Tools for Manpower Planning
The World Bank Models

Volume I
Technical Presentation of the Models

Ismail Serageldin
Bob Li
WORLD BANK STAFF WORKING PAPERS

Tools for Manpower Planning
The World Bank Models

Volume I
Technical Presentation of the Models
Number 587

Volume II
User's Guide for the Country (Compound) Model
Number 588

Volume III
User's Guide for the Regional (Expanded) Model
Number 589

Volume IV
User's Guide for the Migration Model
Number 590
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Ismail Serageldin is chief of the Urban Projects Division and Bob Li is senior operations officer and leader of the Organization and Management Unit, Technical Assistance and Special Studies Division, both in the Europe, Middle East, and North Africa Regional Office of the World Bank.
Foreword

The explosion of international migration in the Middle East and North Africa Region in the 1970s was a major development on the international economic scene with profound implications for both the labor-importing and the labor-exporting countries. The World Bank undertook a research study on the subject in 1978 under the leadership of Ismail Serageldin and his group of committed colleagues in the Technical Assistance and Special Studies Division of the EMENA Projects Department. The study was completed in 1981 and the Report has been widely disseminated. It has been published in book form this year. 1/

The set of simulation models developed by the Technical Assistance and Special Studies Division and elaborated during the research project has been applied to study manpower problems and planning issues in several countries and proven to be a useful tool for manpower planning. The wide availability and a full description of these models is important and to be welcomed.

Vinod Dubey
Chief Economist
Europe, Middle East and North Africa Region

May 1983

Preface

This document, published in four volumes as part of the World Bank's staff working papers, is intended to set forth the mathematical formulation of the Bank's various Manpower Planning Models, most of which have now been used in a number of countries and studies, but whose technical documentation was not hitherto available to the public.

Applied Models are living entities, constantly changing and (we hope) improving to meet the new requirements introduced by their users. The present publication must therefore be seen as a snapshot in time, but one which presents the interested user with the opportunity of reviewing the technical documentation as well as the user's guides as they stand at the beginning of 1983. They are not likely to change significantly until a new round of intensive applications produces a new generation.

The technical presentation provides, for completeness, a detailed discussion (pp. 98-132) of a simultaneous procedure method for the migration model. This has not been implemented to date, partly because time and resources constraints prevented its complete development and elaboration, but it nevertheless sketches out the likely direction of our next round of research and development efforts, planned for 1983/84.

It is important to emphasize, however, that while we were the main protagonists in the development of these models, the work would not have been possible without the support, guidance and incisive comments of many colleagues in and outside the Bank. To all of them we owe a great debt of intellectual and moral gratitude. We emphasize, however, that any errors or shortcomings in the present manuscript are purely our own.
Among those in the Bank who provided constant support and encouragement during the six year life of these manpower planning efforts, of which this document is just a small part, we must thank in particular Mr. Vinod Dubey, Chief Economist of the EMENA region, whose constant personal and technical support from the earliest days to the present have made this task possible. The long-term study efforts have also benefitted from the strong support of Messrs. R. Chaufournier, Vice-President of EMENA; and M.P. Benjenk, currently Vice-President, External Relations and formerly Vice-President of EMENA; and Messrs. A. David Knox, currently Vice-President for West Africa (formerly Projects Director, EMENA); A. Karaosmanoglu, currently Vice-President for East Asia and Pacific (formerly Director of Programs, EMENA), and M.P. Bart, Director of Programs, EMENA; and A.S. El Darwish, Director of Projects, West Africa (formerly Assistant Director of Projects, EMENA); and especially Messrs. R. Picciotto, Director of Projects, EMENA; and J.J. Stewart, Assistant Director of Projects, EMENA. A special mention is also needed of the support given by Mr. D. Avramovic when he was Director of the Bank's Development Economics Department, and Mr. S. Acharya when he was Research Advisor.

Many colleagues from the Bank have contributed valuable comments and insights to the general studies of which these Models were the central part, among these we must name S. Birks, C. Blitzer, F. Colaco, Z. Ecevit, I. Hume, J.P. Jallade, T. King, G. Pennisi, R. Prosser, N. Sherbiny, C. Sinclair, J. Socknat, and M. Wilson. The computer related work was ably done by Peter and Tom Wolfe (Consultants). Earlier versions were programmed by A. McClinton of the Phoenix Corporation. Applications on various countries were undertaken with the support of G. Cima, B. Krishna, B. Smith, M. Pemmarazu, M. Youssef, and M. Allak.

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Among the colleagues from the academic world, special thanks are due to the contributions of Professors I. Sirageldin (Johns Hopkins University), C.S. Kelly (Ohio State University), R. Davis and W. Alonso (both of Harvard University), and the late Arthur Smithies (Harvard University).

Finally, Professor John Kantner (Johns Hopkins University) and Mr. Mervin E. Muller (Senior Advisor to the Vice-President and Controller) reviewed this manuscript, and Mr. R. Wolfe (Consultant) provided editorial support. To each and everyone our thanks and appreciation.

Ismail Serageldin and Bob C. Li

The World Bank
Washington, D.C.
May 1983
NOTE

The purpose of this series of World Bank Staff Working Papers is to describe the structure, input, output, use and operation of the World Bank manpower forecasting Models, implemented for IBM 370 systems.

Staff of the Technical Assistance and Special Studies (TASS) Division of the World Bank are available, under appropriate arrangements, to discuss with potential users the collection and preparation of required input data for running the models. In some cases, the TASS Division can also conduct short orientation and training sessions on the capabilities and operation of the models.
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INTRODUCTION

0.1 This paper describes the manpower model which has been developed by the Technical Assistance and Special Studies Division of the Europe, Middle East, and North Africa Projects Department of the World Bank, with the problems of both labor importing and exporting countries in mind. The principal applications for planners are: (1) to forecast manpower requirements (national and expatriate) required to meet specific sectoral output targets; and (2) to identify and isolate specific problems in the supply of manpower through simulation of flows of students and trainees through the education and training system in the light of such modifiable parameters as participation, repetition and dropout rates, and qualifications required to enter programs. The system also permits the planner to set specific manpower targets through an allocation submodel, such as maximizing the number of nationals in certain occupational categories in a given sector or optimizing the allocation of qualified labor to occupations in those sectors of the economy which are considered as having a high priority. Since the model incorporates sectoral production targets, together with certain assumptions about productivity growth for the sectors concerned, the model can also be used to estimate what production levels might be achieved in given sectors, working with existing and likely indigenous manpower stocks but with certain limits, if so desired, placed on the growth or overall numbers of expatriate manpower.

The model consists of three interrelated simulation models (with optimization capabilities) that relate economic growth, education and training, labor force, unemployment, and the importation/exportation of labor. The three models are a country-specific model, an expanded country model that analyses by region within a specific country, and an
international labor migration model that quantifies labor flows between countries.

The Country Model, which the World Bank has used to analyze manpower problems in more than 10 countries, has been adopted and used by five governments (Saudi Arabia, Kuwait, Tunisia, Algeria, and Portugal) and is presently being considered by a number of other governments in the Middle East and North Africa for adoption as a planning tool in their own agencies.

0.2 The Country-Specific Model

The country model relates growth, education, labor supply and requirements, and the need for nonnational members of the labor force on a national basis. The model provides for a basic flow in input data in a simultaneous process to three submodels: The labor force model (LFM); the manpower requirements model (MRM); and the education simulation model (ESM). The LFM is linked to the MRM; and both are linked along with the ESM to the fourth submodel, the manpower policy model (MPM), which, in turn, generates both output and feedback to earlier stages.

A basic tool for articulating the coherent human resources development strategy represented by the country model is the sector/occupation matrix (SOM). This joins with the four submodels to provide the fifth basic component of the country model. The matrix is defined by economic activity by sector (rows) and by varying occupations (columns).
A simplified schema of the model is shown below in figure 0-1.

**Figure 0-1**

**Country-Specific Model**

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0.3 **Submodels of the Country-Specific Model**

The basic characteristics of the four submodels mentioned above are as follows:
Manpower Requirements Model (MRM)

The MRM requires specification of sector production targets (usually on the basis of a development plan). Its principal function is to calculate occupational requirements in the light of assumptions about initial productivity in the base year and productivity growth. Requirements are then expressed in terms of educational qualifications. For example, senior technical occupations may be regarded as requiring a science or math-based degree or, a more specific example, an agricultural project manager would require a higher agricultural qualification.

Labor Force Model (LFM)

The LFM identifies available national labor force at the beginning of each simulation year by occupation within sector and applies an attrition rate. (Eventually, a promotion filter, or lateral transfer may be incorporated in later versions of the model to take account of movement upwards in the occupational structure); next, the LFM takes account of available new labor force entrants from the ESM, after applying a participation filter (for example, not all outputs from lower secondary girls' programs will enter the labor force--some will marry). The output of the LFM is the net supply of manpower for the simulation year.

Education Simulation Model (ESM)

The ESM simulates flows of students and trainees through the system on the basis of initial enrollments and assumptions about participation rates (e.g., percentage of girls and boys in a program, of an age group, or of graduates entering a course from a previous one, such as percentage of primary graduates going to either lower secondary general or into the labor force), repetition rates, and dropout rates. These parameters can be changed to reflect educational policy decisions such as: higher
participation of girls in a given program; increased flows from secondary to vocational/technical programs, or specification of particular proportions of upper secondary school entrants to literary and science-oriented courses; introduction of "automatic promotion," or limiting of repetition to a minimum number of times. For the purpose of flows to the labor force, the model considers any year of program as an exit point (each program year is called a "course") classifying leavers in two ways (boy/girl; completer/dropout).

**Manpower Policy Model (MPM) and Sector Occupation Matrix (SOM)**

The MPM allocates supply from the labor force and from the ESM to the overall SOM according to specific priorities. For example, in allocating manpower with professional qualifications and senior technical qualifications—e.g., engineers—a priority might be assigned to those occupational categories within the oil industry and within other sectors considered as strategically important, such as public utilities or communications, depending on the country. The MPM can also be set to maximize the number of nationals employed in a specific occupation within a sector. In a case where supply is greater than demand, the participation and repetition coefficients in the ESM will have to be adjusted. Alternatively, the planner may adjust entry requirements elsewhere, introducing alternative follow-on courses. In cases where supply is less than demand, the most critical priorities will be satisfied first. Where priorities are equal and supply insufficient, allocation between occupation/sector cells is made on the basis of each cell's net requirements weighted by the degree of nationalization already obtained.
The allocation of expatriates to the SOM cells is made by a linear programming model (LPM) which can respect these constraints. Because the model as a whole accommodates up to ten nationalities or national groups and there are 234 cells in the SOM, the total variables are 2,340. To make allocation less complex, the SOM has been partitioned into critical skill areas. For example, a "partition" might be managerial and senior technical posts in three key sectors. The LPM allocates available expatriate labor to the most critical partition, then operating within the previously mentioned constraints, then proceeds to the next partition, working with a supply which has been reduced in the previous allocation steps. The process continues until all the residual requirements in the SOM have been satisfied.

0.4 The Expanded Model

The expanded model extends the methodology used in the country model to produce analyses of interregional (within country) labor flows. In the expanded model, there are two major stages of analysis: local analyses, or within regional analyses; and global analyses, which are national analyses within a specific country, in which various local analyses are taken into account in the overall allocation of manpower surplus and deficit in the country.

After all localities or regions in a global unit have gone through their individual local analyses, the global analysis will reallocate pooled leakages from each locality to various other localities, in accordance with a transition matrix or matrices, and will also estimate corresponding
changes in population and enrollments due to labor force migration. The global analysis will then estimate expatriate requirements, taking into account existing available local nationals and expatriates residing in the global unit.

0.5 The Migration Model

In order to deal with the problems of local flows between countries in a supranational region, it is not sufficient to juxtapose country-specific models. The interaction effects also need to be identified and modeled.

The migration model simulation is designed to consider a region of countries, and to determine the pattern of migration of laborers resulting from imbalance in labor supplies and requirements among the countries. Each country has labor requirements (divided into sectors and occupations) determined from user-specified data covering target outputs, productivities, growth, and other national economic goals. Labor availability is determined for each country from user-supplied information about the educational system, existing labor stocks, attrition and sector/occupation distribution, in conjunction with carryover information from the previous simulation year.

The simulation combines information about labor supplies and demands in the regional countries with user-specified data ranking attractiveness of countries to laborers, restrictions imposed by countries on nonnational participation in their labor forces, and other constraints. From these input data and constraints, a pattern of labor allocation is determined which includes local allocation of each national labor force, as well as migration of nationals to other countries. Remaining deficiencies in labor supplies are assumed to be filled by expatriates from an undivided source called "rest of the world."
In essence, the migration model links together the individual country-specific manpower projections produced by the country-specific model, through the regional simulation of labor migration flows. Therefore, many of the computations can be performed independently for each country. After the completion of the "internal" country-specific calculations, the migration model simulates regional interaction, labor importation, and the return home of nonnational workers (less attrition).

As in the country model, each year is simulated by a sequence of computations reflecting, for example, attrition of workers, educational advancement and entry into the workforce, labor importation, and other labor force movements. The order in which each annual simulation is carried out is as follows.

For each country, the attrition of workers from the labor force is computed, based upon attrition rates entered as input data. Attrition of local nationals results in their permanent withdrawal from the labor force. Attrition of nonnational workers (expatriates) results in their return to their home countries, where they must remain for at least one year, before being available again as potential migrant workers.

For each country, the leakage (as distinct from attrition) of nationals from the local labor force is computed based upon leakage rates entered as input data. Nationals who leak out of the labor force are pooled by occupational level according to the sector-occupation combinations from which they leak. The pooled workers are subjected to a zero-to-three-year wait, and are then subpooled either for reallocation into the local labor force (subpool type 1), or for exportation to other countries which import labor (subpool type 2).
In each locality the educational system is simulated using the education simulation model, which produces several categories of school leavers. Underage school leavers are pooled according to skill levels, and are then placed in type 1 subpools for immediate allocation into the local labor force. The stocks of graduates and dropouts are multiplied by course-specific participation rates, and those who survive this "filter" are pooled according to skill levels as potential entrants to the labor force. These pooled graduates and dropouts are divided into two subpools: 1) available for immediate allocation in the local labor force only; or 2) available for exportation to other countries, in a type 2 subpool (if the locality is an exporter of labor at this skill level).

The cell-specific sector/occupation labor requirements for each country are compared with the existing labor force remaining in that country after losses from attrition and leakage, to determine additional labor requirements in each cell.

In each country, pools of any unallocated nationals are formed. Each occupation pool is divided into two subpools. Sub-pool type 1 contains nationals who are available for immediate allocation into the local labor force and nowhere else. As described above, this includes the underage school leavers and unleaked graduates and dropouts from the local educational system, as well as returning nationals who have dropped out of another country's labor force (through attrition). Sub-pool 2 contains all the other nonallocated nationals available for immediate work. This includes, as described above, nationals who have leaked from the local labor force and gone through the zero- to three-year timefilter, leaked graduates and dropouts from the local school system, and any surplus type 1 or type 2 subpool members who were not allocated in the prior simulation year.
Type I subpool members are never subjected to exportation from the home country. Type 2 subpool members are subject to exportation only if the occupational level is one for which the subpool's locality is designated to be a labor-exporting country. There are several rounds of labor exchange and countries exporting labor at one stage might subsequently become importers of labor.

For each country, the simulation immediately allocates type 1 subpools into the local labor force. Before type 2 subpools can be allocated, the total exportation requirement must be calculated.

The labor migration simulation examines each occupation subpool looking at all countries together. For each allocation level at a given occupational level, the importing countries (designated in input data) are determined, and allocation of their type 2 subpools is computed. (Note that, by this point, these subpools are no longer subject to additional exportation.) After the allocation is completed, the remaining need for imports of labor in these importing countries is computed by examining each sector occupation cell corresponding to the specific occupational level.

Within each "competing" cell, an initial estimate of the numbers of the various expatriates to be imported is determined such that after importation the expatriate percentages best correspond to the target fractions entered for the cell. Importation is allowed only from countries designated as suppliers (exporters) at the appropriate occupational and allocation level combination, as stipulated on the data card(s). These initial import input estimates are summed by nationality across all competing cells and each sum is compared to the size of the pool of workers available for export in the corresponding supplier locality. If any of these export pools is inadequate to meet the combined import demand, the
import estimates for corresponding suppliers are reduced on a pro rata basis in all competing cells as necessary to assure no overdraft of supplies.

Since supply limitations may prevent adequate importation to fulfill the labor requirements of all the competing cells, a mechanism for computing additional worker migration is provided. For those competing cells which still have unfulfilled requirements after initial importation, an attempt is made to import additional workers from regional supplier localities with excess supply. All competing cells have equal priority in drawing upon these excess supplies; and within each cell additional supplier expatriates will be imported subject to the overage limits entered by the user. These secondary import figures will be prorated across competing cells to prevent overdraft of supplies, and will be prorated within cells to best maintain the relative expatriate representation designated by the user.

After all excess regional supplies have been allocated to the maximum extent possible within the limitations of the overage figures for specific nationalities, workers from designated nonregional supplier localities will be imported to fulfill remaining worker requirements in the competing cells. These workers will be imported subject to their corresponding overage limits, if stipulated. No prorating across competing cells is necessary, however, since nonregional supplies are presumed to be unlimited.

Finally, any remaining unfulfilled requirements within competing cells will be filled by importation of workers from the last nonregional nationality (generally, the true "rest-of-the-world"), without reference to any user entered limitations.
Once the import pattern is determined for a given allocation level, migration is effected to accomplish the desired importation. This means that the importing cells are allocated their determined worker imports, and the type 2 subpools of exporting localities are reduced by the amount of exportation. The computational technique assures that the type 2 subpools have sufficient workers to satisfy the exportation.

Population aging is simulated for each country in addition to the labor force computations, and population figures are adjusted to reflect the movement of laborers and their dependents from country to country. The numbers of migrating laborers are based upon user-entered dependency rates.

As an aid in analysis, shortages or surpluses of national laborers (based on full nationalization of the labor force) are computed for each occupational level in each country.

A schematic of the Migration Model appears in Figure 0-2.

### 0.6 Applications

The main virtue of this complex methodology is that it allows the simulation of labor flows by nationality in a disaggregated, sector/occupation-specific fashion—this being where the critical bottlenecks and problems arise, even in the presence of aggregate equilibrium situations.

The primary utility of the model for country-level planning lies in its ability to focus attention on the feasibility of reaching given development targets in those countries where labor, rather than capital, is a major constraint. Through use of real data from the national education/training system, the model can show what additional imports of expatriate labor will be required to reach specific output plan targets, and what output targets by sector can be achieved with existing labor.
FIGURE 0-2
MIGRATION MODEL
Worker Flow Diagram for Typical Locality

EDUCATION System

new entrants

graduates dropouts

Participation Filter

Leakage Control

Waiting Workers

Time Filter

Type 1 Subpool

attrition return

Leakage Control

allocation

attrition

importation

REST OF WORLD

LABOR FORCE

Locals Expats

importation

attrition

attrition of nationals

Oblivion

leakage of nationals

allocation

exportation

Type 2 Subpool

attrition of locals

leakage of nationals

allocation

Other Localities
The model can also help answer questions of concern to planners and policymakers such as the following: How soon can manpower and output goals be achieved, if at all? What modifications, in terms of programs, training infrastructure, instructors and redirected student flows, will be needed if goals are to be achieved within a reasonable time horizon?

There are, however, three major prerequisites for such applications of the model: (1) the availability of trained personnel (usually national planners of the planning, education, and other sectoral ministries concerned with training); (2) the maintenance of an up-to-date data base; and (3) good coordination and common understanding between the agencies and ministries involved. This last factor is perhaps the most important. The recommendations flowing from the simulation of plans and policy measures should lead, above all, to appropriate action to modify programs, redirect flows, and change administrative regulations. The model is only a tool—a means to those ends.

This paper comprises three parts, of which this introduction is Part I. Part II describes the methodology of the country-specific model, the expanded model, and the migration model, and discusses applications of the model in detail. Part III is a detailed user's guide.
1.1 Introduction

This chapter presents and analyzes a compound computer-based simulation model (the "country" model) that integrates aspects of a crucial process: the balance between the supplies of and requirements for national and nonnational (expatriate) labor in an expanding economy.\footnote{The terms "requirements" and "supplies" are used instead of "demand" and "supply" since the latter have a specific cost-associated meaning in economic literature. What we mean by requirements and supplies are absolute values that are assumed to be inelastic to price/cost variations. They represent concepts that are more technological than economic in nature.} The chapter is divided into several sections. First, an overview of the model is presented, with a description of its goals and application, its basic structure, and its forecasting capabilities. The sector/occupation matrix (SOM)--a basic tool for articulating a coherent manpower development strategy--is also introduced.

The following sections present more detailed analysis of the four submodels of the country model: the labor force model (LFM); the manpower requirements model (MRM); the education simulation model (ESM); and the manpower policy model (MPM). The discussion of each submodel is structured around four elements: function, data requirements, principal output reports, and technical description.
1.2 Overview: Goals and Applications

The main purpose of the country model is to assist primarily labor-importing countries to develop coherent and workable human resource development strategies. By grouping together a suitable series of analytic submodels in an integrated fashion, the country model provides a tangible, systematic framework within which various policy options can be explored and simulated.

The great value of the country model is its ability to provide simulated solutions derived on an iterative basis involving the sequential and integrated solution of its component blocks or submodels. Such an approach makes it possible to simulate an array of solutions based on rather varied assumptions and constraints. This is preferable to a solution that is based on optimization or constrained maximization, because the pattern requires explicitly quantified tradeoffs. In the countries that would profit from use of this model, such quantified tradeoffs are not yet possible. At the present time, it is necessary to build upon variables whose exact correlations are unknown, and upon the targeting of possibly conflicting or contradictory objectives, such as maximum economic growth versus nationalization of the labor force. Quite apart from difficulties with the data base, the quantification of such tradeoffs is impossible to determine without introducing largely arbitrary value judgments and perhaps even the personal biases of the analyst.

The country model avoids such pitfalls by allowing decision makers to simulate the likely developments associated with any set of policies. It also allows them to undertake a sensitivity analysis on any single policy variable. The model imposes a framework of consistency for analysis of economic growth and structural change, the performance of the education and training system (ETS), and the importation and exportation of labor.
In addressing the requirements for and supplies of labor in an expanding economy in this way, the country model facilitates the resolution of challenges that arise on a geographical, temporal, and functional basis.

From the geographical perspective, although the country model was designed primarily for labor-importing countries, with minor adjustments it can be and has been applied to labor-exporting countries on a subnational, inter-country basis, where the countries of concern can be conceptually defined as comprising the region as a whole. (See Chapters 2 and 3 for a discussion of the Expanded and Migration Models.) However, because the initial design of the model was geared to the urgent needs of the capital-rich (but labor-poor) Arab oil countries, use of the model by labor-importing countries has predominated and, hence, will be emphasized in the subsequent discussion.

From the temporal perspective, the country model also addresses major short- and long-term considerations. Its immediate value has been as an instrument for the identification of potential structural inconsistencies and discontinuities in the initial stage of accelerated industrialization and for setting out alternative strategies to deal with them. For example, it can evaluate the feasibility of any given set of growth targets and explore alternative strategies for rapid growth in the face of short-term constraints imposed by manpower scarcities. Further, however, there are obvious structural discontinuities between the initial stage of industrialization, with great emphasis on infrastructure development, and the long-term patterns of economic growth. When these stages are compressed in time, as is the case with the oil-rich Arab countries, it is essential to develop a transitional strategy that will avoid severe dislocation and high social costs. A transitional strategy is particularly relevant since the
ETS invariably responds with very long lead/lag times. Such a transitional strategy would seek to avoid locking the ETS into a pattern geared to produce huge numbers of personnel within specific categories of manpower for which the short- to medium-term need is acute, but for which the long-term need is only moderate—especially when the time lag for producing such personnel is long, as in the case of, say, port engineers. The country model assists planners as they confront this challenge, although it is recognized that long-term predictions are increasingly speculative.

From the functional perspective, the model can also address such distinctions as that between aggregate analysis and a concentration on critical skills, that is, on a subset of occupations where employment is numerically small but qualitatively significant. The model concentrates on aggregate-level consistency because of its systematic approach, but retains the flexibility for further elaboration in such critical skill areas by partitioning the sector/occupation matrix (SOM) described later.

Within the framework of these general goals, four specific applications of the manpower model may be identified. Others will become evident during subsequent discussions on the constituent submodels and their outputs. The four applications of the country model are:

(1) To help planners in developing countries to forecast national and nonnational manpower requirements necessary to meet specific sectoral output targets;

(2) To identify and isolate specific problems in the supply of manpower through simulation of flows of students and trainees through the ETS in the light of such parameters as participation, repetition, dropout rates, and qualifications required to enter programs;
(3) To use an allocation submodel to set specific manpower targets, such as maximizing the number of nationals in certain occupational categories in a given sector, or improving the allocation of qualified labor to occupations in those sectors of the economy that are considered to have a high priority; and

(4) To estimate what production levels might be achieved in certain sectors, assuming the use of existing, and probably indigenous, manpower stocks, but with limits placed on the growth or overall numbers of nonnational expatriate manpower.

1.3 Detailed Structure of the Model

The basic elements of the country model were described in the preview section. More detailed flows and linkages, as well as sequential operations within each of the submodels, are shown in Figure 1-1. In this figure, the main emphasis is on the systematic nature of the country model as a whole, with flows and linkages represented by solid lines; the various submodels, characterized as "blocks," are shown as rectangles. The detailed components shown in Figures 1.1 will be discussed in subsequent sections of this chapter.
The Sector/Occupation Matrix

A basic tool for articulating the coherent human resources development strategy represented by the country model is the sector/occupation matrix (SOM) illustrated in Figures 1-2, 1-3, 1-4, 1-5. The SOM joins the four submodels already outlined to provide the fifth basic component of the country model. As Figures 1-2 to 1-5 indicate, the matrix is formed by simultaneously analyzing economic activity by sector and by varying levels of occupation. The sectors are divided into two main subdivisions, public and private. These are further divided into categories such as petroleum products or education. Occupations are ranked into a number of subdivisions. An occupation in a given sector is represented by a single cell in the matrix. The SOM thus offers a disaggregated view of the labor force employed. The country model allows for as many as 400 cells in the SOM.

The SOM is a very useful tool for articulating policy choices. This can best be demonstrated by example. Consider a country whose rapid economic growth is generating a demand for labor that will continue to outstrip its best efforts at nationalization and training. Foreign labor will be needed for the foreseeable future. The question is whether government should concentrate its nationalization and training efforts on nationalizing all parts of the labor force, or whether it should give priority to specific areas.

The SOM can help answer this question, but three caveats must be emphasized: (1) nationalization of a sector/occupation does not mean excluding all expatriates; rather it means employing only a large majority of nationals in the sector/occupation; (2) assigning priority to training and
Figure 1-2

THE SECTOR/OCCUPATION MATRIX (SOM) AND ALTERNATIVE POLICY OPTIONS - I "ADMINISTRATIVE CONTROL"

<table>
<thead>
<tr>
<th>Economic activity sectors</th>
<th>Occupational groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Professionals</td>
</tr>
<tr>
<td></td>
<td>Technicians and engineers</td>
</tr>
<tr>
<td></td>
<td>Clerical workers</td>
</tr>
<tr>
<td></td>
<td>Sales workers</td>
</tr>
<tr>
<td></td>
<td>Operators</td>
</tr>
<tr>
<td></td>
<td>Skilled workers</td>
</tr>
<tr>
<td></td>
<td>Semi-skilled workers</td>
</tr>
<tr>
<td></td>
<td>Experts</td>
</tr>
<tr>
<td>Private sectors:</td>
<td></td>
</tr>
<tr>
<td>1. Agriculture, etc.</td>
<td>Priority cells</td>
</tr>
<tr>
<td>2. Petroleum production</td>
<td></td>
</tr>
<tr>
<td>3. Other mining and quarrying</td>
<td>Non-priority cells</td>
</tr>
<tr>
<td>4. Manufacturing (petroleum)</td>
<td>Priority cells</td>
</tr>
<tr>
<td>5. Manufacturing (other)</td>
<td></td>
</tr>
<tr>
<td>6. Utilities</td>
<td></td>
</tr>
<tr>
<td>7. Construction</td>
<td></td>
</tr>
<tr>
<td>8. Trade and commerce</td>
<td></td>
</tr>
<tr>
<td>9. Transport and communications</td>
<td>Priority cells</td>
</tr>
<tr>
<td>10. Finance, etc.</td>
<td></td>
</tr>
<tr>
<td>11. Community services</td>
<td></td>
</tr>
<tr>
<td>12. Nonads</td>
<td></td>
</tr>
<tr>
<td>Government sectors:</td>
<td></td>
</tr>
<tr>
<td>13. Public administration and defense</td>
<td>Priority cells</td>
</tr>
<tr>
<td>14. Education</td>
<td></td>
</tr>
<tr>
<td>15. Health</td>
<td></td>
</tr>
</tbody>
</table>

- Priority cells
- Non-priority cells
- Void cells
Figure 1-3
THE SECTOR/OCCUPATION MATRIX (SOM) AND ALTERNATIVE POLICY OPTIONS-II "KEY SECTORS"

<table>
<thead>
<tr>
<th>Economic activity sectors</th>
<th>Occupational groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Manager's officials</td>
</tr>
<tr>
<td>Private sectors:</td>
<td></td>
</tr>
<tr>
<td>1. Agriculture, etc.</td>
<td></td>
</tr>
<tr>
<td>2. Petroleum production</td>
<td></td>
</tr>
<tr>
<td>3. Other mining and quarrying</td>
<td></td>
</tr>
<tr>
<td>4. Manufacturing (petroleum)</td>
<td></td>
</tr>
<tr>
<td>5. Manufacturing (other)</td>
<td></td>
</tr>
<tr>
<td>6. Utilities</td>
<td></td>
</tr>
<tr>
<td>7. Construction</td>
<td></td>
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<tr>
<td>8. Trade and commerce</td>
<td></td>
</tr>
<tr>
<td>9. Transport and communications</td>
<td></td>
</tr>
<tr>
<td>10. Finance, etc.</td>
<td></td>
</tr>
<tr>
<td>11. Community services</td>
<td></td>
</tr>
<tr>
<td>12. Roads</td>
<td></td>
</tr>
<tr>
<td>Government sectors:</td>
<td></td>
</tr>
<tr>
<td>13. Public administration and defense</td>
<td></td>
</tr>
<tr>
<td>14. Education</td>
<td></td>
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<tr>
<td>15. Health</td>
<td></td>
</tr>
</tbody>
</table>

- Priority cells
- Non-priority cells
- Void cells
**Figure 1-4**

THE SECTOR/OCCUPATION MATRIX (SOM) AND ALTERNATIVE POLICY OPTIONS III "ACROSS THE BOARD"

<table>
<thead>
<tr>
<th>Economic activity sectors</th>
<th>Occupational groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Managers, officials</td>
</tr>
<tr>
<td>Private sectors:</td>
<td></td>
</tr>
<tr>
<td>1. Agriculture, etc.</td>
<td></td>
</tr>
<tr>
<td>2. Petroleum production</td>
<td></td>
</tr>
<tr>
<td>3. Other mining and quarrying</td>
<td></td>
</tr>
<tr>
<td>4. Manufacturing (petroleum)</td>
<td></td>
</tr>
<tr>
<td>5. Manufacturing (other)</td>
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</tr>
<tr>
<td>6. Utilities</td>
<td></td>
</tr>
<tr>
<td>7. Construction</td>
<td></td>
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<tr>
<td>8. Trade and commerce</td>
<td></td>
</tr>
<tr>
<td>9. Transport and communications</td>
<td></td>
</tr>
<tr>
<td>10. Finance, etc.</td>
<td></td>
</tr>
<tr>
<td>11. Community services</td>
<td></td>
</tr>
<tr>
<td>12. Homesteats</td>
<td></td>
</tr>
<tr>
<td>Government sectors:</td>
<td></td>
</tr>
<tr>
<td>13. Public administration and defense</td>
<td></td>
</tr>
<tr>
<td>14. Education</td>
<td></td>
</tr>
<tr>
<td>15. Health</td>
<td></td>
</tr>
</tbody>
</table>

Key:
- ☑ Priority cells
- □ Non-priority cells
- ❌ Void cells
Figure 1-5

THE SECTOR/OCCUPATION MATRIX (SOM) AND ALTERNATIVE POLICY OPTIONS -IV "SELECTED EMPHASIS"

<table>
<thead>
<tr>
<th>Economic activity sectors</th>
<th>Occupational groups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Managerial</td>
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<tr>
<td></td>
<td>Professionals</td>
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<td></td>
<td>Technical and professional</td>
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<td></td>
<td>Clerical workers</td>
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<td></td>
<td>Sales workers</td>
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<td></td>
<td>Service workers</td>
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<tr>
<td></td>
<td>Operators</td>
</tr>
<tr>
<td></td>
<td>Skilled workers</td>
</tr>
<tr>
<td></td>
<td>Semi-skilled workers</td>
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<tr>
<td></td>
<td>Farmers</td>
</tr>
<tr>
<td></td>
<td>Housewives</td>
</tr>
<tr>
<td>Private sector</td>
<td></td>
</tr>
<tr>
<td>1. Agriculture, etc.</td>
<td></td>
</tr>
<tr>
<td>2. Petroleum production</td>
<td></td>
</tr>
<tr>
<td>3. Other mining and quarrying</td>
<td></td>
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<tr>
<td>4. Manufacturing (petroleum)</td>
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<td>5. Manufacturing (other)</td>
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<td>6. Utilities</td>
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<td>7. Construction</td>
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<tr>
<td>8. Trade and commerce</td>
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<tr>
<td>9. Transport and communications</td>
<td></td>
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<tr>
<td>10. Finance, etc.</td>
<td></td>
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<td>11. Community services</td>
<td></td>
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<td>12. Nomads</td>
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<tr>
<td>Government sectors:</td>
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<tr>
<td>13. Public administration and defense</td>
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<tr>
<td>14. Education</td>
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<tr>
<td>15. Health</td>
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</tbody>
</table>

- Priority cells
- Non-priority cells
- Void cells
employment of nationals in one sector/occupation does not mean that other sectors/occupations will be ignored; and (3) selection of priority sectors/occupations does not guarantee that their nationalization will be achieved in the timeframe under discussion.

Four alternatives sketches--purposefully exaggerated for emphasis--indicate the implications of responding to the question posed above. They demonstrate how useful the SOM can be in bringing clarity to the articulation of alternative policy options. The four alternatives are illustrated in Figures 1-2, 1-3, 1-4, and 1-5.

(a) Alternative I: "Administrative Control"

In this sketch, illustrated in Figure 1-2, the government would concentrate on controlling the upper skill levels (professional, managerial, and higher technical) across all sectors and would tolerate as many expatriate workers as necessary to run the economy in the lower skill categories. This would ensure that all decisions in all sectors are made by nationals. However, this alternative has three main drawbacks: (1) it does not recognize the great heterogeneity of the existing national population by assuming that they should (or could) all be channeled into the upper skill levels; (2) it does not afford options for those who drop out of the EIS on their way to becoming managers, professionals, or technicians, or for those currently too old to enter the ETS in the appropriate streaming; and (3) it does not recognize that operatives and skilled workers are equally necessary to keep the economy going and that these occupations would be largely staffed by expatriates.

(b) Alternative II: "Key Sectors"

This alternative is based on the assumption that some sectors are the critical keys that control the economy. In Figure 1-3, four sectors--oil
production, construction, finance, and government administration and defense—have been chosen as key sectors. Government efforts would be geared to achieving nationalization in these sectors at the possible expense of other sectors. Again, there are drawbacks in that other sectors are also significant. Education, for example, controls coming generations; transport and communications could paralyze the country; and so on. This alternative does not sufficiently recognize interlinkages between sectors.

(c) Alternative III: "Across the Board"
This alternative, as Figure 1-4 indicates, depicts the government efforts as aimed at universal nationalization. Although nationalization is a legitimate long-term goal, this alternative would spread national labor resources too thinly, leaving the present labor-deficient situation relatively unaffected for a number of years. The national graduates at all levels would be too few in each sector/occupation to make an immediate impact on the labor shortage.

(d) Alternative IV: "Selected Emphasis"
As Figure 1-5 indicates, this alternative is a stage in the achievement of Alternative III, and combines the goals of Alternatives I and II. It is the most reasonable approach to the problem. Key sectors/occupations, designated as cells within the SOM, would be given priority. After the most important cell is nationalized, the next most important set of cells is given priority, until over the long term, Alternative III is reached.

Having outlined the use of the SOM in articulating policy choices, we will now discuss the general characteristics of the four submodels.

1.5 General Characteristics of the Four Submodels
The LFM accounts for the available labor force at the beginning of each year by sector/occupation categories, including nationals and nonna-
tionals resident in the country. Although some of the labor force is lost through attrition, and will therefore not be available in subsequent years, additional resources will become available through output from education systems and importing of nonnational manpower. The stock of available manpower must be updated accordingly. Also, some members of the labor force will be promoted within or across sectors; and it is necessary, therefore, to introduce transition matrices to simulate internal movements within the labor force itself.

The MRM first compiles the total manpower requirements for each sector/occupation category to achieve given target products by dividing the specified target product by sector productivity, defined as value added per worker per year. Alternatively—as Figure 1-1 indicates—total manpower requirements can be entered directly. This would be appropriate where good data exist (for example, petroleum production in oil countries), or in cases where employment is not necessarily a function of output (for example, government employment). Next, the net manpower requirements are calculated by sector/occupation categories after subtracting the available manpower stock from the total manpower requirements.

The ESM itself has been designed on the basis of an earlier model of the same name originally developed by UNESCO. Basically, it estimates those leaving the school system by age and by level or type. It should be noted that not all those leaving school will join the labor force. Some will be below the legal minimum age to work and will not join the labor force until some years later. Some will not work for social, cultural, or other

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2/ In this discussion, productivity is defined as value added per employed worker in one year, without adjustments for time.
reasons. Thus there is a need to introduce the concept of a filter matrix as a function of time. For those who enter given sector/occupation categories of the labor force, entrance qualifications may change over time, depending on the evolving technological need, and there is, therefore, a need to introduce the concept of entrance qualification matrices as a function of time.

The MPM compares new manpower requirements with manpower supplies from the education system, and attempts to allocate manpower in accordance with a priority matrix. The priority and proportion of nationalization in each sector/occupation is specified by policymakers. The ESM may be called upon to readjust its intakes into given disciplines in order to meet manpower requirements in accordance with the priority matrix for nationalization. After this has been done, policies for the importation or exportation of nonnationals would be articulated. In this exercise, a feasibility linear programming model (LPM) (as opposed to an optimization model) is introduced, taking into account various policy constraints.

1.6 General Programming Approach of the Country Model

The model is basically a Markovian one. Simulation proceeds on an annual basis, and the historical data needed for the simulation of events or activities in a given year will include only those of the preceding year. At the outset of any simulation run, an input editing program is activated to ensure that all needed data are properly prepared. This program edits all required inputs in one pass.\(^3\) The editing to be done will mainly include

\(^3\) This step is made possible because each card format has been designed to contain an identification field which includes ID on submodel, card types, and sequence numbers. This information is sufficient for an edit program to check all data types submitted for a given run.
programming editing and minor logical editing, such as a unit sum of repetitions, dropouts, and promotion rates. As with any computer model, it is the responsibility of users of the model to ensure that the data entered are valid, because the model cannot protect itself from inaccurate or fallacious inputs.

Once the data have passed the edit stage, the simulation starts with a run to bring all base year data up to date. During this stage, input data are sorted in the following order: by year; by block or submodel ID (labor force block, manpower requirement block, education simulation block, and manpower policy block); by card type; and by card sequence number. After sorting is complete, the base year data are read into the allocated areas, and the simulation for $t = 1$ begins.

The main control program then sequentially calls each submodel to simulate events or activities in the year $t = 1$. The first call is made to the LFM, which passes back to the main control program a flag indicating where the base year data are stored. The second call is to the MRM, which calculates the first year manpower requirements by sector and by occupation, and also reads manpower requirements data for the sectors where such data are determined exogenously, for example, government and petroleum sectors. The third call is made to the ESM to obtain manpower requirement estimates for teachers and to calculate net manpower supplies. The fourth call is to an entry point in the MRM to estimate net manpower requirements by sector and occupation. The fifth call is made to the MPM to read a priority matrix into the allocated areas, comparing net manpower requirements with supplies from the ESM. There may be feedback calls to an entry point in the ESM to derive an acceptable education program to produce students in accordance with the priority matrix. After these feedback calls, the MPM then
proceeds to estimate available sector outputs based on the existing available manpower including nationals and nonnationals in the country, and to allocate nonnational manpower requirements in accordance with a linear programming process. This necessarily oversimplified description outlines the first year simulation.

At the beginning of the second year simulation, the cycle just described is repeated, with some minor changes to each submodel. For example, the LFM updates the existing labor force by incorporating additional manpower supplies from the ESM and additional nonnationals permitted to work in the country; estimates attritions; estimates internal labor force movements, if any, and derives the net manpower stock available accordingly. In spite of the minor changes in each submodel, the calling sequences from the main control program to each submodel remain the same as for the year \( t = 1 \).

To summarize, there are four major advantages to this design. First, all necessary input editing is done in one job submission. Second, any number of simulation years can be accommodated by the system, subject to the long-term uncertainties already mentioned. Third, the Markovian approach allows users to simulate for one year, examine the results, proceed for another year, and so on. Fourth, incorporation of the LFM allows the system to take inventories of the existing labor force over time to include nationals and nonnationals. Based on the existing labor force, achievable sectoral outputs, and their nonnational manpower requirements correlates, if any, can be estimated.

Having outlined the main features of the country model, its goals and applications, and its structure and general program approach, it is now appropriate to examine each of the submodels in detail. In the following discussions, a standard format is used for this analysis, comprising four
elements: The function of the submodel; its principal data requirements; the associated output reports; and a technical description. The submodels are discussed in the following order: the labor force model (LFM); the manpower requirements model (MRM) the education simulation model, and the manpower policy model (MPM). Reference should be made to Figure 1-2 throughout the discussion. It should also be noted that the country model and its submodels do not form a fixed system, but rather are designed as a flexible methodological and empirical tool. Thus some aspects of the submodels as described will continue to be refined and supplemented as the model is applied for longer periods, in more countries, under different circumstances.

1.7 The Labor Force Model (LFM)

Function
The LFM identifies the available national labor force at the beginning of each simulation year by occupation within sector, and applies an attrition rate. As a further refinement, a promotion filter may be used to account for upward movement in the occupational structure or lateral transfers.4/ The LFM accounts for available new labor force entrants from the ESM, after applying a participation filter. For example, not all outputs from lower secondary girls' programs will enter the labor force; some will probably marry and remain outside the labor force permanently. The LFM also computes the net supplies of manpower for the simulation year.

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4/ Although the system's logic allows this refinement, the statistical data base needed to estimate transitional matrices is so huge that this step will probably not be used in the near future.
Principal Data Requirements

The principal data requirements for the LFM are: (1) the labor force for the base year, by occupation within sector, disaggregated by nationals and nonnationals (by separate nationalities or groupings of nationalities); and (2) attrition rates by occupation within sector, and by nationality. (Alternatively, an average length of stay, as estimated from immigration records, can be used for expatriates).

Principal Reports

The principal reports of the LFM describe the national labor force by occupation within sector. The reports include: the labor force at the beginning of the simulation year; the numbers affected by attrition; the labor force subsequent to attrition; the current labor force allocations from the ESM; the total labor force availability at the end of the simulation year; the national labor force disaggregated by occupations (summed across sectors); the national labor force by sectors (occupations summed); and various analyses of the expatriate labor force by nationality, by sector, and by occupation for the simulation year. The last category will include: the expatriate labor force; attrition (numbers affected by average length of stay and retirement); the expatriate labor force after attrition; the expatriate requirements needed to fill deficits (after allocation of nationals to the sector/occupation matrix according to established priorities); and the net importation of expatriates.

Technical Description

Two basic categories are involved here: national labor, and the nonnational (expatriate) labor force.

Taking the national labor force first, the following basic inputs are required:
\[ \text{[NLF}(0,i,j)\text{]} = \text{Base year national labor force stock by sector by occupational category mix (i designates sector, j occupational category).} \]

\[ \text{NA}(t,j) = \text{Attrition rates vector by occupation for national labor. It is assumed that NA}(t,j) = \text{NA}(t-1,j) \text{ unless this is specifically changed by entering attrition rates vectors for } t. \]

The following functional relationships emerge:

\[ \text{NLF}(t,i,j) = \text{National labor force at the beginning of year } t, \text{ by sector/occupation category.} \]

(1.1) \[ \text{NLF}(t,i,j) = \text{NLF}(0,i,j), \text{ for } t = 1. \]

(1.2) \[ \text{NLF}(t,i,j) = \text{NLF}(t-1,i,j)(1-\text{NA}(t-1,i,j)) + \text{MSE}(t-1,i,j) \text{ for } t > 2 \text{ where MSE}(t-1,i,j) \text{ is the labor force supplied by the educational system in year } t-1, \text{ by sector, by occupation.} \]

Outputs will then be existing labor force at the beginning of year \( t \) by sector, by occupational category and by year.

It should be noted at this point that the model also allows for the possible introduction of an intersectoral, interoccupational mobility analysis. This analysis would be built upon a "promotion matrix" \[ \text{[PRO}(t,i,j)\text{]} \text{ for national manpower to indicate the fraction of sector/occupation category } (i,j) \text{ in } t+1. \text{ This indicates internal transition within the existing labor force as time advances from } t \text{ to } t+1. \text{ If this matrix is not entered, it is assumed that no such transition takes place during the simulation period, but the design allows for its presence as a dummy routine.} \]

If this matrix were to be entered at a future date, equation (1.2) would read:
(1.3) \[ NLF(t,i,j) = NLF(t-1,i,j) \cdot (1-NA(t-1,j)) + \text{Net LPM}(t-1,i,j) + \text{MSE}(t-1,i,j) \quad \text{for } t \geq 2 \]

Where \([\text{Net LPM}(t-1,i,j)]\) indicates the net change in national labor force due to promotions.

Turning now to the nonnational labor force, the following inputs are required (for a given nationality \(n\));

\[ [XLF(0,i,j)] = \text{Base year nonnational (expatriate) labor force stock by sector by occupational category matrix.} \]

\[ [XA(t,j)] = \text{Attrition rates vector by occupation. It is assumed that } XA(t,j) = XA(t-1,j) \text{ unless this is specifically changed by entering attrition rates vectors for } t. \]

The following functional relationships emerge:

\[ [XLF(t,i,j)] = \text{Nonnational labor force at the beginning of year } t, \text{ by sector, by occupational category.} \]

(1.4) \[ XLF(t,i,j) = XLF(0,i,j) \quad \text{for } t = 1. \]

(1.5) \[ XLF(t,i,j) = XLF(t-1,i,j) \cdot (1-XA(t-1,i,j)) + \text{Net } X(t-1,i,j) \quad \text{for } t \geq 2 \text{ where } [\text{Net } X(t-1,i,j)] \text{ is the net importation or net exportation of nonnational manpower by sector, by occupational category in year } t-1, \text{ as calculated by the MPM.} \]

**Inputs Needed**

Let \([XLF(0,n,i,j)]\) = Expatriate (nonnational labor force in the country by nationality \((n)\) by sector \((i)\) by occupation \((j)\) in the base year, then

(1.6) \[ XLF(0,n) = \sum \sum XLF(0,n,i,j) \]
Where \( [\text{Net } X(t-1,n)] \) is the net importation or exportation of expatriate (nonnational) manpower by nationality in year \( t-1 \) as calculated by the MPM (details of the procedure for the estimation of this element will be found in the description of the MPM itself).

1.8 The Manpower Requirements Model (MRM)

Function

The MRM requires specification of sector production targets, usually on the basis of a national development plan. Its principal function is to calculate occupational requirements for nationals in the light of assumptions about initial productivity in the base year and productivity growth. Requirements are then expressed in terms of educational qualifications. For example, senior technical occupations may be regarded as those requiring a science or math-based degree, or, to be more specific, an agricultural project manager would require a higher agricultural qualification.

Principal Data Requirements

The principal data requirements of the MRM are: gross domestic product (GDP) for the base year by sector, annual sector targets for projected years, sector productivity for the base year, and sector productivity growth rates. If it is desired, labor-output elasticities can also be used to estimate employment needs.

Principal Reports

The principal output reports associated with the MRM include: (1) expected production by sector and related manpower requirements by occupation within
sector, by year (indicating available nationals, existing expatriates, and net additional requirements) and (2) aggregated manpower requirements by sector.

**Technical Description**

For target sectoral products, several options are available:

**Option 1:** Input streaming vector

\[ Q(t,i) \] = The target product for sector i, during period t, measured in monetary terms.

**Option 2:** Given a constant production growth rate \( K \) and the base year sectoral products \( Q(0,i) \)

\[ (1.9) \quad Q(t,i) = Q(t-1,i)(1 + K) \]

**Option 3:** Given variable growth rate \( K(t) \), a function of \( t \), and the base year sectoral products \( Q(0,i) \)

\[ (1.10) \quad Q(t,i) = Q(t-1,i)(1 + K(t)) \]

**Option 4:** Linear interpolation

\[ Q(0,i) \]: Base year sector product vector
\[ Q(T,i) \]: Last simulation year, \( T \), sector product vector.

For target sectoral productivities, again several options are available:

**Option 1:** Input streaming vector

\[ P(t,i) \] = Input productivity data for each period \( t \) and for each sector \( i \).

**Option 2:** Given a constant growth rate \( K \) and the base year productivity vector \( P(0,i) \)

\[ (1.11) \quad P(t,i) = P(t-1,i)(1 + K) \]
Option 3: Given variable growth rate $K(t)$, as a function of $t$, and the base year productivity vector $P(0,i)$

\[(1.12) \quad P(t,i) = P(t-1,i). (1 + K(t))\]

Option 4: Linear interpolation

$P(0,i)$: Base year productivity vector
$P(T,i)$: Last simulation year, $T$, productivity vector

\[(1.13) \quad P(t,i) = P(t-1,i) + \frac{(T,i) - P(0,i)}{T}\]

If both $Q(t,i)$ and $P(t,i)$ are given, then employment estimates are derived by:

\[(1.14) \quad E(t,i) = \frac{Q(t,i)}{P(t,i)}, \quad P(t,i) > 0\]

where $E(t,i)$ is the target employment level for sector $i$ in year $t$.

If data for $Q$ or $P$ are unavailable, $E(t,i)$ must be input and may have one of the following options:

Option 1: Input Stream Vector

$E(t,i)$ = target employment vector for each period $t$ and for each sector $i$.

Option 2: Given a constant employment growth rate $Z$ and the base year employment vector $E(0,i)$

\[(1.15) \quad E(t,i) = E(t-1,i). (1 + Z)\]

Option 3: Given variable employment growth rate $Z(t)$ as a function of $t$ and the base year vector $E(0,i)$

\[(1.16) \quad E(t,i) = E(t-1,i). (1 + Z(t))\]

Option 4: Linear interpolation

$E(0,i)$: Base year employment vector
$E(T,i)$: Last simulation year $T$, employment vector.

To convert the employment estimates into the sector/occupation matrix (SOM), the following inputs are required:
\[ [H(t,i,j)] \] = the matrix defining the distribution of occupation j for each sector i at time t. The elements h(t,i,j) of the matrix have the following properties:

\[(1.17) \sum_j h(t,i,j) = 1.0, \text{ where } h(t,i,j) \text{ is the share of the } j \text{th occupational input in the total labor input in sector } i \text{ in year } t.\]

\[(1.18) 1.0 \geq h(t,i,j) \geq 0.0\]

As was previously noted, total employment by year for some key sectors (for example the petroleum and the government sectors) may be exogenous and should be entered directly, while total requirements for teachers will be obtained from the ESM. These estimates would then be converted by \[ [H(t,i,j)] \] into sector/occupation breakdowns, unless entered as such.

The following functional relationships emerge:

Let \[ [TLF(t,i,j)] \] = the manpower requirement matrix
\[ l(t,i,j) \] = the elements of \[ [TLF(t,i,j)] \]
\[ e(t,i) \] = the elements of \[ [E(t,i)] \], the employment estimates for sector i, in year t
\[ h(t,i,j) \] = the elements of \[ [H(t,i,j)] \]

\[(1.19) l(t,i,j) = e(t,i) \cdot h(t,i,j); \text{ that is, labor requirements in } (i,j) \text{ are derived as the product of target employment in sector } i \text{ and the } j \text{th occupation share}\]

The following properties hold:

\[(1.20) \sum_j l(t,i,j) = \sum_j e(t,i) \cdot h(t,i,j) = e(t,i) \sum h(t,i,j) = e(t,i)\]

where
\[ \sum_i l(t,i,j) = \text{Total manpower requirements for sector } i \text{ at time } t.\]
\[ \sum_j l(t,i,j) = \text{Total manpower requirements for occupational category } j \text{ at time } t.\]

and

\[(1.21) \sum_i \sum_j l(t,i,j) = \sum_i e(t,i)\]
It is now possible to derive net manpower requirements. Let \( \text{Net MR}(t,i,j) \) be the net manpower requirement for the current-year school leavers (dropouts) and nonnationals: and recall that.\( \text{TLF}(t,i,j) \) is the manpower requirement in period \( t \) for sector \( i \) and occupational category \( j \), and \( \text{NLF}(t,i,j) \) is the existing national labor force at the beginning of \( t \) for sector \( i \) and occupational category \( j \), then

\[
\text{Net MR}(t,i,j) = \text{TLF}(t,i,j) - \text{NLF}(t,i,j)
\]

The associate outputs are: (1) estimated employment by sector by year; (2) estimated output by sector by year; (3) estimated manpower requirements by sector by occupational category by year; and (4) net manpower requirements for the current-year school leavers and for nonnationals.

1.9 The Education Simulation Model (ESM)

Function

The ESM or the Educational Training System (ETS), simulates flows of students and trainees through the system on the basis of initial enrollments in the base year and assumptions about participation rates, repetition rates, promotion rates, and dropout rates. Participation rates are defined as those of girls and boys in a program or of a percentage of an age group, or of a percentage of graduates entering a course from a previous one, for example, the percentage of primary graduates going to either lower secondary general establishments or out into the labor force. Repetition, dropout, and promotion rate, by definition, add up to unity. However, dropouts are split into two groups: those leaving at the end of the year having successfully completed the year (i.e., noncontinuing completers) and those who have not successfully completed the year (dropouts). This differentiation is important since employers make this distinction. This schema lends itself to a Markovian type of analysis as can be seen from Figure 1-6.
Figure 1-6

THE MARKOVIAN BASIS OF THE ESM(ETS)

Note: Each student in any given course has one of four possible successor states: (i) repeater in same course; (ii) completer continuing to successor course; (iii) non-continuing completer; (iv) non-completing dropout. The last two constitute exit points from the ETS.
These parameters can be changed to reflect such educational policy decisions as: a greater participation of girls in a given program; increased flows from secondary to vocational/technical programs, or specification of particular proportions of upper secondary school entrants to literary and science-oriented courses; or the introduction of "automatic promotion" or limiting of repetition to a preestablished maximum number of times.

The policy changes are reflected in the pattern of flows of students through and out of the ETS. This can be understood more clearly by looking at a graphic representation of a typical ETS structure as it would be simulated by the ESM (Figure 1-7). For the purpose of flows to the labor force, the model considers any year of any program as a "course." Each course has two exit points since the model classifies ETS leavers in two ways: completer and dropout.

The treatment of ETS leavers is graphically illustrated in Figure 1-8, which indicates that exit points from courses feed through a participation matrix into pools from which a number of given occupations in specified sectors can draw. This procedure overcomes one of the most common objections to most manpower modeling, namely the education-occupation correspondence. The approach allows each output point from the ETS to lead to more than one occupation in a given sector. It also allows each occupation in a given sector to draw on more than one exit point of the ETS. If adequate statistical data were available, probability distribution functions could be employed. The design of the model allows for this possibility. However, even without the probability functions, the pooling method provides a great deal of realism to the modeling work. It also ensures a certain flexibility. For example, it might be assumed that skilled clerical occupations draw upon completers (but not dropouts) from years two
Figure 1-7
A TYPICAL ETS STRUCTURE IN TERMS OF COURSES FOR SIMULATION BY THE ESM
Figure 1-8

THE POOLING CONCEPT

A set of ETS exit points
Another set of ETS exit points
A third set of ETS exit points

Participation matrix

POOL 1

A set of SOM cells

POOL 2

A second set of SOM cells

POOL 3

A third set of SOM cells
and three of the preparatory program. Planners can insert their own information about the changing recruitment practices of employers. This flexibility is important since manpower surpluses or shortages may raise or lower recruitment levels as expressed in educational attainment. One inviolable rule of the system is that no cell (occupation in a given sector) in the sector/occupation matrix (SOM) may draw upon more than one pool. A pool, however, can be made as large or as small as conditions warrant. The total number of pools (or exit points) is theoretically bounded by the size of the SOM, which can have as many as 400 pools, although such extreme disaggregation would greatly diminish the flexibility and usefulness of the pooling approach.

**Principal Data Requirements**

The principal base line data requirements for the ESM are: base year enrollments of nationals in each course (as defined above—this means for every year of the program, in every level and branch of the system), together with age/grade distribution, if possible; participation, dropout, and repetition rates; stock of teachers by type; and desirable student/teacher ratios for each program.

**Principal Reports**

The principal reports of the ESM are divided into two main categories: status of underage school leavers by age and level (that is, those who are too young to enter the labor force) if the age/grade distribution is given; and current dropouts and potential participants (filtered for participation) by grade and by program.

**Technical Description**

The UNESCO ESM model has been significantly modified for use as part of the country model. The two most important modifications involve streaming control and age and labor force participation.
In regard to streaming control, it was important that the educational system should not produce more students in any discipline than the number needed to meet the manpower requirements. A feedback mechanism was therefore required so that the ESM, while taking into account repetition, dropout, and promotion rates in various grades, was able to readjust its intake at postprimary levels in order to meet the manpower requirements in accordance with national priorities (as defined by the priority matrix).

This feedback originally applied only to requirements for teachers, but was expanded to include other disciplines. Adjustments were made to promotion distribution functions so that intakes for a given discipline would not produce more students than target graduates, who, after being filtered by a participation matrix and mapped by an entrance qualification matrix, would merge into the existing labor force.

The modifications regarding age and labor force participation are more complex to describe. Among those leaving school, there are underage students who will not be able to participate in the labor force because of the minimum legal age requirements. As a result, the ESM was modified to be able to calculate underage dropouts by age and by educational level.

Finally, it should be noted that the ESM should also try to account for those who never attend any form of schooling but who ultimately enter the labor force. The programming effort needed to do this is insignificant if the data are available.

In general, the Markovian structure of the model can be summarized as follows:

Each student (s) in any given course (c) at time (t) has one of several possible successor states in t + 1: s (rep), s (pro), s (cont), s (non cont), and s (d).
Where: 1. $s(\text{rep})$ = repeater in same course;
2. $s(\text{pro})$ = completer (promoted), whether continuing or not continuing to successor course $c$;
3. $s(\text{cont})$ = completer (promoted) continuing to successor course;
4. $s(\text{non cont})$ = completer (promoted) not continuing in ETS; and
5. $s(\text{d})$ = dropout (non completer)

Let total enrollment in course $c$ at time $t = TS(t,c)$,

epro(t,c) = promotion rate in course $c$ at time $t$
rep(t,c) = repetition rate in course $c$ at time $t$
d(t,c) = dropout rate in course $c$ at time $t$

then:

(1.23) $\text{epr}(t,c) + \text{rep}(t,c) + d(t,c) = 1.0$

(1.24) $s(\text{pro}, t+1) = TS(t,c) \cdot \text{rep}(t,c)$

(1.25) $s(\text{d},t+1) = TS(t,c) \cdot d(t,c)$

(1.26) $s(\text{pro}, t+1) = TS(t,c) \cdot \text{epr}(t,c)$

Where $s(\text{pro}, t+1)$ is the total number of students/trainees to be promoted into higher courses or become graduates in time $t$.

The treatment of output of the ESM is as follows:
Assuming the existence of the following input:

\[
[UAD(0,c,a)] = \text{the existing cumulative underage dropouts by course } c \\
\text{and by age } a \text{ in base year. It is assumed that } c \text{ and } a \\
\text{are well defined. Also let:} \\
AA = \text{the minimum legal age to work minus one, and} \\
BB = \text{the minimum age allowed to attend any school} \\
\text{Where } BB < AA.
\]

\[
[FIL(t,c)] = \text{rates of graduates from course } c, \text{ in year } t, \text{ to} \\
\text{participate in the labor force. Unless } FIL(t,c) \text{ is} \\
\text{modified, it is assumed to be the same as the preceding} \\
\text{year.}
\]

\[
[EQM(t,c,i,j)] = \text{entrance qualification matrix for graduates from course} \\
c \text{ into sector } i \text{ and occupational category } j \text{ in year } t. \\
\text{Unless modified, it is assumed to be the same as the} \\
\text{preceding year. } EQM(t,c,i,j) \text{ should be applied to} \\
\text{graduates filtered by } FIL(t,c).
\]

Two functional relationships emerge: the calculation of underage dropouts, 
and manpower supplies by the ESM.

Approaching first the calculation of current underage dropouts

\[
[CUD(t,c,a)] \text{, it is necessary to note that:} \\
[UAD(t,c,a)] = \text{cumulative underage dropouts by course } c \text{ and by age } a \\
at the end of year } t; \\
[UAD(t-1,c,a-1)] = \text{the cumulative underage dropouts by course } c \text{ and by age} \\
a-1 \text{ at the end of year } t-1; \\
[CUD(t,c,a)] = \text{the current year flow of underage dropouts by course } c \\
\text{and by age } a \text{ in year } t.
\]
(1.27) \( UAD(t, c, a) = UAD(t-1, c, a-1) + CUD(t, c, a) \)

for all \( c \) and \( a \) which satisfies the constraint
\[ BB + 1 < a < AA, t > 1 \]

(1.28) \( UAD(t, c, BB) = CUD(t, c, BB) \) for all of \( c \).

It should also be noted that \([UAD(t-1, c, AA)]\) will be allowed to go into the labor market in year \( t \), because in year \( t \) those students of age \( AA \) in year \( t-1 \) will reach the legal minimum age to work.

Turning now to manpower supplies by the ESM:

Let \([LG(t, c)]\) = the number of graduates from course \( c \) who will be eligible to participate in the labor force after filtered by \( FIL(t, c) \) in year \( t \).

(1.29) \([LG(t, c) = FIL(t, c)] G(t, c)\]

Where: \([G(t, c)]\) is the number of graduates from course \( c \) in year \( t \).

To provide realism, the filtering matrix \([FIL(t, c)]\) can be made age-specific, allowing a number of underage dropouts to participate in the labor force, even though they are below the legal entry age. This concept is graphically illustrated in Figure 1.9.

\( MSE(t, i, j)\) = Manpower supplies by ESM to go into labor force by sector \( i \), occupational category \( j \), in year \( t \).

(1.30) \( MSE(t, i, j) = EQM(t, c, i, j) LG(t, c) \) where \([LG(t, c)]\) is summed for all \( c \) having the same \( i \) and \( j \) in \( EQM(t, c, i, j) \). This, in effect, says that graduates from different courses may be qualified into the same sector/occupation.

Associated reports are category.

re: (1) underage dropouts by age and by course and year (cumulative data); and (2) manpower supplies by ESM into the existing labor force by sector by occupational category by year.

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Figure 1-9

THE TREATMENT OF UNDERAGE SCHOOL LEAVERS:

THE FILTER MATRIX

![Diagram of the filter matrix showing the treatment of underage school leavers. The diagram illustrates the flow of individuals from underage, minimum legal age of entry into labor force, above minimum legal age, and their participation in the labor force over time. It includes age-specific filters and output of individuals eligible to participate in labor force.]
Incorporation of Additional Capability

An additional capability has also been incorporated into UNESCO's ESM system. Its purpose is to ensure that the teacher training facilities in an educational system will not produce more teachers than what is required. The expanded capability includes an algorithm for backward calculations to determine desired intakes for a given level of teachers' training (or targeting); and a search scheme for needed data, such as dropout/repeating rates at a given point in time. The details are given below:

Inputs

The following additional data are required, some for the purpose of clarity and some for computational requirements:

a. Teacher Group Descriptions
b. Base Year Teacher Stock by Group
c. Attrition Rates by Teacher Group
   This includes both voluntary and involuntary withdrawals from the teaching forces.
d. Course Number

Definition of Variables and Algorithm

\[ ST(0,g) = \text{Base year teacher stock for group } g; \text{ it is a vector input, in which the dimension is equal to the total number of teacher groupings.} \]

\[ AT(g) = \text{Constant annual attrition rates for group } g; \text{ it is a vector input. } AT(g) \leq 0 \]

\[ ST(t,g) = \text{Teachers available in year } t \geq 1 \text{ for group } g; \]
\[ = ST(t-1,g) \times (1 - AT(g)) \text{ for each group } g; \]

\[ TTR(t,g) = \text{Total teacher requirements in } t \geq 1 \text{ for group } g \text{ as projected by ESM} \]
Net TR(t, g) = Net teacher requirement in t> 1 for group g
= TTR(t, g) - ST(t, g)
= Total required, less those available)

Note: This is also called the target graduates, from which the desired intakes will be calculated, taking into accounts both the dropout/repeating rates and the years in stream.

[DIT(t, g)] = Desired intakes in year t to produce target graduates
[NetTr(t+b, g)] from which will be calculated DIT(t, g), where b is years in stream.

[PIT(t, g)] = Projected intakes in year t for teacher group g as calculated by the ESM. This is a straightforward application of distribution patterns (PPDD values) to a given graduating class.

Algorithm

1. If PIT(t, g) = DIT(t, g), no adjustment is required for group g, i.e., the projected intakes are less than or equal to the desired intakes. Therefore, no over-production of teachers in group g is anticipated.

2. If PIT(t, g) > DIT(t, g), the following adjustments should be made, but note that any adjustments could be done only for t>1, because actual intakes (i.e., intakes that took place in or before the base year) cannot be readjusted. Namely, intake adjustments could be done only for target graduates in t + b and beyond.

To adjust, the difference (i.e., PIT(t, g) - DIT(t, g)) should be redistributed in accordance with the conditional (or revised) PPDD distribution excluding the proportion allocated for the intake into teacher group g in t for a given graduating class. To illustrate, let the original PRDD distribution for a given graduating class, say, of 1,000 students be:
20% or 200 students for teacher training
50% or 500 students for general studies
30% or 300 students available for the labor market

and let the desired intake as calculated by the ESM for teacher training be 120 students. Since the desired intake of 120 $DIT(t,g)$ is less than the projected intake of 200 $PIT(t,g)$, the difference of 80 (200-120) should be redistributed in accordance with the conditional distribution of 50/80 and 30/80 to general studies and available for the labor market, respectively. If we compare against the original projection, the adjusted intake will be as follows:

<table>
<thead>
<tr>
<th></th>
<th>Original Projection</th>
<th>Revised Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher Training</td>
<td>200</td>
<td>120</td>
</tr>
<tr>
<td>General Studies</td>
<td>500</td>
<td>550</td>
</tr>
<tr>
<td>Available for the Labor Market</td>
<td>300</td>
<td>330</td>
</tr>
<tr>
<td></td>
<td>1,000</td>
<td>1,000</td>
</tr>
</tbody>
</table>

1.10 THE MANPOWER POLICY MODEL (MPM)

Function

The basic function of the MPM is to allocate supplies from the existing surviving labor force, from the ESM, and from foreign sources of labor to the overall SOM according to specific priorities and constraints. For example, in allocating manpower with professional qualifications and senior technical qualifications—i.e., engineers—a priority might be assigned to those occupational categories within sectors considered to be strategically important (for example, in the oil industry).

The MPM can also maximize the number of nationals employed in a specific occupation within a sector. In a case where supplies exceed requirements,
adjustments in participation and repetition coefficients in the ESM will have to be made. Alternatively, the planner may adjust entry requirements elsewhere, introducing alternative labor force entry points and/or ESM follow on courses. In cases where supplies are smaller than requirements, the most critical priorities will be satisfied first. Where priorities are equal and supplies are insufficient, allocation between sector/occupation cells is made on the basis of each cell's net requirements weighted by the degree of nationalization already obtained.

Special note must be taken of the allocation of expatriate personnel. Once the available national labor force has been allocated to the SOM (that is, the existing labor force less attrition, plus the new entrants from the ESM) the residual requirements—in the form of expatriate personnel—can be estimated.

To simulate reality, four sets of constraints are introduced into the model to govern allocation of expatriate labor and the solution of the related forecasts:

**Quantitative constraints**, by nationality groups, limiting the maximum numbers of each group that the model may draw from. This set provides some realistic ceilings within which the forecast must remain.

**Qualitative constraints**, to reflect either the entry requirements of specific positions (for example, that nonnationals cannot be considered for teaching requirements) or the nature of the supplying labor force (for example, that Americans will not be used for unskilled labor).

**Policy constraints**, limiting the allowable proportion of expatriates in any single sector, occupation, or cell in the SOM. Such constraints could also be reflected as a limit of the allowable proportion of any single nationality group among expatriates in any single sector, occupation, or cell in the SOM.
Boundary constraints, limiting the extent to which the magnitude of the forecast components can vary from year to year. This can be viewed as a smoothing function, providing a maximum feasible band within which the forecast must remain.

The allocation of expatriates to the SOM cells is made by a linear programming model (LPM) that can respect these constraints. Since the model as a whole accommodates up to 10 nationalities or national groups, and there can be as many as 400 SOM cells, the total variables (or possibilities of assignment to a nationality pool) are 4,000. To make allocation less complex, the SOM can be partitioned into critical skill areas—for example, into the category of managerial and senior technical posts in key sectors. The LPM allocates available expatriate labor, in the light of the previously mentioned constraints, to the most critical partition. It then proceeds to the next partition, while taking into account those from a given nationality and/or skill mix who have already been used in the preceding allocation. The process continues until residual SOM requirements are satisfied.

Principal Data Requirements

The MPM has two basic categories of data requirements. The first consists of SOM priorities, which may be either judgmental or based on labor market surveys designed to inventory critical skill needs on the part of both public and private enterprises. The second consists of the appropriate targets and constraints for the percentage of nationalization and expatriate mix. This is a policy decision that is made by national decisionmakers.

Principal Reports

The MPM produces a variety of reports, including allocation reports (such as the allocation of "pooled" leavers by occupation within sector), and a
nationalization program analyses report (comprising (a) sector/occupation requirements, (b) existing national labor force, (c) nationalization, (d) number of nationals needed, (e) the difference between (a) and (b), (f) current ESM supplies, and (g) net additional requirements). It also provides nationality for every occupation within a given sector, total sector employment distribution by nationality, total employment by occupation distributed by nationality group, comparison of target sectoral outputs with achievable outputs given the existing (national and nonnational) labor force, and manpower availability by pool.

Technical Description
As indicated, the MPM articulates manpower policies, taking into account national priorities in the process of nationalization and policy constraints on the expatriate labor force. Manpower supplies from the educational system are allocated in accordance with a priority matrix in which the priority of each sector/occupation and the fraction of nationalization are specified. The priority matrix is defined as PM(i,j,m,f) where f indicates the fraction, and p, the priority of nationalization for sector i, occupation j. The manpower supplies from the ETS are pooled and allocated to each sector/occupation in accordance with the priority matrix PM(i,j,m,f). The priority f, as supplied by policymakers, will determine the sequence of allocation among the set of sector/occupation cells competing for the same pool of manpower supplies. If manpower supplies exceed requirements the question of priority allocation will not arise. However, when requirements exceed supplies, one of several allocation mechanisms can be used to allocate the pooled manpower supplies among competing sector/occupations having the same priority rating. The model allows a choice of four possible methods.
Method 1--The allocation is done in proportion to the net additional requirements needed to achieve nationalization targets. Namely, each shortage required to achieve the nationalization program will have equal weight to command the allocation of manpower supplies from a given pool. With this method, no consideration is given to the percentage of nationalization already achieved, nor does the method aim at necessarily completing nationalization of any given sector/occupation.

Method 2--Here the sector/occupation having the lowest achieved percentage of nationalization will get its allocation first among the competing sector/occupations having the same priority for the same pool.

Method 3--This method maximizes the total number of sector/occupations that would have achieved the nationalization program after allocation of the current year's manpower supplies. The rules are:

(a) the competing sector/occupation requiring the fewest number of the pooled manpower supplies to achieve the nationalization program will get its allocation first;

(b) If there are still unallocated supplies, then the sector/occupation requiring the next fewest number of the pooled manpower to achieve its nationalization program will get the next allocation; and

(c) So on until all available pooled manpower supplies are exhausted.

Method 4--This method is a variant of method 1, weighted by the percent that is still required to achieved the nationalization program of a given sector/occupation.

Let \( f(i,j) \) be the target share of workers in sector \( i \) and occupation \( j \), that is national labor force

\[ [TLF(t,i,j)] \] is the estimated total manpower requirements for sector \( i \) and occupation \( j \)
Then, \( NG(t,i,j) = TLF(t,i,j) \). \( f(i,j) \) is the target level of national labor which meets the nationalization goal.

Recall that \( NLF(t,i,j) \) is the existing national labor force in sector \( i \) and occupation \( j \).

Then, the net additional manpower requirements \( NAR(t,i,j) \) to achieve the nationalization program for sector \( i \) and occupation \( j \) are given by
\[
[NAR(t,i,j)] = NG(t,i,j) - NLF(t,i,j).
\] It is to be noted that if and when \( NAR(t,i,j) \leq 0 \), then \( NAR(t,i,j) = 0 \). Namely, the required fraction of the nationalization program has already been achieved.

Let \( PER(t,i,j) \) be the percent of the target of national workers still needed to nationalize in a given sector/occupation \( (i,j) \) in \( t \), that is:
\[
PER(t,i,j) = \frac{NAR(t,i,j)}{NG(t,i,j)} \times 100
\]

Using the above parameters, the allocation formula for Method 4 for a given set of \( i \) and \( j \) having the same priority and sharing a common pooled manpower supply, will be as follows:
\[
(1.33) Alloc(t,i,j) = \frac{NAR(t,i,j) \cdot PER(t,i,j) \cdot pool}{\sum_{i,j} NAR(t,i,j) \cdot PER(t,i,j)}
\]
for \( i \) and \( j \) sharing the pooled manpower supply.

It should be noted that if \( Alloc(t,i,j) > NAR(t,i,j) \), then the actual allocation should be less than or equal to \( NAR(t,i,j) \), and whatever remains in the pool will be allocated to the next priority \( i \) and \( j \) sharing the pooled manpower supply.

There are certainly other methods that can be devised to reflect policymakers' choices, and further refinements to the model are possible in this area. Further work in this area is being carried out at present.

Turning now to the linear programming package, one of many that can be introduced into the single country exercise, the following application is for labor-importing countries. There the task is to minimize the total
imputed cost (social and economic) of having expatriates work in the country, assuming that it is possible to impute unit costs of having one expatriate-man-year of a given nationality work in a given sector/occupational category. The LP package has linear constraints in sector/occupational restrictions, as well as in the number of persons of a given nationality allowed to work in the country.

The linear programming will be solved for each period to minimize an objective function representing the total imputed cost of having the expatriate labor force work in the country to supplement the manpower shortage for the desired output targets.

1.34 \[ Z = \sum_{ijn} \text{COST}(t,i,j,n) \cdot XLF(t,i,j,n) \]

Where: \( \text{COST}(t,i,j,n) \) designates the imputed unit cost of having one expatriate man-year of nationality \( n \) work in sector \( i \) and occupational category \( j \); and

\( XLF(t,i,j,n) \) designates the number of expatriate labor force personnel of nationality \( n \) working in sector \( i \) and occupational category \( j \). If imputed costs are not easily available, the linear programming package can be used exclusively to test for feasibility within the given constraints. The constraints are that:

(i) the expatriate labor force allowed to work in a particular sector must equal or exceed the sectoral manpower shortage;

(ii) the expatriate labor force allowed to work in a particular occupation must equal or exceed the occupational manpower shortage; and

(iii) the share of expatriate labor force from a particular country be within certain bounds.
Symbolically, the linear programming

\[ Z = \sum_{nij} \text{COST}(n,i,j) \times \text{XLF}(n,i,j) \]

subject to (t,i,j,n) \cdot \text{XLF}(t,i,j,n)

(i) \[ \sum_{n_{ji}} XLF(t,i,j,n) \geq \text{NMR}(t,i) \]; where \( N_{ji} \) is a given nationality set for sector \( i \);

(ii) \[ \sum_{n_{2j}} XLF(t,i,j,n) \geq \text{NMR}(t,j) \]; where \( N_{2j} \) is a given nationality set for occupation \( j \);

(iii) \[ B_1(n) \leq \sum_{i,j} XLF(t,i,j,n) \leq B_2(n) \]

where: \( B_1(n) = \) lower bound
\( B_2(n) = \) upper bound

The implications of this process are that the LP package, as indicated, will be solved for each period \( t \), and the solution will be in terms of the number of nonnational labor force personnel with nationality \( n \) working in a given sector/occupation \((i,j)\); that is, \( XLF(t,i,j,n) \). Since \( XLF(t,i,j,n) \) indicates the level of nonnational labor force personnel required in year \( t \) needed to meet the manpower shortage, the difference between \( XLF(t,i,j,n) \) and \( XLF(t-1,i,j,n) \) yields the required movement of nonnational labor force personnel from year \( t-1 \) to year \( t \). Therefore, if \( XLF(t,i,j,n) > XLF(t-1,i,j,n) \), then the difference indicates the net importation of nonnational labor force personnel of nationality \( n \) to work in sector \( i \) and occupation \( j \). On the other hand, if \( XLF(t,i,j,n) < XLF(t-1,i,j,n) \), the difference will imply net exportation.

It is to be noted that:

\[ \sum_{i} XLF(t,i,j,n) = \text{total nonnational labor force of nationality} \ n \ \text{working in occupation} \ j \ \text{in year} \ t; \]

\[ \sum_{j} XLF(t,i,j,n) = \text{total nonnational labor force of nationality} \ n \ \text{working in sector} \ i \ \text{in year} \ t; \ \text{and} \]

\[ \sum_{ij} XLF(t,i,j,n) = \text{total nonnational labor force of nationality} \ n \ \text{in the country in year} \ t. \]
Chapter 2. THE EXPANDED MODEL

2.1 Introduction

The expanded model produces regional and national manpower analyses including interregional labor force migration and the associated movement of nonmembers of the labor force. The expanded model comprises two major stages of analysis: local analysis, which refers to regional analyses within the country, and global analysis, which refers to national analyses. This labeling was adopted to avoid confusion with the supranational region that could refer to a group of nations.

2.2 Local Analyses

In a local analysis, each locality is treated as a separate entity with a unique information: estimated manpower stocks by sector/occupation, estimated manpower requirements to meet its economic development targets, an education/training system (ETS), and manpower allocation priorities with respect to the allocation of manpower from ETS. However, expatriates are not allocated at the local level but rather at the global level, due to the international context of immigration.

There are leakages of manpower from one locality to others. The attrition of labor force in one locality could be an addition to another's; or losses from the labor force in one locality could be an addition to another's, or could be permanent losses. Therefore, attrition must be interpreted with caution since the current-year graduates may not accept jobs within their region, thereby affecting the traditional entrance rates into the labor force in each locality. The situation may have to be interpreted in a broader context to allow participation with other localities. Also, leakages of dropouts from one locality to another may take place. These leakages are similar in concept, although opposite to
the much-discussed case of "brain-drain", where the outflow of skilled manpower continues due to better social, political, economic, and financial conditions prevailing somewhere else, despite the existence of a real local need for skilled manpower and the government's best efforts to retain it.

The migration of labor from one locality to another could cause other population movements as well, due to the movement of dependents, including students currently enrolled in the local FTS. These associated movements will change the demographic picture, enrollment figures, and, consequently, the local requirements of infrastructure.

These leakages and associated movements are not explicitly dealt with in the country model, but if they are viewed in the context of a locality, there could be positive or negative flows of manpower, which the expanded model is equipped to handle.

It may be useful to relate the country model to local analyses, and to describe in general terms how the country model has been modified or expanded for local analyses. Recall that the country model contains four major submodels:

- Labor Force Model (LFM)
- Manpower Requirements Model (MRM)
- Education Simulation Model (ESM)
- Manpower Policy Model (MPM)

As mentioned earlier, the country model computes separately each locality's available labor force by sector/occupation category and its estimated manpower requirements and supplies. The expanded model's local analyses add to this process an accounting of leakages in both labor-force and non-labor-force populations in each locality.
Another major difference between the country model and the expanded model for local analyses is in the manpower policy submodel. The MPM in the country model allocates expatriates along with the national labor force at the country level. Expatriates are not allocated at the local level in the country model, and the MPM, likewise, does not attempt this in the local analyses. The local analyses do, however, allocate available local manpower supplies, minus leakages, in accordance with the local priority matrix. Further, the local analyses calculate achievable outputs in each locality, taking into account available labor force nationals and expatriates, using the method applied at the country level in the country model.

2.3 Global Analyses

In a global analysis, leakages into and out of localities are reallocated. A mechanism has also been incorporated which updates population and enrollment figures in each locality resulting from the movements of labor force, and, in some cases, unemployment is calculated for those "leakage labor force" members in a transient state. Furthermore, a manpower allocation mechanism for expatriates has been added. From this general description of a global analysis, it may be appropriate to consider the global analysis as a consolidation analysis, in which the emphasis is placed on the reallocation of surpluses, deficits, leakages, updating of the associated movements of non-labor force population, the allocation of expatriates, and estimates of the labor force in a transient state.

The Pool Concept

The pool concept was introduced in the country model. Those with similar qualifications, or those considered to have similar qualifications, are pooled together. For example, the education/training system supplies
graduates and dropouts, and they are pooled (called Category I) according to their qualifications. From these pools various sector/occupations draw their manpower needs in accordance with a priority matrix. The concept of pooling is also used in the expanded model to pool leakages from local labor forces, graduates, and dropouts. The pooled labor force, by locality, is then reallocated to the corresponding pool identification of other localities (called Category II) in accordance with a transition matrix or matrices as a function of time. These two categories of pools differ in that Category I is for graduates and dropouts, who will be allocated in the current year to local manpower requirements during the local analysis, while Category II is for leakages, who will be reallocated with a time lag, during the global analysis, to various localities.

**Time Lags**

In the allocation or reallocation of both categories of pools, time lags could exist. However, it is more reasonable to assume greater time lag in the global analysis than in the local analysis. Graduates are more likely to go into the labor force in the year they graduate, if they do go into the labor force in the locality; while leakages, who go into labor forces in other localities, tend to have a time lag. Therefore, it is assumed that the allocation of pools (Category I) of current-year graduates and dropouts in the local analysis will have no time lag, and that the reallocation of leakages will have a constant time lag, whatever they may be, in the global analysis, throughout the simulation time horizon in the expanded model. As a matter of system design approach, the time lag is treated as a controllable parameter. Users could change its value to see what impact the time lag has on manpower supplies and demands in the global analysis. It is anticipated that providing employment information nationwide could reduce time lags in labor force movements.
Initial and Terminal Conditions

Initial and terminal conditions must be considered, particularly when the time lag is long and the simulation horizon is short. Initial data sets have been provided to satisfy the requirements of initial conditions, and users' options are incorporated into the system to allow users' selection of how terminal data (i.e., leakages yet not reallocated) should be treated at the end of the simulation horizon.

Transition Matrices

In the reallocation of leakage labor force, some localities may be preferred to others by those who are looking for jobs. This preference is taken into account in the transition matrix or matrices.

Misallocations

If, after the reallocation of leakage labor force, a condition results in which surpluses continue to exist in some localities and deficits exist in other localities, this will indicate the misallocation of national human resources. The expanded model will provide this type of analysis if and when such a condition exists.

After the reallocation of leakage labor force, the corresponding non-labor-force movements are updated by locality, including local population and enrollment figures.

2.4 Overall System Design Specifications

As mentioned earlier, each locality will go through its own analysis every year (or every period). The computational algorithms in local analysis are very similar to the country model, with additional computations required to account for leakages, surpluses, or deficits, and to update the associated changes in local population and student enrollments.
After all localities in a global unit have gone through their individual local analysis in a given year (or period), the global analysis will then start to re-allocate pooled leakages from each locality to various localities in accordance with a transition matrix or transition matrices, and will also estimate corresponding changes in population and enrollments due to labor force migration. All these calculations will take time lags into account. After the reallocation processes for leakages and surpluses are completed, the global analysis will then start to estimate expatriate requirements, taking into account existing available local nationals and expatriates residing in the global unit. See Table 2-1 for a comparative description, by labor force category, of attrition and leakage between local nationals and expatriates.

Leakage labor force available to each locality from other localities is reallocated by the global analysis via transition matrices in accordance with the local priority matrix. The system design also allows for the introduction of different allocation rules for such labor-force leakages as may be required in the future.

2.5 Phases

The following phases, to be executed in each time period, will give a general idea of how the expanded model will perform each simulation run:

Phase I

Local Analyses for All Localities
- Estimate labor force inventories
- Estimate labor force requirements
- Estimate education/training and supplies
- Estimate manpower leakages and pooling
### Table 2-1
GLOBAL ANALYSIS: Expatriates and Local Nationals
Attrition and Leakage

<table>
<thead>
<tr>
<th>Labor Force Category</th>
<th>Expatriates</th>
<th>Local Nationals</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Existing Labor Force</td>
<td>(a) Attrition - Dropout from the labor force</td>
<td>(a) Attrition - Dropout from the local labor force</td>
</tr>
<tr>
<td></td>
<td>(b) Leakages - No leakage reallocation will be calculated</td>
<td>(b) Leakage - Assumed available for reallocation within the country</td>
</tr>
<tr>
<td>(2) Current Graduates</td>
<td>Assumed not applicable</td>
<td>(a) Leakage - Assumed available for reallocation within the country</td>
</tr>
<tr>
<td>(3) Dropouts</td>
<td>Assumed not applicable</td>
<td>(a) Leakage - Assumed available for reallocation within the country</td>
</tr>
</tbody>
</table>
- Perform manpower allocations of graduates minus leakage

**Global Analysis**
- Reallocate leakages to localities, with time lags taken into account
- Estimate non-labor-force movements and adjustments, with time lags taken into account

**Phase II**

**Local Analyses**
- Allocate manpower reallocated by the global analysis
- Calculate achievable local outputs

**Global Analysis**
- Calculate global achievable outputs
- Calculate labor force in a transient state
- Estimate net requirements for expatriates
- Apply linear programming submodel

2.6 **Assumptions**

As mentioned, it might be appropriate to consider the global analysis as a consolidation analysis of various local analyses; therefore, some commonalities must exist among localities:
- Similar education/training structure at the local level
- Similar definition of pools
- Similar sector/occupation matrix
- Free movement of surplus or leaked manpower and associated population changes.

2.7 **Outputs/Reports**

In addition to most of the outputs/report capability of the country model, the following flow analysis reports are available with the expanded model:
- Leaked labor force by sector/occupation, by year, by locality
- Leaked graduates by pools, by year, by locality
- Leaked dropouts by age, by year, by locality
- Associated changes in population and enrollment, by year, by locality
- Achievable outputs by sector, by year, by locality
- Achievable global outputs by sector, by year
- Labor force in a transient state, by year

2.8 Internal Specifications: Local Analysis

In the country model, a nation is considered to be a single unit, within which internal leakage flows are not explicitly dealt with. However, in the expanded model, two additional dimensions are introduced into the system design: one relates to the dimension of space, i.e., locality, and the other relates to time lag in flow analyses. It should be noted that a time period is different from a time lag—they should not be confused or used interchangeably.

To make this description as self-contained as possible, some specifications described in the glossary will be repeated here. In the remainder of this chapter, the following symbols will be used throughout, and will have the meaning defined below unless otherwise noted:

\[ r = \text{localities} \]
\[ \text{lag} = \text{time lag} \]
\[ t = \text{time period} \]
\[ i = \text{sector ID} \]
\[ j = \text{occupation ID} \]
\[ n = \text{nationalities other than local nationals} \]
\[ p = \text{pool ID} \]
Labor Force Model: National Labor Force

Inputs: The following base year data are required:

NLF(0, i, j, r) = Base year national labor force stock by sector i, occupation j and locality r.

NA(t, j, r) = Attrition rates vector by occupation j and r for national labor. It is assumed that NA(t, j, r) = NA(t-1, j, r) unless specifically changed by entering attrition rates vector for a given t.

LEAK(0, r, p, t-lag = Initial stocks of leaked labor force from locality r in pool number p and available for reallocation by the global analysis, in time period t, taking into account time lag.

When t-lag = 0, the initial data should be input. The time lag variable "lag" specifies the number of periods the analysis will go beyond the base year for the initial data set. When t-lag = 1, the data will be computed by the system, taking into account leakage rates in the existing labor force, graduates, and dropouts.

Functional Relationships

NLF(t, i, j, r) = National labor force at the beginning of year t, by sector i, occupation j and locality r;

NLF(t, i, j, r) = NLF(0, i, j, r) for t = 1

NLF(t, i, j, r) = NLF(t-1, i, j, r) * (1-NA(t-1, j, r)) + MSE(t-1, i, j, r) - LKLF(t-1, i, j, r).NLF(t-1, i, j, r) + REALLOCATED (t-1, i, j, r, t-lag)

(For t>2)
Where $MSE(t-1,i,j,r)$ is the labor supply from ESM:

$LKLF(t-1,i,j,r)$ is the rate of leakage, and $LKLF.NLF$ are leakages;

$REALLOCATED(t-1,i,j,r,t-lag)$ is the reallocated leakages, with lags by the global analysis.

What this functional relationship says is that the existing available labor force in sector $i$, occupation $j$, locality $r$, and year $t$, is the sum of workers remaining after attrition, plus those supplied from ESM, and leakages reallocated by the global analyses, minus the leakages in year $t-1$.

**Outputs**

The output from this functional relationship is the existing national labor force at the beginning of year $t$ by sector, by occupation, and by locality.

**Labor Force Model: Expatriate Labor Force**

**Inputs**

The following base year data for the expatriate labor force are required:

$$XLF(O,i,j,r,n)$$

Base year expatriate labor of nationality $n$, working in locality $r$, in sector $i$, and occupation $j$.

$$XA(t,j,r,n)$$

Attrition rates vector by occupation $j$, locality $r$, and nationality $n$. It is assumed $XA(t,j,r,n) = XA(t-1,j,r,n)$ unless specifically changed by entering attrition rates vector for $t$. It is further assumed, when no detailed attrition rate data are available for various nationalities,
that all nationalities will have the same
attrition rates by occupation and locality. When
no detailed attrition rate data are available by
locality, it will then be assumed that attrition
rate will be by occupation only.

When the expanded model is to be applied at the international level
and when time lags exist in the movement of expatriates across national
boundaries, the similar initial conditions, i.e., initial date of labor
force in a transient state, should also be provided by sector, by
occupation, by locality, and by nationality.

Functional Relationships

\[ XLF(t,i,j,r,n) = \begin{cases} 
\text{Expatriate labor force at the beginning of year } t \\
\text{in sector } i, \text{ occupation } j, \text{ locality } r, \text{ and } \\
\text{nationality } n. 
\end{cases} \]

\[ XLF(t,i,j,r,n) = XLF(0,i,j,r,n) \text{ for } t = 1 \]

\[ XLF(t,i,j,r,n) = XLF(t-1,i,j,r,n) \cdot (1 - XA(t-1,j,r,n)) + \text{Net} \]

\[ X(t-1,i,j,r,n) \text{ (For } t \geq 2) \]

The net expatriate labor force at the beginning of year \( t \), \( \text{Net} \cdot X(t-1,i,j,r,n) \) is the sum of what remains after attrition, and what is
allocated by the manpower policy submodel of the global analysis. It is
assumed that the leakages of expatriates are included in the attrition
computation.

Outputs

The following outputs/reports are available, as in the country model:

- Expatriate labor force by sector, by occupation, by year
- Expatriate labor force by sector, by occupation, by locality, by
  year

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- Expatriate labor force by nationality, by year
- Expatriate labor force by nationality, by locality, by year

**Manpower Requirements Model**

The methods for estimating manpower requirements differ between the country model and the expanded model in only one respect, the additional dimensions of locality in the expanded model. Since each locality is treated as an entity by itself having its own development targets, it has its own manpower requirements estimates. The expanded model accordingly requires input data broken down by locality, and produces output/reports with breakdowns by locality.

The country model provides a choice of three major methods for inputing manpower requirements: the elasticity method, the productivity growth method, and the direct input method. These are also available in the expanded model.

**Education Simulation Model**

The ESM Submodel used in the country model is also used in the expanded model, with one additional dimension (locality) for local analyses in the expanded model. No changes have been made in calculation of graduates and dropouts, the accounting of dropouts under the minimum legal working age, and the concept of pooling via filtering by participation rates.

Input data required by the ESM are broken down by locality. The ESM is run for each locality to estimate manpower supplies. Outputs/reports available for ESM have breakdowns by locality. The expanded model also provides aggregated reports similar to those available from the ESM in the country model.
Estimation of Leakages

As mentioned, the major differences between the country model and the expanded model in local analyses lie in the accounting of leakages in the local labor-force and non-labor-force populations. There are three possible major labor force categories that could have leakages:

- The existing labor force
- The graduates
- The dropouts

There are also two possible major categories of non-labor-force leakages due to labor force migrations:

- Local population
- Local enrollments

In this section, only the leakages from the labor force will be discussed. The non-labor-force leakages will be discussed in a later section on global analyses because, by definition, associated movements for the non-labor-force depend on labor force distribution. Therefore, it is only after the reallocation of leakage labor force is completed, with consideration for time lags, that the adjustments of non-labor-force population can be calculated.

Labor Force Leakages

Inputs

The following input data are required to estimate pooled leakage labor force:

\[ \text{LKL}(t, i, j, r) = \text{The leakage rate for the existing labor force in sector } i, \text{ occupation } j \text{ in locality } r, \text{ in time period } t. \]
The data about how sector i and occupation j are defined in the pool p.

The leakage rate for the graduates in the pool p in locality r and in time period t.

The leakage rate for the dropouts in the pool p in locality r and the time period t. This leakage rate should be distinguished from the leakage of underage entrants and potential entrants analysis as currently calculated in the country model. It is assumed that the leakages to global units come from the underage leakage pools.

Functional Relationships

The pooled leakages, in time period t, in pool p, in locality r to be reallocated with time lag of "lag" periods.

\[ LKPOOL(t,r,p,t-\text{lag}) = \sum_i \sum_j NLF(t-1,i,j,r).LKL(t-1,i,j,r) \]
\[ + \ \text{SCPOOL}(t-1,r,p).LKSC(t-1,r,p) \]
\[ + \ \text{UGPOOL}(t-1,r,p).LKUG(t-1,r,p) \]

What this functional relationship says is that the total pooled leakages from a given locality's pool and available for later (time lag) reallocations is the sum of the leakages from the existing labor force NLF(t-1,i,j,r), graduates SCPOOL(t-1,r,p), and the underage UGPOOL(t-1,r,p), provided they all have the same pool number p, and locality r.

Outputs

The outputs/reports available from the calculations include:

- Leakage report, by sector, by occupation
Leakage report, by pool, by year

Manpower Policy Model

The manpower Policy Model in the country model serves to articulate manpower policies for both nationals and expatriates. In the expanded model, however, only the allocation of nationals is dealt with in the local analysis. The distribution of expatriates is done at the global level, due to national and international immigration policies.

Recall that there are two major categories of manpower supplies from ESM—the graduates and the dropouts. Although by law the dropouts are not allowed to go into the labor force until they reach the minimum legal age, they do, in some cases, participate illegally in the labor force. In the country model provisions are made available for the leakage of dropouts into the labor force. (Note the difference between the leakages as described here, which are available for local analysis with time lag, and the leakages to global unit, which are available for global reallocation with a time lag). Leaked dropouts are first pooled by their educational level as specified by users, and from these pools, the leakages to both the local unit and the global unit are calculated. Next, the underage leakage pools are separated into two types: one available to local analysis without a time lag, and the other available to global analysis with a time lag for later reallocation. Those available for local analysis in the year (or period) the leakage occur, will be allocated in conjunction with the allocation of pooled graduates, in accordance with the manpower allocation priority matrix to meet local nationalization programs.

Before the allocation of available local manpower takes place, the following adjustments must be made to avoid double counting:

$$SCPOOL(t,r,p)(1-LKSC(t,r,p))$$
This states that the leakage of graduates to global analyses are subtracted from the graduate pool.

\[ UGPOOL(t,r,p) \times (1 - LKUG(t,r,p)) \]

This states that the leakage of dropouts to global analyses are subtracted from the dropout pool.

Note that the adjustments of the leakages from the existing labor force have already been taken into account in the recursive functions of existing available labor force.

After the above adjustments have been completed, the manpower allocation rules as detailed in the country model can be applied, taking into account the priority matrix of each locality as specified by users of the model.

2.9 Phase I Internal Specifications: Global Analysis

After local analyses have been performed for each locality, the leakage labor from various localities becomes known. This leakage labor is then reallocated to other localities in accordance with transition matrices as a function of time. This is the first step in the global analysis.

Once reallocation to various localities is completed, the global analysis estimates movements of non-labor-force population, deriving both population and enrollment figures. The following discussion addresses the reallocation process and the adjustments for non-labor-force population movements.

Transition Matrix and Reallocation Process

Transition matrices by pool and by year are introduced to estimate transition of leaked labor force. Each row and column of the matrices will designate a locality number.
Each matrix is a square matrix, whose rows designate "from" or "source" and whose columns designate "to" or "recipient" in the transition of leaked labor force. Each element in a matrix is the rate of transfer for a given pool of leakage labor force, and the sum of all row elements in a given row must be equal to 100%. The diagonal elements in a matrix represent those choosing to stay in their own localities after they are considered as leaked labor force. If this situation is considered unlikely to occur, then all the diagonal elements have zero values. The number of rows (or the number of columns) is equal to the number of localities to be included in the global unit. The mathematical operations required to obtain reallocation of a set of pools with the same pool ID from each locality are described below.

Let the transition matrix \([\text{TRAN}(p)]\) for pool ID \(p\) be defined as follows:

\[
\text{TRAN}(p) = \begin{pmatrix}
a(11), A(12), A(13) , & \ldots \ldots \ldots \ldots & a(1R) \\
a(21), A(22), A(23) , & \ldots \ldots \ldots \ldots & a(2R) \\
\vdots & & \vdots \\
a(R1), A(R2), a(R3) , & \ldots \ldots \ldots \ldots & a(RR)
\end{pmatrix}
\]

Where \(\sum_{r=1}^{R} a(1r) = \sum_{r=1}^{R} a(2r) = \ldots = 1.0; R = \text{total number of localities.}\)

Also let \(\text{PL}(r,p)\) be the pooled leakages in locality \(r\) for pool ID \(p\). By definition, there is one and only one \(\text{PL}(r,p)\) for each locality \(r\) for a given \(p\). Therefore, there is a total of \(R\) pools, one from each
locality. For locality 1, the PL(1,p) will be distributed according to a(21), a(22), ...a(2R); and so on. Let TRANp be the matrix of the redistributed leakage labor force:

\[
\begin{bmatrix}
\ b(11), b(12), b(13), & \ldots & \ldots & \ldots & b(1R) \\
\ b(21), b(22), b(23), & \ldots & \ldots & \ldots & b(2R) \\
\ b(R1), b(R2), b(R3), & \ldots & \ldots & \ldots & b(RR)
\end{bmatrix}
\]

The summation by "recipient" localities is the reallocated leakage labor force, which is allocated by the recipient localities in accordance with the local priority matrices.

Adjustments of Non-Labor-Force Movements

Recall that the migration of labor force leakages takes place with a time lag. Therefore, by definition, the movements of the associated non-labor force migration will also take place with a time lag. To simplify the programming tasks without loss of validity, the movements of the associated non-labor-force will be assumed to take place with the same time lag as that of the labor force leakage migrations. The calculations of non-labor-force population movements are done by the global analyses after the calculations of reallocations for leakage labor force.

It is further assumed that the associated population movements are functions of the leakages of the existing labor force only. Recall that three general categories of leakages could take place— from the existing labor force, from graduates, and from the underage dropouts. Nevertheless, the leakages from the last two cause almost no associated movement of non-labor-force general population. This is due primarily to their youth, unmarried status, and general lack of financial means to support a family at that point in their lives. This assumption does not cause any noticeable distortions in the simulation results.
Although no associated movements due to the migration of the leaked graduates and the underage dropouts are assumed, these two categories of leakages are part of the population figures in the locality where they are or will be staying. As leakages occur, they will move into other localities, and should, therefore, be included in the population figures of the locality they are moving into, and excluded from the population figures of the locality they are moving out of. These move-in and move-out calculations also apply to the leakages of the existing labor force, which will cause associated movements of non-labor force population.

Adjustments of Population Figures

In the expanded model, the following inputs are assumed for each locality:

- Base-year population figures by age, by sex (this includes those in schools and those not attending any schools).
- New births by year, by locality, by sex
- Survival rates by age, by year, by sex

In addition to these general demographic data, the following data are needed:

\[ \text{RATE}(t,a,r) = \text{Rate of associated movements in population out of locality } r, \text{ for age group } a, \text{ per 100 existing labor force migrations.} \]

Although it might be claimed that there could be some relationships between family size and the level of income/education/occupation/pools, the same rate is applied across all pooled leakages of the existing labor force in a given locality. Namely, regardless of what pool the leaked existing labor force belongs to, as long as they are all from the same locality, they will have the same \text{RATE}(t,a,r) of associated non-labor-force movements out of their locality.
Functional Relationships

- Move-outs \((t,r,t-lag)\) of existing labor force;
- Move-ins \((t,r,t-lag)\) of existing labor force;
- Move-outs \((t,a,r,t-lag, \text{graduates})\);
- Move-ins \((t,a,r,t-lag, \text{graduates})\);
- Move-outs \((t,a,r,t-lag, \text{dropouts})\);
- Move-ins \((t,a,r,t-lag, \text{dropouts})\).

Although in quantitative terms move-outs and move-ins have some cancellation effects, they should be kept separated for the purposes of flow analyses, as well as stock computations of existing populations in various localities that take into account cancellation effects. For a given locality \(r'\), the calculations of population at the beginning of each period will then be:

\[
POP(t,a,r') = POP(t-1,a,r').SURVIVERATE(t-1,a) - RATE(t-1,a,r').MOVEOUTS(t-1,r',t-lag)/100 \]
\[
+ \sum_{r \neq r'} RATE(t-1,a,r) \times MOVEINS(t-1,r,t-lag)/100 \]
\[
- MOVEOUTS(t-1,a,r't-lag, \text{graduates}) \]
\[
- MOVEOUTS(t-1,a,r't-lag, \text{dropouts}) \]
\[
+ \sum_{r \neq r'} MOVEINS(t-1,a,r,t-lag, \text{graduates}) \]
\[
+ \sum_{r \neq r'} MOVEINS(t-1,r,t-lag, \text{dropouts}) \]

In a very simplified explanation, this function says that the population figures for a given age group in a given locality is the sum of what is surviving, plus all move-ins, less all move-outs. During the course of the simulation run, the new births by year by locality should also be calculated by using the input provided by users of the model.
Outputs

The outputs/reports to be made available include both stock and flow analyses of population migrations due to labor force movements.

Adjustments of Enrollments

In the current ESM system, detailed information about enrollment statistics is kept within the country model. The movements of students are only a function of labor force movements, by virtue of the definitional relationship between associated movements in population and labor-force movements. Therefore, there are also two-way movements (move-ins and move-outs) into and out of the local education/training system. The computational step for the adjustments of enrollments (with time lags) is very much the same as that in the adjustments of population figures, provided the dimensionality is in terms of course number \( c \) and locality \( r \). 1/

Input

The following input is required:

\[
RATES(t,c,r) = \text{Rate of associated movements in course number } c, \\
\text{out of locality } r \text{ to go into the same course number } c \text{ in other localities due to per 100 existing labor force migrations. (Sum of } \\
RATES(t,c,r) \text{ for all } c \text{ equal to 1.0)}
\]

1/ Another possibility also being explored as present, is to link the rate \( RATES(t,c,r) \) to the associated non-labor-force population figures rather than the labor force figures. While this has more conceptual clarity and would not necessarily require locality adjustments, it may lead to cumulation of error by applying an estimated coefficient to a figure derived from the application of another estimated coefficient to a product of still another coefficient estimate.
Functional Relationships

For a given locality \( r' \)

\[
\text{MSE}(t,c,r') = \text{MSE}(t-1,c,r') - \text{RATES}(t-1,c,r') \cdot \text{MOVEOUTS}(t-1,r',t-\text{lag})/100 + \sum_{r \neq r'} \text{MOVEINS}(t-1,r,t-\text{lag})/100
\]

This functional relationship states that the enrollment figure for a given course \( c \) at the beginning of a period \( t \) in locality \( r \) is what is remaining from the previous period \( t-1 \), less the associated move-outs from the course, plus all the associated move-ins from other localities.

Outputs

The outputs/reports include both stock and flow analyses of student enrollments.

2.10 Phase II Internal Specifications: Local Analyses

Allocation of Reallocated Workers

Subsequent to the global analyses on the reallocation of the leakage labor force, and the adjustments of nonlabor migrations, Phase II of each local analysis starts to allocate the reallocated manpower supplies from various localities. The rules on the allocation of the local ESM manpower supplies in accordance with a priority matrix continue to apply to the local allocation of workers reallocated by the global analyses.

Calculations of Net Local Manpower Requirements

The calculations of the net manpower requirements start, by taking into account what is available in the local labor force, both local nationals and expatriates. The mathematical descriptions of these calculations are identical to those in the manpower policy model of the country model, and therefore, will not be repeated here.
Calculations of Achievable Local Outputs

As in the manpower policy of the country model, local achievable outputs can be estimated by taking into account the existing available labor force, both local nationals and expatriates, and sectoral productivities in the locality.

The backward calculations and the mathematical specifications for these calculations are also identical to those in the manpower policy model of the country model.

Surplus Manpower Supplies

Some pools may have surplus manpower supplies after the allocation of the reallocated labor force is completed by the local analyses. In this case, two possible treatments of surplus manpower supplies can be considered:

- This surplus manpower could be considered to stay where they are and be available for allocation in the following years, either in their locality or through leakages to other localities. In this case, they could be considered to be unemployed in their locality in the year when the surplus situation occurs.

- The surplus manpower supplies could be considered to be available for reallocation, with a time lag, to other localities by the global analyses in the year the situation occurs.

The difference between these two approaches is that the latter will automatically treat the surplus as leakages, while the former will not. In the current system design for the expanded model, the first approach is utilized for its simplicity. A Bayesian approach could be considered in the future to take into account what is happening in the trend on the requirements for, and supplies of, leakage manpower.
2.11 Phase II Internal Specifications: Global Analysis

Global Achievable Outputs

Once the estimates of achievable local outputs are complete for each locality, the computation of global achievable outputs starts. It is correctly assumed that sectoral productivities are different from locality to locality; therefore, the calculations of global achievable outputs should be done by summing all local achievable outputs in the global unit.

Labor Force in a Transient State

The consideration of time lags in labor force migration implies that there are some segments of the labor force, who are willing and able to hold a job, and who are in a transient state and unemployed, due to circumstances beyond their control. In a manpower-short nation, this is detrimental to national development efforts. The information/reports about transient national labor (i.e., moving or waiting to find jobs) will be of value to decision makers in manpower planning. The expanded model is designed to keep track of this information, and to produce reports on the status of national workers still waiting for reallocation in various localities.

The expanded model also calculates the value of output lost due to a segment of the labor force being in a transient state, taking into account local productivities.

Furthermore, the expanded model produces an overview-report on global conditions of manpower supplies and requirements. Following the Phase II local analyses, complete information will be available regarding manpower supplies and requirements for each locality. If manpower surplus exists in one locality, while deficits exists in other localities, then a manpower misallocation exists. The expanded model produces a report on manpower allocation or misallocation by summarizing manpower surpluses and deficits in various localities.
Net Expatriate Manpower Requirements

Upon the completion of Phase II local analysis calculations, the net manpower shortage/surplus at each locality is known. From this, net additional requirements of expatriates are estimated. In this calculation, those in a transient state, and surplus manpower not yet allocated, should be taken into account in deriving the net additional requirements of expatriates. This is based on the reasoning that any expatriate who is allowed to work in a nation should not deprive local nationals of existing job opportunities, even though the misallocations exist.

Linear Programming Applications

The linear programming submodel in the country model is intended to be applied at the national level. Once the total national manpower shortages are known, the linear programming submodel is applied and the manpower shortage is met by filling these openings with expatriates, who are assumed to be residual and available.
Chapter 3  THE MIGRATION MODEL

3.1 Background

The basic purpose of the "migration," or international model, is to simulate labor flows between labor-exporting and labor-importing countries in a supra-national region, such as the Arab countries in the Middle East and North Africa.

The structure of the migration model allows for a choice between two mechanisms for allocating labor among the countries within the region, once individual country requirements have been determined by application of the country model.

The two alternative methods of solving the problem are a sequential one and a simultaneous one. Within the sequential solution, the penultimate step may be solved either by a series of small sequential steps or as a linear programming optimizing simultaneous solution.

On the whole, the simultaneous solution method is certainly more elegant and conceptually more satisfactory. Nevertheless, the sequential solution probably has merit, at least insofar as one can probably relate more directly with the ordinal rankings it requires than with the simultaneous solutions parameters, although the latter have more interpretive policy meaning. In the final analysis, both methods should be developed, letting actual usage be the testing ground for the empirical superiority of one method over the other.
3.2 Sequential Solution Procedure

Framework

The simulation is designed to consider a region of countries and determine the pattern of migration of laborers resulting from imbalance in labor supplies and demands among the countries. Each country has labor requirements (divided into sectors and occupations) determined from user-specified data covering target outputs, productivities, growth, etc. Labor availability is determined for each country from user-supplied information about the educational system, existing labor stocks, attrition, sector/occupation distribution, etc., in conjunction with carryover information from the previous simulation year.

The simulation combines information about labor supplies and demands in the regional countries with user-specified data ranking attractiveness of countries to laborers, restrictions imposed by countries on nonnational participation in their labor forces, etc. From these, a pattern of labor allocation is determined. It includes both local allocation of each national labor force and migration of nationals to other countries. Remaining deficiencies in labor supplies are assumed to be filled by expatriates from an undivided source called "the rest of the world."

Steps

The following sequence of events occur in the annual cycling of the international migration simulation:
Initial Local Phase I (For each country)

- Compute attrition (attrition of local nationals assumes that they are lost to the labor force forever; attrition of nonnationals assumes that they return to their country of origin).
- Simulate the education system for nationals (ESM). Nonnationals are not included in the education computations. There is no movement of children into or out of the educational system associated with migration (not numerically significant in terms of their entry into the labor force).
- Compute labor requirements based on the information input about sector outputs, productivities, growth rates, etc.

Global Interaction Phase 1

Increase the net labor available in each country to account for the returning nationals who left other countries by attrition. (Note: There may be some merit to introducing a time lag before these returnees are available for work again.)

Local Phase II (For each country)

- Compute the net labor availability by pool, including the attrition return of nationals previously working in other countries.
- Allocate available nationals to fill local needs as much as possible.
- Determine surplus nationals available for export.
- Determine allocated nationals not subject to export according to user-supplied tolerance levels.
- Determine remaining allocated nationals available for export, if surplus laborers are insufficient to meet the needs of importing countries.

(Note: There could also be a time lag here.)

Global Interaction Phase II

Compute the labor migration pattern: In order to provide for flexibility in determining migration patterns, movements are determined for single pool levels or groups of pool levels. Groups are processed independently and in an order specified by the user.

For each pool group processed, the allocation mechanism will permit one to specify a priority of importing countries. Migration will be determined to satisfy the requirements of a higher priority country before a lower priority country's needs are considered. Countries not specified are considered to be labor-exporting countries for the pool.

Migration into any country will be subject to user-specified restrictions on expatriate representation in that country. These restrictions, which may vary from country to country, may be general (e.g., no more than 40% nonnational laborers in the work force) or very specific (e.g., no more than 15% of laborers in technical occupations in the oil sector are to be from a given country).
When attempting to import laborers to fill the requirements of an importing country, the first source of workers will be those who are surplus nationals in exporting countries (with a time lag considered). If these are insufficient to fill the needs of an importing country, there will be an attempt to seek workers from the nonsurplus labor forces of labor-exporting countries. This stealing of workers will be limited to the user-specified tolerance levels for each labor-exporting country.

There are various possibilities for undertaking the next step in the sequence: the determination to fulfill a pool group need in an importing country. Two possibilities are advanced: a sequential method and a linear programming method.

The sequential method would require the user to specify a ranking of exporting countries that may supply a designated importing country. The surplus nationals in those exporting countries would be chosen for importation according to the ranking designated, subject to the expatriate constraints imposed by the importing country. The method would require a sector/occupation cell-by-cell determination of needs, restrictions, and availabilities of imported laborers. The sequential nature of this method would not ensure an optimal allocation of imported workers. That is, a choice of importation to one cell may, because of expatriate restrictions, unnecessarily restrict importation possibilities for later cells.
The alternative, but more costly approach in terms of computer time is to use a linear programming allocation mechanism. With this method, the needs of an importing country, the supplies available from exporting countries, and the expatriate participation constraints are considered simultaneously.

**Final Local Phase III (For each country)**

- Revise the available labor figures to reflect migration in and/or out according to the pattern computed in the global interaction phase.
- Compute labor surplus or shortages.
- Compute achievable output.
- Compute residual requirements to be filled with expatriates from outside the countries simulated.
- Import these expatriates to fill the labor requirements of the country.
- Compute the final labor force breakdown.

Note that, in addition to these steps, the system will compute the general population figures in each country, by nationality and by age-group (where possible), adjusting these figures for passage of time (aging, births, and deaths), as well as for migration (attrition and importation/exportation).
3.3 Conditions of Excess Supply or Demand

This section describes two methods of expatriate manpower allocations under two different manpower supply conditions (defined as available for exportation) within the Region under study:

(A) When the demand of a group of labor importing countries for a given exporting country is less than or equal to the supply of the exporting country for a given pool; or

(B) When the demand of a group of labor importing countries exceeds the supply of a given labor exporting country for a given pool.

Condition A—Excess Supply

In the case of excess supply (or supply equals demand), the labor importing countries could use special program cards, which prescribe the desired expatriate distribution at the end of a given year, to allocate the labor supply of a given exporting country for a given pool. Any remaining unallocated labor supply will be assumed as "not exported".

To further facilitate the use of these special cards for target control, the International Migration Model will provide a linear interpolation capability between the base year and the target year. The use of this capability will prescribe a linear step course of actions from the base year through the target year in order to achieve the desired target distribution.
interpolation capability between the base year and the target year. The use of this capability will prescribe a linear step course of actions from the base year through the target year in order to achieve the desired target distribution.

**Condition B - Deficit Supply**

If the combined importing countries' demands for a given exporting country in a given pool exceed what this exporting country can supply, then the deficit supply Condition (B) exists for this particular exporting country and, in order to make up the shortages, the supplies from other exporting countries for the similar pool will have to be increased, if an excess supply condition exists in the other exporting countries. What follows is a proposed allocation mechanism to handle the deficit supply condition.

**Step 1**

For a given labor exporting country n in a given occupation pool j, because the supply V is less than the total demand W, the actual allocation Net X to a given labor importing country i for this pool will be reduced to:

\[
Net \ X(i, j, n) = W(i, j, n) \cdot \frac{V(j, n)}{\sum_i W(i, j, n)}
\]

While the Shortage K (i, j, n) will be
\[ K(i,j,n) = W(i,j,n) - Net X(i,j,n) \]

**Step 2**

For the sake of discussion, let \( S(j,n) \) designate excess supply or surplus of exporting country \( n \) and pool \( j \), then the actual allocation \( Net X(i,j,n) \) for the desired demand \( W(i,j,n) \) will be met from the supply \( V(j,n) \), and the excess supply \( S(j,n) \) will be

\[
S(j,n) = V(j,n) - \sum_{i} W(i,j,n)
\]

The above two steps will be applied to all \( i,n \), and \( V \) while the shortage \( K(i,j,n) \) will be made up from Excess Supply \( S(j,n) \) in accordance with the following steps.

**Step 3**

For a given labor importing country \( i \), rank the expatriate target distributions for exporting countries that are in the set \( S(j,n) \) \( (i.e., \) countries with excess supply of pool \( j \) \) in an increasing order.

Let \( U(n) \)

be the rank set of expatriate target distributions of exporting countries which has the following relationship:
U(1) < U(2) < U(3)

To fill up the shortage in the given importing country i, the expatriate S(1) will be allocated first, then S(2), then S(3), etc. However, the number of additional expatriates to be reallocated depends on U(n) in accordance with the following ranges:

- for 0 < U(n) ≤ d(1), use x(1)%
- for d(1) < U(n) ≤ d(2), use x(2)%
- for d(n) < U(n) < 1, use x(m)%

Where d(m) < 1.0 and x(m) are input data supplied by users of the Migration Model; and

Where x(m) could be considered as overage allowed over and above target distribution.

Step 4

The application of Step 3 could result in two consequences:

Consequence 1

There exists enough supply of S(n) to meet the combined additional allocation in accordance with Step 3 calculations;
Consequence 2

There does not exist enough supply of $S(n)$ to meet the combined additional allocation in accordance with Step 3 calculations. In this case, whatever available supply from $S(n)$ will be proportionally allocated to importing countries using the following weight

$$\frac{\text{Excess Supply } S(j,n)}{\text{total additional demand} \sum_{i} K(i,j,n)}$$

Although shortages will continue to exist, the reallocation process will be terminated and the rest of the shortages will be made up with the labor force from the rest of the world.
The general procedure discussed in this section draws on a more general theory of movements or transitions. This procedure has four main advantages. First, it is based on a very general approach and, therefore, in spite of its apparent complexity, makes a minimum of arbitrary assumptions. Second, it makes full use of the information now being gathered by the World Bank on current distribution of the labor force and future plans or forecasts of the demand and supply of labor. Third, it yields certain values that can be interpreted and may assist in the diagnosis of the situation. Fourth, it permits judgmental modification of certain parameters to incorporate knowledge of expectations not included in the data on which the model is calibrated, or to reflect policy preferences.

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1/ This method was developed by Prof. William Alonso of Harvard University and refined/adapted in discussions with Bob Li and I. Serageldin of the TASS Division.

The procedure suggested here could be called "systemic" because it simultaneously considers both the composition and the interrelation of the national demands and supplies of labor. Therefore, it is more stable than the sequential allocation approach that has been discussed earlier. By comparison to the optimizing (e.g. linear programming) approach, the systemic approach is more behavioral; it does not include the dubious task of choosing an appropriate objective function. However, the systemic approach may conceivably be combined with an optimizing procedure for certain purposes.

**Data Needed to Run the Model**

The World Bank is currently engaged in generating data that will provide an inventory of (the region's) labor by country, by nationality, by industry, and by occupation (or pool). This amounts to a vast matrix of nationality and pool by nation, industry, and pool. Although data difficulties will result in some aggregation of some of these categories, this presents no intrinsic difficult for the systemic approach.

Whereas the model is calibrated on the matrix of the present distribution of labor, its principal use is to generate a distribution of labor at some future date that is consistent with the supply of pools of labor of various nationalities and with the demand for various types of labor by various sectors in the various countries.
General Structure Behind the Model

Since it is assumed that there is no significant occupational mobility among pools, each pool of labor may be treated independently. If categories in the large matrix are appropriately grouped, each pool of labor will constitute a submatrix along the major diagonal of the large matrix, the rest of which consists of zeros. Therefore, it is convenient to deal with the submatrices independently.

The majority of the pools—with the possible exception of that of the least skilled labor—are expected to be in a condition of regional labor shortage, meaning that the region will have to import labor from the rest of the world. Therefore, the discussions that follow will be concerned with the approach for pools in which there is a regional labor shortage. The approach for pools in which there's a regional labor surplus is slightly different and will be presented later in this section.

For a given pool, then, let:

\[ V(n) = \text{the supply (number of nationals from country } n \text{ in the region, regardless of what country they are in). For the current period for which data are being gathered it is the marginal sum of a row in the Matrix. For planning or forecasting, it is generated by other elements of the compound model, exogenous to the allocation model presented here.} \]

\[ V(F=1) = \text{a dummy slack variable for workers from the rest of the world} \]
W(i) the demand (number) for workers in sector i or in country i, regardless of nationality. For the present period, it is the column sum for that sector or country, including workers from the rest of the world. For planning or projection, the figure is produced by the World Bank staff exogenously to this allocation model. For ease of exposition, i stands both for sector and nation. Note that for a given occupation pool (j), W(i) = TLF (t,i,j) in the country model.

M(n,i) = the number of workers of nationality n in country i (sector i).

M(f,i) = number of workers from the rest of the world in country i (sector i).

The following functional relationships are utilized:

\[ V(n) = \sum_{i} M(n,i) \]
where: n\(\neq\)F

\[ W(i) = \sum_{n} M(n,i) = (NLF(i) + XLF(i)) \]

\[ \sum_{i} M(F,i) = \sum_{i} W(i) - \sum_{n} V(n) \]
where n \(\neq\) F

Thus, for the relevant pool: (a) Equation (6.1) says that labor from country n is the sum of its workers regardless of where they are working;
(b) equation (6.2) says that the effective demand at country i (sector i) is defined as the total number of national and nonnational workers present, regardless of origin; and (c) equation (6.3) says that, for a pool in labor deficit in the region (i.e., $\sum V < \sum W$), the rest of the world will make up the deficit.

This is based on several assumptions, of course, principally that, for dates in the future, (a) the national supply pools can be forecast (or planned), (b) the various national demands can be forecast or planned and will be met, (c) the supply and demand of the regional labor pool are sufficiently integrated that it has first crack at clearing the market, and (d) the rest of the world stands ready to meet any regional deficits, no less and no more. These appear to be workable assumptions, but at some future time one may want to modify them to make the model more useful or relevant.

$z(n,i) = \text{a numerical statement of the accessibility of } i \text{ (country, sector) by nationals of a given country } (p). \text{ Note that this is within a given labor pool. It may be thought of in many ways: as the ease of movement, as the attractiveness of wage differences, or as cultural compatibility. Although this variable is conceptually crucial to the model, it will not be present as such in the operational model and will only be estimated inferentially to a proportion. Therefore, the important thing at this time is to grasp that } z(n, i) \text{ is a measure of transitivity. It may be helpful to think of } z(n, i) = x_{pref(n, i)} \cdot i_{pref(n, i)}, \text{ where } x_{pref(n, i)} \text{ is the}
preference of workers of origin n for nation i (sector i), and
ipref is the preference of the host nation i (sector i) for
nationals from n. Obviously, if either forbids the other
xpref(n, i) or ipref(n, i) = 0), then z(n, i) = 0, and as will
be seen below, no interaction takes place. While banning is a
simple extreme form, it is likely that much of the policy
interest will lie in less drastic increases or decreases of
the estimated z's (z's), which will be discussed below.

z(F, i): The accessibility from the rest of the world to country-sector i
is defined as unity.

The basic interaction equation is a flow of M workers from n to i
proportionate to the product of supply at n and demand at i, with
the flow screened by accessibility z(n, i):

\[ M(n, i) = \frac{V(n) \cdot W(i) \cdot z(n, i)}{D(n) \cdot C(i)} \]

where \( D(i) \) and \( C(i) \) are defined as follows:

\[ D(n) = \sum_{i \in C(i)} W(i) \cdot z(n, i) \]

\[ C(i) = \sum_{n \in D(n)} V(n) \cdot z(n, i) + 1 \]
For workers from the rest of the world \((n = F)\), the equivalent equations are:

\[
(3.4a) \quad M(F, i) = \frac{W(i)}{C(i)} \cdot z(F, i) = \frac{W(i)}{C(i)}
\]

\[
(3.5a) \quad D(F) = \sum_{i} \frac{W(i)}{C(i)} \cdot z(F, i) = \sum_{i} \frac{W(i)}{C(i)}
\]

**Interpretation of the Equations**

Equation (3.4) corresponds, in the general model, to the case \(X(n) = Y(i) = 0\). That is to say that we regard equations (3.1) and (3.2) as constraints. Or that all of the workers available in a pool must be placed in jobs within the region (remember that we are limiting this to pools in regional labor deficit), and all of the jobs within the region must be filled. These two constraints ensure that the labor deficit will be met exactly by workers from the rest of the world, which amounts to equation (3.3). Accordingly, equations (3.4a) and (3.5a) are predicated on \(X(F) = 1\), \(V(F) = 1\), \(z(F, i) = 1\), which ensures that the number of workers from the rest of the world will respond exactly to the regional deficit.

A brief interpretation of the equations follows:

Accept intuitively that \(C(i)\) is the potential supply of workers per job opening at \(i\).
Then $D(i)$ may be interpreted as a measure of the job opportunities per worker at $i$, and the right hand side of equation (3.5) may be read as the sum total of job openings in the region, weighted inversely by the respective potential workers (i.e., by the chance of getting that job) and weighted positively by their accessibility to workers from $n$. Conversely, $C(i)$ may now be interpreted, in the right hand side of equation (3.6), as the sum total of workers in the region, each weighted inversely by the alternative opportunities available to that worker (i.e., the chance of getting him) and positively by his accessibility to the job at $i$.

Note that this is followed by the addition of unity: this represents the potential contribution of the rest of the world to the supply of workers per job at $i$. This follows mathematically from the parameters we are using for $F$, but it can be easily grasped intuitively that, if we are saying that any unfilled job will be filled by workers from the rest of the world, their potential contribution to any job is one.

According to equation (3.4) then, the number of workers from $n$ at $i$ will be proportional to the number of workers in the pool from $n$, weighted inversely by the per-worker sum total of opportunities in the region (i.e., the chance of getting each worker), times the number of openings in $i$, weighted inversely by the potential number of workers per opening (i.e., the chance of getting that job), and this product weighted by the mutual attraction of $n$ and $i$, or the accessibility of $i$ from $n$. 

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Equations (3.4), (3.5) and (3.6) make evident another interpretation of \( z(n, i) \): it is the spatially discounted value of a unit.

In spite of its complicated appearance, the \( M(n, i) \) of equation (3.4) and (3.4a), if summed over \( n \), will indeed reduce to \( W(i) \) and will reduce to \( V(n) \) if summed over \( i \), as required in equations (3.1) and (3.2).

**Calibration of the Model**

The inventory of labor force being carried out by the World Bank will be a matrix of \( M(n, i) \) and, by definition, the row marginals will be \( V(n) \) and the column marginals \( W(i) \).

The one primary variable that cannot be observed directly is the \( z(n,i) \) matrix. (\( D(n) \) and \( C(n) \) are variables derived from the others). Therefore it is necessary to estimate it. If we have an estimated \( \hat{z}(n,i) \) matrix for any projected set of \( V \)'s and \( W \)'s, we can forecast the \( M \) matrix, with the usual assumption that the relations \( z \) are unchanged from one period to the next.

From our estimates of \( \hat{z} \), and the projections of \( V \) and \( W \), we will then compute \( \hat{C} \) and \( \hat{D} \). We will then be in a position to estimate \( \hat{M} \).

At this point the notation will be modified slightly by leaving out \( (n) \) and \( (i) \) except in cases of ambiguity. A \( (0) \) or \( (T) \) will denote the date of the variable, where \( (0) \) refers to the calibration date and \( (T) \) to the projection date to be used.
Thus:

\[ V(O), W(O), M(O), \text{etc.: actual supply of workers from } n V(n), \text{ demand for workers at } i W(i), \text{ workers from } n \text{ at } i M(n, i), \text{ etc., at the calibration date } (0). \]

\[ z(O), D(O), C(O), M(O): \text{ estimated transitivity, } z(n, i), \text{ regional demand } D(n), \text{ regional supply } C(i), \text{ and workers from } n \text{ at } i M(n, i). \]

\[ D(T), C(T), V(T), W(T), M(T), z(T): \text{ the equivalent variables at date of projection } (T). \]

\[ k: \text{ an arbitrary constant that can conveniently be set at } W. \]

We now estimate \( z(0) \) from observed variables:

\[ (3.7) \quad \hat{z}(0) = \frac{M(0) k}{V(0) W(0)} \]

This is equivalent to estimating \( \hat{z}(0) \) as the ratio of the observed \( M(0) \) to that which might be expected by double proportionality to the row and column marginals. It is closely related to the logic of the contingency table (and related also to maximum likelihood estimates). If the constant \( k \) is set at \( \sum \Sigma M(0) = \sum W(0) \), the relation to these standard approaches becomes obvious.

It also becomes clear why it is convenient to set \( k = \sum W(0) \): because it centers the resulting values of \( \hat{z}(0) \) on unity. But it does not matter what value is used for \( k \): the mathematics of this systemic
approach guarantee that \( \hat{z}, \hat{D}, \hat{C} \) will adjust proportionately to give the same result.

In addition, readers with a background in applied economics will recognize the parallels of the approach suggested here to the RAS method of updating input-output tables on the basis of incomplete information as developed by Leontief, Stone, Bacharach, and most recently by Fisch and Gordon. Similarly, readers with a background in traffic modeling will recognize the similarities to the entropy approach of A. Wilson and his associates. Those with a background in sociology will find distinct echoes from the current lively investigation of intergenerational occupational mobility.

In brief, then, the approach presented here is closely related operationally to these various approaches to the estimation of a transitivity operator. The essence of the differences lies in the pattern of available data and unknowns in the various problems at hand and in the implicit assumptions in the various literature as to theoretical values of the transitivity coefficients \( X(n) \) and \( Y(i) \).

Aspects of the Estimating Process:

It is necessary to make one point strongly: \( z(0) \) is not strictly an estimate of \( z \). By joining equations \( (3.4) \) and \( (3.7) \), we have.
Thus, \( \hat{z}(0) \) is not strictly an estimate of \( z \), but rather of \( k \). The distinction makes no operational difference for estimation, but is important for interpretation.

We would next compute \( \hat{C}(0) \), and \( \hat{D}(0) \) using \( W(0), V(0), \hat{z}(0) \):

\[
(3.9) \quad \hat{D}(0) = \sum_{n \in F} W(0) \hat{z}(0) / \hat{C}(0)
\]

\[
(3.10) \quad \hat{C}(0) = \sum_{n \in F} V(0) \hat{z}(0) + 1.
\]

We can do this by setting \( \hat{C}(0) \)'s at an arbitrary value, estimating \( \hat{D}(0) \)'s using this value, reestimating \( \hat{C}(0) \)'s and continuing to iterate until they converge. From some numerical experiments, they should converge at about the rate of one significant digit per dozen iterations; that is to say, they should converge quickly. The solution is unique.

Without attempting a full proof here, the following will be true:
- all $D(O)'s$ will be equal to $k$ (except for $\hat{D}(F)$, which will be equal to $\sum W - \sum V$), and all $C(O)'s$ will be equal to 1.

- $\hat{C}(O)\hat{D}(O) = k$. (This derives, by substituting equation (3.8) into equation (3.9) or (3.10).

- $\hat{M} = M$, within the limits of round-off error; in other words, the estimation is exact for the calibration period. This can be seen by joining equations (3.4) and (3.8) and $\hat{C}(O)\hat{D}(O) = k$.

- although $\hat{z}(O)$ is an estimate of $(z/C(O)D(O))$ rather than of $\hat{z}$, it will be highly correlated with $z$ except under perverse conditions; therefore, for practical purposes, in policy or alternative scenario uses of the model, proportional changes in $\hat{z}(O)$ can be considered as proportional changes in $\hat{z}$.

- $\hat{C}(O)$ and $\hat{D}(O)$ have no interpretive or diagnostic use. They appear to be balancing accounting factors in the model. However, as will be seen below, $\hat{C}(T)$ and $\hat{D}(T)$ do have interpretive meaning. For the rest of the world, the relevant equations are (retaining $V(O,F) = 1$):

(3.11) $\hat{z}(0,F,i) = \frac{kM(F,i)}{W(T)}$
Projection of the Model

We will now consider the use of this systemic allocation model for projection without policy intervention. This amounts to accepting a set of projected $V(T)$, $W(T)$, and an unchanging matrix of $z$ for which the matrix of $\hat{z}(0)$ is substituted.

We then generate $\hat{M}(T)$ for countries within the region \(n \notin F\), by analogy to equations (3.4), (3.5), and (3.6).
\[ (3.14) \quad \hat{M}(T) = \frac{V(T) W(T) z(O)}{C(T) D(T)} \quad n \neq F \]

where (3.15) \[ \hat{D}(T) = \frac{W(T) z(O)}{C(T)} \quad n \neq F \]

\[ (3.16) \quad \hat{C}(T) = \frac{V(T)}{D(T)} \hat{z}(O) + \hat{z}(T,F,i) \quad n \neq F \]

There is no known analytic solution for finding \( \hat{C}(T) \) and \( \hat{D}(T) \) simultaneously. Therefore, the solution procedure is to assume an arbitrary set of values for \( \hat{C}(T) \), derived from these estimates of \( \hat{D}(T) \), use these to recalculate \( \hat{C}(T) \), and continue iteratively until convergence to the derived number of significant digits.

The relation of equations (3.14), (3.15), and (3.16) apply to the situation of labor for nationals within the region. For the rest of the world, we still assume \( X(F) = 1, V(F) = 1 \); therefore, by analogy to equations (3.4a), (3.5a):

\[ (3.17) \quad \hat{M}(T,F,i) = \frac{W(T)}{C(T)} \hat{z}(F,i) \]

\[ (3.18) \quad \hat{D}(F,T) = \sum_{i} M(T,F,i) = \sum_{i} \frac{W(T,i)}{C(T,i)} \hat{z}(F,i) \]
\(C(F)\) is undefined within the model, since by assumption there is no rest-of-the-world destination. (Note: This has not always been the case since World War II; witness the brain-drain of many technical specialists out of developing and into developed countries. But, by assumption, this does not occur here.)

**Summary of the Projection Procedure**

Having obtained the \(M(0)\) matrix, which the World Bank is doing,

\[
\begin{align*}
\hat{z}(O) &= \frac{k \cdot M(O)}{\sum_{n} M(O) \sum_{i} M(O)} \\
\hat{z}(O,F,i) &= \frac{k \cdot M(O,F,i)}{\sum_{n} M(O,n,i)}
\end{align*}
\]

Having obtained a set of \(V(T), W(T)\) from national plan and projection, determine that this is a pool in labor deficit by \((\sum W(T) - \sum V(T)) < 0\); estimate by interaction until they converge:

\[
D(T) = \frac{W(T)}{C(T)} \hat{z}(0); \quad D(T,F) = \sum W(T) \hat{z}(0,F); \text{ and } C(T) = \sum_{n} V(T) \hat{z}(0) + z(0,F,1)
\]
using $\hat{z}(0)$, $\hat{D}(T)$, $\hat{C}(T)$, $V(T)$, $W(T)$ estimate

$$\hat{M}(T) = \frac{V(T)}{C(T)} W(T) \hat{z}(0),$$
and

$$\hat{M}(T,F,i) = \frac{W(T)}{C(T)} \hat{z}(0,F,i).$$

The Relation of $\hat{M}(T)$ to $M(T)$, $\hat{z}(0)$ to $Z$, $\hat{D}(T)$ to $D(T)$, $\hat{C}(T)$ to $C(T)$

$\hat{M}(T)$ will be the exact estimate of $M(T)$ if the structural relations of labor exchange within the region are unchanged from date 0 to date $T$. The reason is as follows:

If we knew true $\hat{z}$'s, then we could calculate equation (3.19) rather than equation (3.14).

$$(3.19) \quad M(T) = \frac{V(T) W(T)}{C(T) D(T)} z$$

Substituting the relation noted on equation (3.8), $\hat{z} = \frac{kz}{n + F}$, into equation (3.14).
Clearly, then, from this equation, the approximation of \( M(T) \) by \( \hat{M}(T) \) will be exact if 

\[
\frac{1}{k} \frac{C(T)D(T)C(0)D(0)}{C(T)D(T)} = C(T)D(T).
\]

Although there is no strong proof that this is the case, it is consistent with numerical experiments and with the mathematical structure of the model.

What happens is that the individual \( \hat{C}(T) \) and \( \hat{D}(T) \) are differentiated by the structure of the model to make this approximation of \( M(T) \) by \( \hat{M}(T) \) exact, or nearly so.

Since \( k \) is an arbitrary constant, set it for the moment at 1. Then

\[
\frac{\hat{C}(T)D(0)}{\hat{D}(T)D(0)} = C(T)D(T),
\]

and, a strong conjecture can be made that

\[
\begin{align*}
\hat{C}(T) & = C(T) \\
\hat{D}(T) & = D(T)
\end{align*}
\]

That is to say, the estimation procedure produces a set of \( \hat{C} \) and \( \hat{D} \) such that they translate the corresponding \( C(0) \) and \( D(0) \) into the correct \( C(T) \) and \( D(T) \).
From equations (3.21) and (3.22) it follows that, although we cannot know directly the true values of \( C \) and \( D \) at either date, we can know how they are changing. Rewrite the last two equations as:

\[
(3.21a) \quad \hat{C}(T) = \frac{C(T)}{C(O)}
\]

\[
(3.22a) \quad \hat{D}(T) = \frac{D(T)}{D(O)}
\]

Similarly, if we define \( Y^* \) as the ratio of an earlier to a later value for that variable (i.e., \( Y^* = Y(O)/Y(T) \)) then the prior combinations of equations yield.

\[
(3.23) \quad \hat{M}(T) = k \frac{V^*W^*M(O)}{\hat{C}(T)\hat{D}(T)}
\]

\[
(3.24) \quad M^* = \frac{V^*W^*}{\hat{C}(T)\hat{D}(T)}
\]

That is to say, \( \hat{C}(T) \) and \( \hat{D}(T) \), in accordance with equations (3.21a) and (3.22a), modify the relevant marginal changes in \( V \) and \( W \) (i.e., \( V^* \) and \( W^* \)), to update the \( M(O) \) observed earlier to the current \( \hat{M}(T) \).
Therefore, knowing $\hat{C}(T)$, we can tell by how much the supply of labor (true $C$) has changed from date 0 to date $T$ for a given destination. Similarly, knowing $\hat{D}(T)$ we would know how the demand (true $D$) has changed for a pool of workers of a given nationality.

Since industry prefers to have as plentiful a supply as possible, and workers as many opportunities as possible, $\hat{C}$ and $\hat{D}$ are useful indicators of whether the situation is improving or deteriorating for particular industries or groups of workers. They provide a means of evaluating alternative projections or policy scenarios. They also suggest a very interesting optimizing approach that will be discussed in the last part of this section.

There is, as yet, no analytic proof of the relations of equations (3.21a) and (3.22a). But extensive numerical analysis yields this result, and algebraic analysis shows, through various paths, its consistency with the structure of the model. While a strict proof is still wanting, we can proceed with confidence, on both the basis of the analysis and numerical experimentation done for this project, and the related techniques mentioned earlier in this paper.

Procedure for Pools in Regional Labor Surplus

If $\sum V > \sum W$, this pool is in regional labor surplus. The suggested procedure is parallel to that for the workers from the rest of the world.
We assume that countries for which a national labor surplus is projected (i.e., $V(T,i) > W(T,i)$) will retain those workers who cannot find work at home or abroad. In other words, we assume that countries do not export their unemployment.

For this purpose we add to the set of $W(T)$'s a set of $W(T,u,i)$, one for each country $i$ with surplus labor. And we assign the following values:

$W(u,i) = 1;$
$Y(u,i) = 1;$

$\hat{z}(n,u,i) = \frac{kM(0,n,u,i)}{V(0,n)}$ for countries in labor surplus in this pool;

$\hat{z}(n,u,i) = 0$ for countries in labor deficit in this pool;

$\hat{z}(i,u,n) = 0, i \neq n$ that is, unemployment is not exported;

$M(0,n,u,i) =$ observed unemployed (in that pool) in country $i$ in period 0.

This procedure will ensure that $\hat{M}(T,n,u,i)$ will be the total unemployed in that pool in that country in period $T$, and that:

(a) $\sum_j M(T,n,i) = W(T,n)$, that is, that all members of that country's pool are accounted for; and
(b) $\sum_{i} H(T,n,i) = V(T,n)$, that is, that the demand for the labor in that country is met. Note that it is possible that, if some $Z(i,n)$ are nonzero, there will be some workers from other countries in the region working in country $i$ in spite of its unemployment. This may be quite realistic. But if one wants to prevent this, one only has set all $Z(n,i)$ at zero for $i \neq n$.

The equations to be used to operate the labor surplus case are:

(3.25) $\hat{Z}(n,i) = \frac{M(O,n,i)}{V(O,n) W(O,i)}$

(3.26) $\hat{M}(T,n,i) = V(T,n) W(T,i) \cdot \hat{Z}(n,i), i \neq (u,n)$

(3.27) $\hat{D}(T,i) = \sum_{i} \frac{W(T,i)}{C(T,i)} \cdot \hat{Z}(n,i) + \hat{Z}(i,u,n)$

(3.28) $\hat{C}(T,i) = \sum_{n} \frac{V(T,n)}{D(T,n)} \cdot \hat{Z}(n,i)$
The procedure, then, is exactly as in the case of labor deficit. First, determine that $\sum V > \sum W$. Then calculate $\hat{z}$'s from the $M(0)$ matrix. Then, by iteration, estimate $\hat{C}(T)$'s and $\hat{D}(T)$'s. Use $\hat{z}, \hat{C}(T), \hat{D}(T), V(T),$ and $W(T)$ to estimate the $\hat{M}(T)$'s.

Note the further symmetry with the labor deficit case: instead of having a slack-variable rest-of-the-world origin, we have a slack-variable national destination for each country; instead of a " + $\hat{z}(F, i)$" at the tail end of the definition of $\hat{C}$, we have " + $\hat{z}(n, u, i)$" accordingly at the tail end of $D$; and whereas in the case of labor deficit we could specify $\hat{D}$ but not $\hat{C}$ for the slack variable, in the case of labor surplus we can specify $\hat{C}$ but not $\hat{D}$.

Remember, of course, that there is no "rest of the world" in the case of regional labor surplus. It is assumed that nationals of the region will have first call on the labor deficits that may exist in some of the region's countries, even though the region as a whole is in surplus. It may be possible to construct a procedure that includes both slack variables
for supply of labor by the rest of the world and for the absorption of unemployment in labor-surplus countries. However, this possibility is still to be explored. The resulting system would be very complex, and considerable analytic and numerical exploration would probably be needed before its properties could be fully understood.

Regions that Change between Surplus and Deficit

Whether in the case of regional labor surplus or deficit, the procedures outlines above presume that an observed inflow/outflow in the base period provides the basis for the estimation of transitoriness in the later period. As long as there has been a migrant flow in the direction of interest, \( z \) can be estimated.

But consider a case where, for a given pool, a country goes from deficit to surplus, or vice versa, from the base to the projection period. Then there is no base-period migration flow in or out of the country on the basis of which that particular \( z \) may be estimated. Yet, if the situation changes in the nation from deficit to surplus, or vice versa, some new flow will arise for which there is no prior experience on which to calibrate \( \hat{z} \). Such cases will probably be rare. Where they occur, best results can probably be obtained if the relevant \( \hat{z} \) is made equal to the average of the observed \( \hat{z} \)'s (i.e., \( \hat{z}(F,i)'s \), or \( \hat{z}(n,u,i) \)).
Aggregation, Collapsing Categories, and Data Efficiencies

The proposed procedure is perfectly tolerant of aggregation or disaggregation of classes of origin, or destination. For instance, if several industries in a country are aggregated into \( W(y) = W(i,1) + W(i,2) \ldots \), then \( \hat{z}(n,y) = \frac{M(n,y)}{V(n) W(y)} \) for all \( i,1; i,2; \) etc., instead of \( V(n) W(y) \).

\[ \hat{z}(n,i,1) = \frac{M(n,i,1)}{V(n) W(i,1)} \text{ etc. Clearly, } \hat{z}(n,y) \text{ will be an average value of the } \frac{M(n,i,1)}{V(n) W(i,1)} \text{'s:} \]

\[ \frac{z(n,y)}{V(n) W(y)} = \frac{M(n,i,1)}{V(n) W(y)} + \frac{M(n,i,2)}{V(n) W(y)} + \ldots \]

A similar process involves aggregations of origins, as might occur if several small countries of origin are grouped as suppliers of a certain type of labor.

The advantage of this is that, where the data are sketchy or aggregated, they can still be used in the general framework. If later or more detailed data become available, or one wishes to disaggregate into more detail (by whatever combination of data, assumptions, or policy), it can be done locally, without reestimating the whole model.

The same applies in the other direction, of course if, for any reason, some of the distinctions among categories of destination or origin are uninteresting, the model may be collapsed accordingly.
Policy Uses

Thus far, procedures described amount to using the model for projection, perhaps under alternative assumptions as to \( V(T) \) and \( W(T) \). But clearly an important use of the model is for policy simulation. Three principal approaches come to mind: modifying \( z' \)'s, limiting \( M' \)'s or optimization.

\(^\wedge\)

Modifying \( z' \)'s

In the first case, imagine that a certain \( \hat{z}(n,i) \) is regarded as too low by the host country \( i \), which would like to fill more of its labor needs with nationals from \( n \). Country \( i \) tries to increase labor from \( n \) by a variety of devices: propaganda, direct recruitment, facilitation of visas and work permits, special facilities such as housing, wage supplements, family permits and family allowances, etc. In so doing, it would be trying to raise the value of \( \hat{z}(n,i) \). There is no clear procedure by which one could assign a given increase (or decrease) to \( \hat{z}(n,i) \) associated with a particular package of inducements (or restraints) to labor migrants from \( n \) to \( i \). Therefore, the increase (or decrease) attributed to \( \hat{z}(n,i) \) must be a matter of judgment: one might say that the policies have made it 60% easier (or 50% harder) to go from \( n \) to \( i \), and therefore multiply the original \( \hat{z}(n,i) \) by 1.6 (or by .5).

Conversely, a labor supplying country \( n \) may alter its preferences, for whatever reasons, as to the destination of its nationals, and attempt to change the \( \hat{z}(n,i) \)'s by one or another means: visas, propaganda, placement
programs, etc. Again, it would be a matter of judgment as to the proportion by which the $z(n,i)$'s would be changed.

Recall the early section of this description in which $\hat{z}(n,i)$ was imagined to be the product of $x_{pref}(i,n)$ and $i_{pref}(i,n)$ where $x_{pref}(i,n)$ was the preference or affinity of origin $n$ for destination $i$, and $i_{pref}(i,n)$ was the preference or affinity of destination $i$ for origin $n$.

Clearly, we cannot measure $x_{pref}(i,n)$ or $i_{pref}(i,n)$ directly; in fact, we cannot measure $\hat{z}(n,i)$, but only estimate $\hat{z}(n,i)$. But, conceptually, a policy-induced increase of 50% in $i_{pref}(i,n)$ would increase its value by a factor of 1.5, and would increase $z(n,i)$ by the same amount. Similarly, a 30% increase (decrease) in $x_{pref}(i,n)$ would result in an increase by a factor of 1.3 (a decrease by a factor of .7) in $z(n,i)$. Simultaneously, changes in $x_{pref}(i,n)$ and $i_{pref}(i,n)$ would result in changes in $z(n,i)$ proportional to the factor changes in $x_{pref}(i,n)$ and $i_{pref}(i,n)$.

In the extreme case, where $i$ bans workers from $n$, or where $n$ forbids its workers to go to $i$, we have that $x_{pref}(i,n) = 0$ or $i_{pref}(i,n) = 0$, and in either case $z(n,i) = 0$. This case, although extreme, it not unknown in the Middle East.

But, of course, $z(n,i)$ cannot be measured directly. One can only estimate $\hat{z} = MVW/\hat{z} = zkw/CD$. But $\hat{z}$ is highly correlated to $z$, and, so, proportional changes in $z$ will result in approximate proportional changes in $\hat{z}$.

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Therefore, if judgmental proportional changes are apportioned to \( x_{\text{pref}}(i,n) \) or \( i_{\text{pref}}(i,n) \), \( \hat{z}(n,i) \) should be changed by the product of these changes.

These changes may originate in origin or destination country policies, or in events that are not the result of conscious policy, such as social conflict, health factors, "beaten track" effects of friends and relatives, etc. Whatever their source, relative changes in the putative \( x_{\text{pref}}(i,n) \) and \( i_{\text{pref}}(n,i) \) would be echoed in \( z(n,i) \) and strongly reflected in the operational estimated \( z(n,i) \).

It is important to recall here that the \( \hat{z} \)'s are estimated nearly independently from each other: \( \hat{z} = \hat{M}k/VW \). Therefore, for practical purposes individual \( \hat{z} \)'s may be changed one at a time to reflect changes in policies or circumstances, without having to be concerned with modifying the other \( \hat{z} \)'s.

Increasing the value of a particular \( \hat{z} \) will have, in general, the effect of increasing the value of the corresponding \( \hat{M} \) by about the same proportion. The values of the other \( \hat{M} \)'s for that row and column will be accordingly depressed, since, under the constraints of this model, if more go from \( n \) to \( i \), fewer will go from \( i \) elsewhere and fewer will arrive at \( i \) from elsewhere; therefore, as the row \( n \) and column \( i \) values decline (except for \( \hat{M}(n,i) \) itself), the values of the other elements in the \( \hat{M} \) matrix will tend to rise slightly.

The directions of these ripples resulting from a change in \( \hat{x}(n,i) \) will be reversed, of course, if it is decreased rather than increased.
At any rate, having this general understanding of the direction of effects, policies, or scenarios may be tried out on the model by modifying z's.

**Limiting M's**

There will be cases when a host country i will decide that it wants no more than a given ratio \( F(n,i) \) of workers from origin n for a given pool. In such cases, if the model run without constraints yields \( \hat{M}(n,i)/W(N,i) < F(n,i) \), there is no problem. But, if \( \hat{M}(n,i)/W(n,i) > F(n,i) \), then one would proceed as follows:

(a) set \( \hat{M}(n,i) = W(n,i) \cdot F(n,i) \);
(b) set \( \hat{z}(n,i) = 0 \) to ensure that no more workers from n come to i;
(c) rerun the model;
(d) check again for exceeded limits;
(e) run again if necessary.

**Optimization and Evaluation**

It might be useful to have a sense of the efficiency of current or projected patterns of labor movement within the region. Two approaches can be suggested:
(1) A simple measure of the efficiency of population movements, by now traditional in the migration literature, is the ratio of net changes in stock to the actual flows. Allowing that the model proposed here generates estimates of stocks at a given date rather than actual behavioral flows, we can adopt the concept to measure the ratio of the minimum expatriation of labor within the region to the actual expatriation. For a given labor pool in regional deficit, the maximum expatriation within the region for nations with labor deficit is zero, and for nations with labor surplus, it is the surplus. Thus, the minimum number of moves in the region is $J - \sum Y(i)$ where, $Y(i) = 0$ if $W(i) > V(i)$; $Y(i) = (V(i) - W(i))$ if $W(i) < V(i)$. For a labor pool in regional surplus, $Y(i) = (W(i) - V(i))$ if $W(i) > V(i)$ and $Y(i) = 0$ if $W(i) < V(i)$. The actual number of moves within the region are $\sum M$.

This measure of efficiency of migration is then the ratio of the minimum necessary moves within the region to the total number of actual moves within the region: $J/\sum M$

It may be interesting for policy to keep track of this evaluator of migration efficiency under various assumptions as to $V(T)$, $W(T)$, and $z$.

(2) It would be useful, both for evaluation and for policy design, to have an optimized solution for reference or as a benchmark. The main problem is that there is no clearly acceptable or interpretable objective function: what is to be optimized?

A possible objective function comes to mind. If $\hat{z}(n,i)$ is the ease of movement or transitivity from $n$ to $i$, then $\hat{z}^{-1}(n,i)$ is a measure of the difficulty or work done in going once from $n$ to $i$. 

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Therefore, \( \sum z^{-1} \) is an estimated measure of the migratory effort or cost within the region and a potential objective function to be minimized, subject to the constraints provided by \( V \) and \( W \).

Note that \( Mz^{-1} = VW/CD \), so that minimizing migratory effort \( (Mz^{-1}) \) is akin to maximizing the product of demand and supply of labor \( (CD) \). This appears to be a very reasonable dual: maximizing the opportunities available to workers \( (D) \) and the pool of workers available per job \( (C) \). It is particularly attractive because it echoes perfectly the logic of such optimizing models as those that economize in the use of resources. The clearest parallel is that to models that minimize transport costs and that have as their dual the maximization of the value of resources (rents and quasi-rents).

At this writing, the nature of such an optimization has not been properly explored. The first question that comes to mind is whether the iterative equilibrating procedure suggested here results in itself in that optimum, in the style of neoclassical economics and the invisible hand. That is to say, that the sum total of bilateral transactions would be optimal for the whole. On the other hand, it may be that such an optimum lies elsewhere. In either case, there might be much to be learned from a contrast and comparison of optimization of simulation within this system.
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
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<tbody>
<tr>
<td>AA</td>
<td>Minimum legal age to work minus one</td>
</tr>
<tr>
<td>a(l,l)</td>
<td>Element of transition matrix TRAN (p)</td>
</tr>
<tr>
<td>At(g)</td>
<td>Constant annual teacher attrition rate for group g</td>
</tr>
<tr>
<td>B</td>
<td>Bounds of optimizing function</td>
</tr>
<tr>
<td>BB</td>
<td>Minimum age allowed to attend any school</td>
</tr>
<tr>
<td>c</td>
<td>Course in ESM</td>
</tr>
<tr>
<td>C(i)</td>
<td>Potential supply of workers per job opening at i</td>
</tr>
<tr>
<td>COST(i,j,n)</td>
<td>Imputed cost of one expatriate man-year working in sector i.</td>
</tr>
<tr>
<td>D(i)</td>
<td>Job opportunities per worker at sector/country i</td>
</tr>
<tr>
<td>D(noncont)</td>
<td>Completer (promoted) not continuing in ETS</td>
</tr>
<tr>
<td>d(t,c)</td>
<td>Dropout rate in course c at time t</td>
</tr>
<tr>
<td>E(t,i)</td>
<td>Target employment level</td>
</tr>
<tr>
<td>e(i,t)</td>
<td>Elements of the employment estimates for sector i at year t</td>
</tr>
<tr>
<td>epro(t,c)</td>
<td>Promotion rate in course c at time t</td>
</tr>
<tr>
<td>EQM(t,c,i,j)</td>
<td>Entrance qualification matrix</td>
</tr>
<tr>
<td>f</td>
<td>Target national share of workers</td>
</tr>
<tr>
<td>f(i,j)</td>
<td>Target share of workers that is national labor force</td>
</tr>
<tr>
<td>FIL(t,c)</td>
<td>Rates of graduates from course c in t</td>
</tr>
</tbody>
</table>
Teacher group

G(t,c) Number of graduates from course c in year t

H(t,i,j) Occupation distribution matrix

h(i,j) Element for share of jth occupational input in total labor input in sector i

i pr:ef (i,n) Preference of host nation i and sector i for nationals from n (migration model)

i sector/county

j Occupation

k Arbitrary constant (migration model)

K Constant growth rate of output

lag Time lag

LEAK (o,r,p,t-lag) Initial stock of leaked labor force

l(i,j,t) Elements of the manpower requirement matrix

LG(t,c) Number of graduates from course c participation in labor participation in labor force after filtered
LKLF (t,i,j,r) The leakage rate for the existing labor force
LKPRO (t,i,j,i,j) Promotion matrix
LKPOOL (t,r,p,t-lag) Pooled leakages
LKSC (t,r,p) Leakage rate for current school leavers

M(F,i) Number of workers from rest of world in country i
M(n,i) Number of workers of nationality n in the region in country i, sector i
moveins, moveouts moveins, moveouts
MSE Labor force supplied by ETS
MSE(t,i,j) Manpower supplies by ESM to go into labor force
n Nationality or worker; Origin of worker (in migration model)

NA(t,j) Attrition rate vector for national labor
NAR (t,i,j) Net additional manpower requirement
Net MR(i,j) Net manpower requirement for current school leavers
Net NLPM Net change in national labor force due to promotions
Net TR(g) Net teacher requirement in group g
Net X (t-1,i,j,r,n) Global allocation of expatriates by MPM
Net X Net importation or exportation of nonnational manpower
NG(t,i,j) Target level national labor in sector i occupation j which meets goal.

NLF(t,i,j) National labor force
NLF(0,i,j) Base year national labor force
O Base Period (migration model)
p Pool ID (in migration model)
PER(t,i,j) Percent of target still needed to meet nationalization goal for a given sector/occupation
PIT(t,g) Target intake of teachers of group g as calculated by ESM in year t

P(t,i) Input productivity data
PL(r,p) Pooled leakages in locality r for pool p
PM Priority matrix
POP(t,a,r) Population of age a in locality r
Q(t,i) Target product for sector i in year t
Q(0,i) Base year sectoral product
R Total number of localities
Locality; Student (in ESM); Years in stream (in PS of ESM)

RATES (t,c,r) Rate of non-labor movement
Reallocated
(t-1,i,j,r,t-lag) Reallocated leakages

rep (t,c) Repetition rate in course c at time t
RLLF Matrix of redistributed leakage labor force
S (cont) Completer (promoted) continuing to course Cl
S (d) Dropout (non-completer)
S (noncont) Completer (promoted) not continuing in ETS
S(pro) Completed (promoted) whether or not continuing
S(rep) Repeater in same course
SAL (t,c,a) Current year underage school leavers
SCPOOL (t-l,r,p) Current year school leavers
SOM Sector/occupation matrix
ST(t,g) Teachers available in year t>1 for group g
ST(0,g) Base year teacher stock for group g
<table>
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<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Survivor Rate</td>
<td>Rate of survival of population</td>
</tr>
<tr>
<td>T</td>
<td>The value at the calibration date; last simulation year</td>
</tr>
<tr>
<td>t</td>
<td>Year (of analysis)</td>
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<tr>
<td>TLP(t,i,j)</td>
<td>The manpower requirement matrix</td>
</tr>
<tr>
<td>TRAN(p)</td>
<td>Transition matrix for pool ID</td>
</tr>
<tr>
<td>TS(t,c)</td>
<td>Total students in course c at time t</td>
</tr>
<tr>
<td>TTR(t,g)</td>
<td>Total teacher requirement for group i</td>
</tr>
<tr>
<td>UAS(t,c,a)</td>
<td>Existing cumulative underage school leavers by course c and age a in year t</td>
</tr>
<tr>
<td>UGPOOL(T-1,r,p)</td>
<td>Underage school leavers</td>
</tr>
<tr>
<td>V</td>
<td>Unemployed</td>
</tr>
<tr>
<td>V(F-1)</td>
<td>Dummy slack variable for workers from rest of world</td>
</tr>
<tr>
<td>V(n)</td>
<td>The supply of nationals from country n in the region</td>
</tr>
<tr>
<td>V(O,n)</td>
<td>The supply of workers from country n at the calibration date</td>
</tr>
<tr>
<td>W(M)</td>
<td>Demand for workers in sector in country i regardless of nationality</td>
</tr>
<tr>
<td>Symbol</td>
<td>Definition</td>
</tr>
<tr>
<td>--------</td>
<td>------------</td>
</tr>
<tr>
<td>XA(t,j)</td>
<td>Attrition rate vector for foreign labor</td>
</tr>
<tr>
<td>xpref (i,n)</td>
<td>Preference of workers of origin n for nation i (migration model)</td>
</tr>
<tr>
<td>XLF</td>
<td>Non-national labor force stock</td>
</tr>
<tr>
<td>XLF (0,i,j)</td>
<td>Base year non-national labor force</td>
</tr>
<tr>
<td>Y</td>
<td>Number of moves V-W (migration model)</td>
</tr>
<tr>
<td>Z</td>
<td>Constant employment growth rate; objective function minimizing cost of employing expatriate labor</td>
</tr>
<tr>
<td>z(F,i)</td>
<td>Accessibility from rest of world to country i</td>
</tr>
<tr>
<td>z(n,i)</td>
<td>Accessibility of country i from country n</td>
</tr>
</tbody>
</table>
Part III USER'S GUIDE

The User's Guide is presented in three parts, each corresponding to one of the three interrelated models: country specific (compound), regional (expanded), and migration. The purpose of the guide is to provide users with information on the features of each model, available reports and outputs, and instructions on how to use the models. The user has a choice of which of the models to use, and the information contained in the preceding discussion should be of assistance in making a selection.

Each part of the guide is being published as a separate volume in the World Bank Staff Working Papers series. Volume II (Number 588) is the User's Guide for the Country (Compound) Model; Volume III (Number 589) is the User's Guide for the Regional (Expanded) Model; and Volume IV (Number 590) is the User's Guide for the Migration Model.
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