2a.R.-	-Clodomiro Silva s/n	1-1°/6°	29	1063	33
-32 -Mx 2a.R.-	-Cam. Int. Pehuenche-Perquín	1°/4°	4	42	1
-42 -Mx 2a.R.-	-Bajo Lircay	1°/4°	4	58	2
-60 -Mx 2a.R.-	-Fdo. El Colorado	1°/4°	5	113	2
-63 -Mx 2a.R.-	-Hda. Mariposa	1°/6°	9	356	9
-66 -Mx 2a.R. (-)	-Fdo. La Hormiga	1°/4°	4	113	3
014 - Primary Private Common					
-2 -Mx. G.R. (-) "Municipal Sta. Camila" Santa Camila		1°/3°	3	77	1
-18 -Mx. S.R. -	-Los Montes-Hda. Mariposa	1°/2°	2	76	1
-21 -Mx. S.R. -	-Fdo. La Esperanza - La Experanza.	1°/4°	4	116	2
-28 -Mx. R. -	-Sta. Elena. Fdo. Sta. Elena	1°/3°	3	77	1
-36 -Mx. G.R. (-)	-Dgo. Escalona-Vilches Bajo	1°/3°	3	134	1

3.2 *Computing Facilities Deficits*

In Map 17.5 the information of Table 17.8 is coded and mapped.

Map 17.5

Schools Available in San Clemente, 1966



It is now possible to compare Map 17.4 to Map 17.5, in order to see how many teachers and classrooms the schools should have in 1970, or the number of new classrooms to be built in order to match demand. (Note that an additional map might also be useful to show capacities under the alternative of scheduling more than one shift.)

Table 17.9

Demand and Deficit of Classrooms for 1970[a,b]

Counties	Urban		Rural		Total			Installed		Deficit		
	Basic	Middle	Bas.	Mid.	Bas.	Mid.	CPU	Bas.	Mid.	Bas.	Mid.	CPU
Talca	509	74	53	7	562	81	15	271	146	-291	+65	-24
San Clemente	35	5	89	13	124	18	3	60	-	- 64	-18	-
Pelarco	16	2	57	8	73	10	2	42	-	- 31	-10	-
Río Claro	5	1	41	6	46	7	1	17	-	- 29	- 7	-
Pencahue	3	-	35	5	38	5	1	16	-	- 22	- 5	-
Maule	4	1	62	9	66	10	2	41	-	- 25	-10	-
Depto. TALCA Total	572	83	337	48	909	131	24	447	146	-462	+15	-24
Molina	83	12	93	13	176	25	5	64	44	-112	+19	- 7
Valdivia de Lontué	14	2	47	7	61	9	2	26	-	- 35	- 9	-
Depto. LONTUE Total	97	14	140	20	237	34	7	90	44	-147	+10	- 7
Curepto	10	2	57	8	67	10	2	26	1	- 41	- 9	- 2
Depto. CUREPTO Total	10	2	57	8	67	10	2	26	1	- 41	- 9	- 2
TOTAL	679	99	534	76	1,213	175	33	563	191	-650	+16	-33

[a]The number of required classrooms were estimated by dividing the number of students by 48, e.g. 5933 (Table 7) divided by 48 = 124.

[b]Capacity has been computed excluding spaces for administrative purposes, aisles, teachers' houses, boarding areas, library or other spaces not for teaching purposes.

The demand for additional school facilities is shown in the figures computed in Table 17.9. San Clemente County must build 64 additional classrooms at Basic Educational level if schools are to be operated in only one shift (this was then the current policy). If schools are operated in double shifts, only two additional classrooms would be needed. Note the assumption behind this arithmetic. It is one often made by planners. Without further analysis they assume that 60 existing installed classrooms can be multiplied by 2 to yield 120: $124 - 120/2 = 4/2 = 2$. This in turn assumes:

— That the 1965 installed capacity of 60 classrooms will still remain adequate space in 1970. Though the survey might inventory it as adequate space in the base year, it might not still be adequate (without extensive repair) in the target year 1970.

— That population is distributed in such a way that all students could attend double sessions in the 60 rooms. The map analysis of San Clemente shows that this might be possible given existing residence patterns, but planners cannot be certain that this will prevail in the plan year. It also assumes that schools would require an exact doubling of classrooms. This must be checked school-by-school. In the Talca situation it was checked and adjustments were made.

Also note that there are no precise data on the effects of migration. Past patterns were analyzed, and it was shown that there had been no effect on

San Clemente. This does not mean, however, that these patterns will not change. The planner can never be sure of this. At best he is a sage—never a seer.

At the national level enrollments of seven-year-olds had increased rapidly in the period prior to the TALCA study. This increase, as Table 17.9A will indicate can be attributed to both rapid increase in the seven-year-old population base, and a larger percent of that base enrolled in school mainly at first and second grade. The TALCA study, though an example of school mapping at the local level, also used national trends as rough guidelines for estimation of local changes.

Table 17.9A

Population Enrollment Changes

Year	Seven Years Population	(Table 2) Maximum % Enrollments	Estimated Newcomers of Seven Years Cohort
1954	166,600	80.60%	134,000
1962	218,000	95.84	209,000

5.1 *Assigning New Teachers*

The assignment of new teachers requires the definition of catchment areas for each secondary school. The area covered will depend on the time and cost of transportation required for students to reach the school. The maximum time is around 45 minutes: (a) 3 km for a 7-year-old child who is walking; (b) 12 to 15 km for someone riding a bicycle; (c) 30 to 40 km for someone riding a bus.

Table 17.10

Index of Priority of the National Plan for School Construction, 1966-1970
(Classroom Units)

Province of Talca

Counties and Departments	Capacity = C			Demand = D				Deficit = D-C			Capacity/Demand = C/D			Demand/Deficit = 1 - C/D			Index of Priority (D-C) (1 - C/D)		
	Basic	Mid.	Total	Bas.	Mid.	Prev.	Total	Basic	Mid.	Total	Basic	Mid.	Total	Basic	Mid.	Total	Basic	Mid.	Total
Talca	271	146	417	562	81	15	658	291	-50	241	0.48	1.52	0.63	0.52	-	0.37	151.32	-	89.17
San Clemente	60	-	60	124	18	3	145	64	21	85	0.48	-	0.41	0.52	1.00	0.59	[illegible]	21.00	50.15
Pelarco	42	-	42	73	10	2	85	31	12	43	0.57	-	0.49	0.43	1.00	0.51	13.33	12.00	21.93
Río Claro	17	-	17	46	7	1	54	29	8	37	0.36	-	0.31	0.64	1.00	0.69	18.56	8.00	25.53
Panquehue	16	-	16	38	5	1	44	22	6	28	0.42	-	0.36	0.58	1.00	0.64	12.76	6.00	17.92
Maule	41	-	41	66	10	2	78	25	12	37	0.62	-	0.52	0.38	1.00	0.48	9.50	12.00	17.76
Depto. TALCA	447	146	593	909	131	24	1.064	462	+9	471	0.49	0.94	0.55	0.51	0.06	0.45	235.62	0.54	211.95
Molina	64	44	108	176	25	5	206	112	-14	98	0.36	1.46	0.52	0.64	-	0.48	71.68	-	47.04
Valdivia de Lontué	26	-	26	61	9	2	72	35	11	36	0.42	-	0.36	0.58	1.00	0.64	20.30	11.00	23.04
Depto. LONTUE	90	44	134	237	34	7	278	147	-3	144	0.37	1.07	0.48	0.63	-	0.52	92.61	-	74.88
Curepto	26	1	27	67	10	2	79	41	11	56	0.38	0.08	0.34	0.62	0.82	0.66	25.42	9.02	36.96
Depto. CUREPTO	26	1	27	67	10	2	79	41	11	56	0.38	0.08	0.34	0.62	0.82	0.66	25.42	9.02	36.96
PROVINCIA DE TALCA	563	191	754	1.213	175	33	1.421	650	+17	667	0.46	0.91	0.53	0.54	0.09	0.47	351.00	1.53	313.49

5.0 *Estimating Needs Based on Enrollment Flow*

Pressure for expansion of the school system is heavy in developing countries, given the high rates of population growth. In Chile, each year the country was studied by a task force charged with reporting on student flows. Each task group was provided with school maps, including lists of unlocated villages or schools, such as in Map 17.6. Local authorities could then provide additional information to update standard maps like 17.4 and 17.5.

Local rates of repetition and dropout were compared with national or regional averages in search of atypical cases and their causes.

As part of the Chilean School Reform an 8-year Basic School level was established. Grades 7 and 8 had to be shifted from middle schools as part of the San Clemente mapping.

Map 17.6

San Clemente, Unidentified Population and Schools

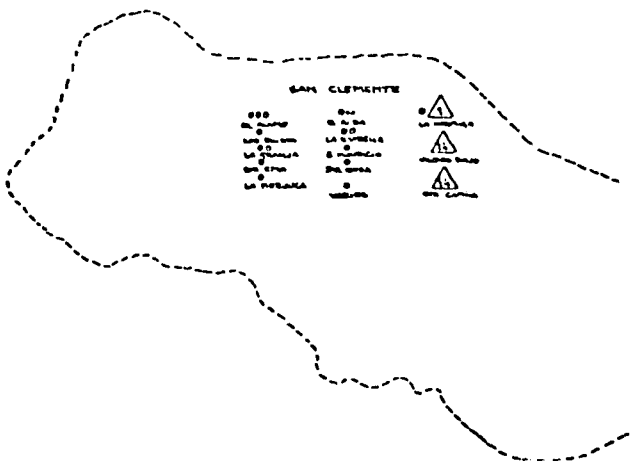


Table 17.11 shows the school needs analysis by the local task force in San Clemente: (a) 4 seventh grades will disappear in secondary schools and will be created in Basic schools, (b) 3 eighth grades will be added in secondary schools (in addition to the eighth grades created in basic education); and (c) 17 new first sections in secondary are to be created. On-site discussions with the principals is always required before reaching a final decision.

In planning, the social dynamics of the process, and not mere techniques are always important. Before the procedure was carried out for the first time, a national seminar for all principals was sponsored by the Ministry. In addition to the information about the purpose and method, a case study was worked out, and this was used to explain the procedure to the principals in a participatory discussion format. See Schiefelbein (1974).

The actual working out of the provisional results was a simple thing:

Table 17.11

Provisional Results

	7°	8°	9°	10°	11°	12°
School 1	-	-2	-2	-1	-	-
School 2	+1	-3	-2	-1	+1	
Commercial	-		-4	-2	-	
Industrial	-		-2		-	
Fem. Technical	-		-	1	-	
Middle (secondary)	+3	-3	-7		-	
Normal Schools	-	+5	-		-	
Annex	-		-		-	
Total	+4	-3	-17	-5	+1	-

- to create
+ to abolish
Total to create
25

Estimation of the local results was also guided by the national pattern which showed a strong and steady increase in the Basic and Secondary levels of school.

Table 17.12

Growth in School Enrollment by Levels from 1964–1970

		1964	1970	Increase or Decrease % 1964-70
Basic (1)	Pub	1,088.8	1,610.7	47.9
	Priv	464.5	512.7	10.4
	Tot	1,553.3	2,123.4	36.7
Secondary (2)	Pub	62.1	154.4	148.5
	Priv	37.1	61.1	64.6
	Tot	99.2	215.5	117.1

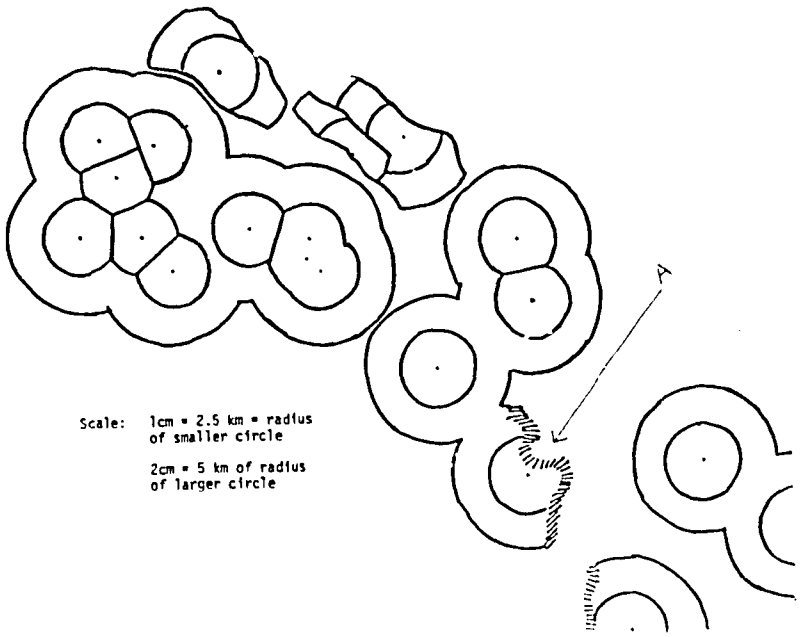
4.0 *Priority Indices for Showing Area Need*

Table 17.10 shows different ways to compute priority indexes. A quotient between capacity available and demand would give preferential attention to those counties or provinces with lower indexes. A quotient between deficit and demand will give preference to those places with a higher coefficient, but it is equivalent to the previous index. The third index will give relatively more weight to absolute deficits. The specific index to use will depend on general educational policies of the country; but no all-purpose, all-area norms are ever completely objective or acceptable. Norms vary with circumstances.

Map 17.7 shows walking distance catchment areas for the primary schools in San Clemente.

Map 17.7

Catchment Areas, San Clemente



In Map 17.7, which shows the catchment areas of San Clemente, the smaller circle corresponds to a 2.5 km radius, which would give an area of about 20 km². The outer circles have a 5.0 km radius, which would yield an area of about 80 km². Most of the areas in the map depict a whole circle with the standard radius but, in some cases, rivers or mountains reduce the area that can be served from a given school location. Note that area A is broken by a mountain and gorge.

Other maps may help to identify the area features which limit attendance for students in areas where access is affected by natural barriers or lack of roads. (Exhibit 17.1 is a highway map of the San Clemente area, and it was used in the location analysis. Exhibit 17.2 shows the river system in the area. Other maps might also serve the planner.

In the case of populations which are distributed in relatively flat lands, more simple methods based on density of population may be used. The area may be covered by hexagons (Hallak 1976). These formulas are discussed in Chapter 16 under Area Planning. (The formula is 2.598 r^2d, where r is the radius, d is the school age population density, and 2.598 is the factor to

compute the area of a hexagon with distance r from center to side). Local information on bus routes and schedules, roads, bicycle usage, bridges over rivers and creeks, mountains, and other geographical features, are of key importance for a realistic appraisal of possible alternative ways of determining locations and assigning teachers or other resources to the area. The additional information should be recorded in maps and tables.

6.0 *Final Comments: Limitations on Mapping*

Maps are far from being precise, and it not easy to put together information from two sets of maps. (As an exercise the reader should try to compare Maps 17.1 and 17.9.) However, people with training in geography or urban planning are often available to help. In the Chilean exercise, Ministry of Education planners were assisted with technical help from the Military Mapping Institute and from the Directorate of Census and Statistics. A professor in the School of Architecture at the University of Chile assigned students from his urban planning course to help educational planners inventory space needs. The task of a planner is to find expert help from specialists.

An entire country of the size, if not the shape, of Chile, can be shown in 15 large maps (2- to 2-meters each); but for certain occasions it is necessary to work with larger-scale maps of small area, for example, in meeting with principals or district inspectors. These meetings also offer an opportunity to update local information. There may be no need to prepare a new map; suitable symbols may be added to show new information.

Working on problems at the local level may lead to increasing the estimates of resources required for program implementation, because catchment areas tend to be reduced by geographical features. Resources cannot be fully utilized because of indivisibilities in schools, rooms, or teachers. In many isolated areas it may be necessary to return to one-room, one-teacher multigrade schools, at least until the development of the country permits busing students for longer distances.

Successful work in planning depends on the accuracy of data. Sound local information is critical for planning, and local educators should be trained in the use of maps and in the handling of basic data. The experience from this case suggests that local school officials will take the initiative and do a great deal of work in planning. The planner must stimulate this local initiative. After two or three visits to a region, the school principals in Talca organized themselves to get information and present their own solutions to confront planners. In many cases the local proposal was the best.

Training for local people in mapping and data analysis is a basic requirement, and also an important by-product of local planning. Central planners cannot handle all areas; continuing locally based research is necessary. Distances from different cities, villages or farms, means of transportation, schedules, fares, and other relevant information should be collected at the local level. Use of bicycles deserves special attention in all cases where roads are usable all year round. Large cities present some special problems, but more information is available, and more experiences from developed coun-

tries may be applied in the urban areas of less developed countries. Each rural area is unique.

The catchment area for large cities and population centers must be determined, and often it includes a broad area of the surrounding countryside. The techniques are basically the same as presented above.

The available information always forces the planner to create new ways to insure consistency in marshaling the fragmented data with which planners must work when analyzing local situations.

Exhibit 17.1

Map 17.8 Highways

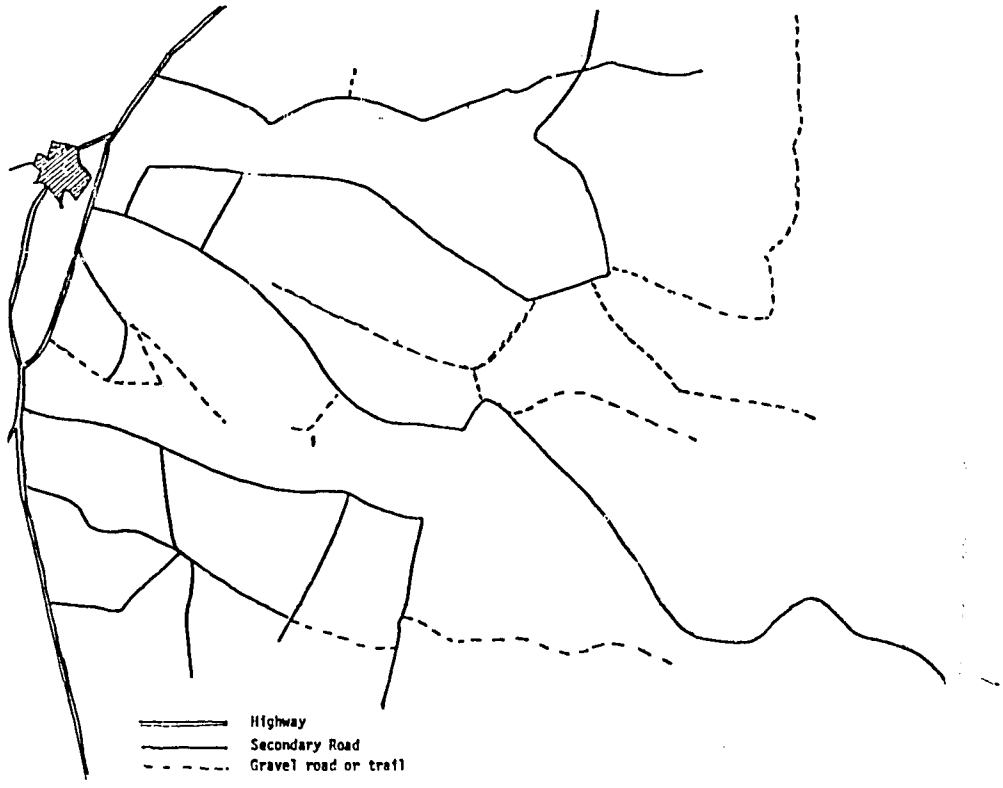
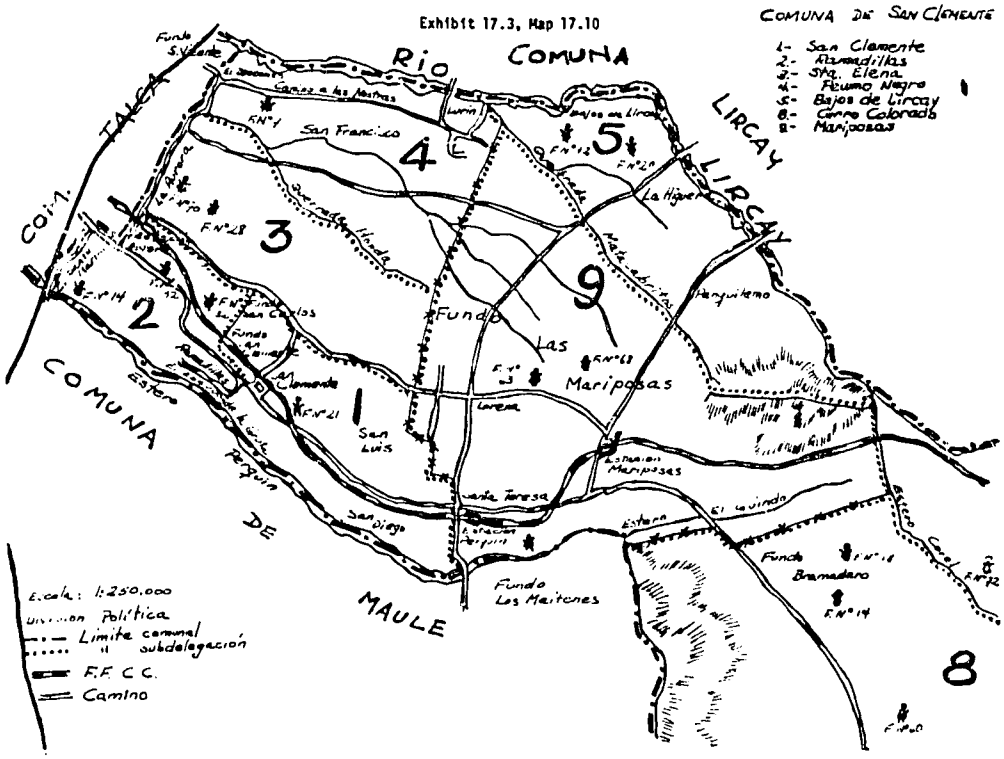


Exhibit 17.2

Map 17.9 Hidrographic System

Exhibit 17.3

Map 17.10



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