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ABSTRACT

The analysis and description of four manpower nursing requirements models-- the Pugh-Roberts, the Vector, the Community Systems Foundation (CSF), and the Western Interstate Commission of Higher Education (WICHE)--are presented in this report. The introduction provides an overview of the project which was designed to analyze these different models. The main body of the report (chapters 2 and 3) consists of a comprehensive description of the four models. Chapter 2 provides an individual overview of each of the models, highlighting their significant features in a comparative fashion. Chapter 3 contains a detailed analysis that focuses on each model's intended uses, comprehensiveness, theoretical construction, and operational feasibility. In chapter 4 the validity tests performed by the model builders are first described and then selected future validity tests are proposed. Finally, two types of model interaction--vertical and horizontal--are examined in chapter 5. (JH)

# Comparative Analysis of Four Manpower Nursing Requirements Models

Prepared under contract number 231-77-0062
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The Nurse Planning Information Series, sponsored by the Division of Nursing in the Bureau of Health Manpower, has been designated as a special series to support health manpower planning and specifically to meet the information needs of the nursing component of the National Health Planning Information Center.

Three other series published by the Center are Health Planning Methods and Technology, Health Planning Information, and Health Planning Bibliography. All of these were designed to respond to information needs of the Bureau of Health Planning.

The documents included in all series are being added to the Center's data files and will be made available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161. A listing of titles of these publications can be obtained from the National Health Planning Information Center.

## FOREWORD

The Division of Nursing continually assesses and projects requirements for registered nurses across the Nation as a basis for its recommendations in ensuring adequate nursing care. Recognizing the need for refinement and review of requirements projection methodologies, the Division launched four studies concerned with the projection of nursing resources and requirements. Thus four separate requirements models were developed. Since these models differ as to type, requirement definition, structure, assumption, and data input and output, it was necessary to clarify these differences for model users. This report, then, resulted from a comparative analysis of the four models, undertaken for the Division by Applied Management Sciences. It adds to the ability of policymakers, planners, and others to understand and use the models and model results.

This publication is the sixth volume in the Nurse Planning Information Series. The series is composed of several selected monographs and bibliographies relevant to health planning.

The nursing component of the National Health Planning Information Center provides health planners with a centralized, comprehensive source of information on nurse manpower planning to facilitate an improved health care delivery system in the United States. The component acquires, screens, synthesizes, disseminates, and makes available specialized documentary material on nursing, as well as methodological information on a wide variety of topics relevant to health planning and resources development.

The other volumes in the series are:

Accountability: Its Meaning and Its Relevance to the Health Care Field
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Nurse Practitioners and the Expanded Role of the Nurse: A Bibliography

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Special thanks to the model builders for their time and assistance. These are: Mr. Gary B. Hirsch, Senior Consultant, Pugh-Roberts Associates; Dr. Timothy Doyle, Program Director, Vector Research, Inc.; Dr. Ronald Gue, President and Mr. William Wrightson, Jr., Associate, CSF Ltd; Ms. Jo Eleanor Elliott, R. N., Director of Nursing Programs and Ms. Jeanne Kearns, R. N., Associate Director of Nursing Programs, for the Western Interstate Commission of Higher Education (WICHE); and Dr. Wayne Kirschling, Director of Basic Studies, and Mr. Ken Sauer, Senior Staff Associate, for the National Center for Higher Education Management Systems (NCHEMS).

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# I. INTRODUCTION

The Division of Nursing administers programs that are designed to support the development of a nursing supply that adequately meets the needs of the U.S. health care system. This involves monitoring current developments in the nurse manpower sector and projecting future nursing requirements. Specifically, under Public Law 94-63, the Secretary of the Department of Health, Education, and Welfare (HEW) is required to report annually to the Congress on the supply of, and requirements for, nursing personnel. In addition, the Secretary is to recommend legislation to provide for an adequate and equitable distribution of nurses throughout the country.

In order to meet these reporting requirements, suitable measures of current nursing requirements must be available, as well as appropriate methods of projecting future requirements. Historically, there have been at least four general types of methodologies for measuring nursing requirements. First, there are methodologies that use criteria based on existing practices; these rely on medians or quartiles of state nurse/population ratios. Second, there are methods that attempt to develop optimal ratios to use in determining nursing requirements. Third, there are requirements measures that adopt the economist's concepts of supply and demand. Finally, there is an eclectic approach to measuring nurse requirements that includes optimizing criteria, standards of existing practice, and demand measures. 1/

This last approach is the one that was adopted in the report of the Surgeon General's Consultant Group on Nursing, Toward Quality in Nursing, which was issued in 1963. 2/ The methodology for

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1/ Variations of these requirements measures have been discussed in the literature on nurse manpower. These include the use of vacancy rates, subjective perceptions of shortages by directors of nursing services and hospital administrators, the difficulty RNs have in finding jobs, and so forth. Some of these notions are developed in Frank Sloan, The Geographic Distribution of Nurses and Public Policy, HEW Publication No. (HRA) 75-53, May 1975.

2/ Department of Health, Education, and Welfare, Surgeon General's Consultant Group on Nursing, Towards Quality in Nursing: Needs and Goals, Public Health Service Publication No. 922, (Washington: Government Printing Office, 1963).

projecting nursing requirements in that report is a refinement of the methodology developed in an instructional manual, Measuring Nursing Resources, issued in 1949 by the Division of Nursing Resources. 3/

## The Division of Nursing Models

Although some refinements had been made in the approach adopted by the Surgeon General's Consultant Group, there had not been any intensive review since its initial implementation, nor had there been any new methodology for measuring nursing requirements developed for wide use in planning studies. Therefore, in order to refine and review existing requirements-projection methodologies and to produce a set of methodologies that should be more useful than the limited methodologies then available, the Division of Nursing granted contracts to four research firms for the purpose of developing forecasting models of the nursing sector of the economy. These four models are:

A National Model of the Supply of, Demand for, and Distribution of Nursing Personnel and Services.
Pugh-Roberts Associates, Inc., Cambridge, Massachusetts 4/

Analysis and Planning for Improved Distribution of Nursing Personnel and Services: State Model. Western Interstate Commission of Higher Education (WICHE), Boulder, Colorado

The Impact of Health Care System Changes on the Nation's Requirements for Registered Nurses in 1985. Vector Research, Inc., Ann Arbor, Michigan

A Micro Model for Assessing Nursing Manpower Demand and Supply. Community Systems Foundation, Ltd. (CSF). Washington, D.C.

Recognizing the need for different modeling approaches to address the estimation problem at different goegraphical levels and under different assumptions about the future health care environment, each of the models was designed for a special purpose. In

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3/ Department of Health, Education, and Welfare, Division of Nursing Resources, Measuring Nursing Resources, (Washington, 1949).

4/ Conducted under subcontract to Western Interstate Commission on Higher Education (WICHE).

order to provide forecasts of nursing requirements at the national level, the Vector model referenced above was developed. This model is specifically concerned with assessing the impact of the following three changes in the health care system on national requirements for registered nurses:

- the introduction of national health insurance (NHI)
- increased enrollments in health maintenance organizations (HMOs)
- the reformulation of nursing roles

This national model is the first part of a two-part study done by Vector Research. The second part, separately bound, examines the impact of these same health system changes on nursing requirements at the state level. Both versions of the Vector model are concerned solely with nursing requirements and do not provide forecasts of nurse supply.

In contrast with the Vector model, the CSF model was developed for the purpose of focusing on nursing manpower supply and demand at the institutional and substate levels. Specifically, the model estimates the demand for nurse manpower in four types of employment settings:

- acute care
- long-term care
- ambulatory care
- community and public health care

These demand estimates can then be combined with nurse supply projections at the county or multiple-county level in order to derive estimates of nursing shortages or surpluses.

The Pugh-Roberts model is a national nurse market model that includes detailed specifications of the supply and demand sides of the nurse manpower markets. In contrast to the CSF model, where the supply projections are independent of the demand estimates, the Pugh-Roberts model explicitly takes account of the interactions of nurse supply and demand, and thus reflects supply-demand feedback in the market for nurses. In addition, it employs a modeling technique that was designed for flexibility in addressing a range of policy issues, and is intended to be used principally for evaluating alternative policies and programs.

The WICHE model, on the other hand, is intended to be used as a guide for planning at the state level. Central to the WICHE model is a requirements planning process, in which state planning groups establish health care goals that are used in determing nursing requirements. Thus, "requirements" refers to the number of nursing personnel that will be needed to meet a particular set of health care goals.

## Purpose of the Project

It is clear that the above models are quite heterogeneous with respect to goals, techniques, data requirements, cost of implementation, output definitions, geographical coverage, and so forth. It is, therefore, inappropriate that this project undertake a critical comparison of the four models. Comparisons will be made of the four models, but these comparisons will be of a descriptive nature. The intent of the project is to provide an easily understood description of each model, to point out the intended and potential uses of each model, and to allow choices among the models to be made by the reader as circumstances dictate. The models are different in design, each has substantial potential for usage, and, to a very great extent, the heterogeneity of intended uses of the models makes them largely noncompetitive. Therefore, the degree to which each model is ultimately implemented will depend on the goals of their users relative to the potential of each model as perceived by the users, rather than on a judgment of the present contractor relative to which of the four models is universally "best".

## Review of the Project Tasks

The technical analysis of the four nursing manpower models in this report has three major objectives: to distinguish each model according to its potential uses and application areas, structural characteristics, and operational requirements; to propose future model validation tests; and to examine possibilities for model interactions. To achieve these objectives, this project was carried out in three broad phases: a preliminary review of the four Division of Nursing models and other research literature on health manpower models; the development of an analytical framework to be used in describing the models; and the application of the analytical framework to each of the four models.

During the first phase of the project, the Applied Management Sciences staff reviewed several previous research studies involving the evaluation of health manpower models. This review was undertaken in order to identify methodologies that might usefully be applied to the Division of Nursing models and to suggest a taxonomy of model characteristics that could be incorporated into the analytical framework. Since this review was intended simply to provide a general overview of the methodologies that have been used in the past, Applied Management Sciences did not attempt to identify all such previous efforts.

Two previous studies were particularly useful, however, because of the similarity of their objectives and those of the present project. These included a study by Vector Research 5/ that evaluated 56 health manpower models in terms of their usefulness for policy analysis purposes and a previous study by Applied Management Science 6/ that evaluated 10 health manpower models for the Manpower Analysis Branch, Bureau of Health Manpower. In this latter study, models were characterized by scope and purpose, model structure, estimation techniques, endogenous and exogenous variables, data requirements and sources, validation techniques, and model results.

The findings of the brief literature review were used during the second phase of the project to develop a framework of analysis that could be applied to the four Division of Nursing models. As previously mentioned, the four models use different approaches in modeling the nursing sector and are concerned with different aspects of the requirements estimation problem. It was therefore necessary to develop a list of model characteristics or descriptors that is detailed enough to capture the significant features of each model and yet general enough to be applied to the four different models.

There are four general sets of model characteristics that were used to guide the development of the analytical framework in the second phase of the project:

- purposes and uses
- comprehensiveness
- theoretical construction
- operational feasibility and costs of implementation

The first component of the framework serves to distinguish the models in terms of the uses originally intended for them by the model builders. The second component provides a detailed description of each model's coverage of specific elements of the nursing

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5/ Vector Research, Inc., An Analysis of Health Manpower Models. HEW Publication No. (HRA) 75-19, Washington, U.S. Government Printing Office, 1975.

6/ Deane, R.T., and Litkowski, T.I. The Assessment of Health Manpower Modeling Efforts and Development of Alternative Modeling Strategies. HEW Publication No. (HRA) 77-17. U.S. Government Printing Office, 1977.

sector and related health care sectors. The third component describes the model structure and analyzes the factors affecting nursing requirements and supply that are considered by each model. It also examines and describes the assumptions underlying each model's development. The fourth component discusses the modeling technique and the procedures used, and identifies the resources and data required to implement each of the models.

Each of these four major components of the analytical framework was further divided into subcomponents, and table shells were constructed for several of these subcomponents in order to provide a concise and convenient description of each of the four models. The analysis was structured according to these components and subcomponents as applied across the four models.

The third and last phase of the project (upon which this report is based) consisted of applying the analytical framework to each of the models, developing proposed validity tests for each of the models, and examining the possibilities for model interaction. The first task involved a review of the materials provided by the model builders. Next, site visits and interviews with the model builders were conducted as necessary to discuss the intended uses of each model and to acquire additional information necessary to conduct the analysis. This analysis was intended to assist model users in determining the types of forecasts and simulations that can be developed and in interpreting the results obtained. In addition, the analysis should be helpful in determining the suitability of the models for particular applications and in assessing the feasibility of implementing the models for their intended uses, as well as other potential applications. Table shells and narrative descriptions corresponding to the components of the analytical framework were thus prepared to serve these purposes. The review of the materials supplied by the model builders, along with the site visit interviews, provided information on the type and extent of validation undertaken by the model builders. This information is recorded as part of the analysis, along with suggestions for other future validation efforts. Finally, the structural characteristics of the models and their data sources were compared in order to determine the possibilities for model interaction and any modifications that might be necessary to accommodate these interactions. The analysis and description of the four models is presented in the following chapters of this report.

## Organization of the Report

The following four chapters of this report present the results of the analysis of each of the four nursing manpower models. The main body of the report (Chapters 2 and 3) consists of the comprehensive description of the four models in an attempt to assist potential model users in determining appropriate application areas for each model. Chapter 2 provides individual overviews of each of the four models that highlight their significant features in a comparative fashion, while Chapter 3 contains a more detailed analysis that focuses on each model's intended uses, comprehensiveness, theoretical construction, and operational feasibility. In Chapter 4, the validity tests performed by the model builders are first described, and then selected future validity tests are proposed. In Chapter 5, two types of model interaction possibilities are examined. The first type may be referred to as vertical interactions, in which the inputs and outputs of two or more models are directly linked. The second type may be referred to as horizontal interactions, in which the outputs of two or more models are compared in a more informal way such as to reassess the results of one model with the outputs of another or just to provide a range of alternative forecasts.

## II. OVERVIEW OF THE DIVISION OF NURSING MODELS

The four models described in this report were developed in response to specific needs and objectives of the Division of Nursing, and differ from one another in terms of policy issues they were designed to address, geographical coverage, modeling technique, data requirements, and so forth. Therefore, in order to assist potential model users in evaluating the usefulness of each model for particular applications, the significant features of each model will be described in this and the following chapter. In this chapter, brief descriptions of each model are presented, along with a comparison of the four models presented in a set of tables that summarize several of their key features. This will provide an overview which will serve to distinguish the four models in terms of the types of forecasts they produce. In Chapter 3, a more detailed description of each model is presented that focuses on intended uses, comprehensiveness of the coverage, theoretical construction, and operational feasibility.

### A. OVERVIEW OF THE FOUR MODELS

#### VECTOR MODELS

Vector Research was given a specific mandate to develop a nursing manpower model for the purpose of evaluating the effects of three anticipated health system changes on future requirements for nurses.1/ These changes involved the implementation of NHI, expanded enrollments in HMOs, and the reformulation of nursing roles. Therefore, the Vector model was specifically designed to enable model users to simulate a variety of alternative scenarios involving one or more of these changes and to estimate the resulting impact on nursing requirements. The final report of the Vector project, in fact, consists primarily of a description and interpretation of the results of several of these simulations.

The Vector model consists of three separate modules that provide forecasts of the future U.S. population, health service demands, and nursing requirements. The population forecasts are based on Bureau of Census projections of the distribution of age and sex cohorts over time and census statistics on the income distribution of the

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1/ Two versions of the Vector model were developed and are operational: a national model and a state model. The national model was developed first, and then a state model was developed that is similar to the national model in all respects. In fact, the state model supersedes the national model in the sense that it can also produce national forecasts either by aggregation or by using national data as inputs.

population. In addition, these population forecasts also characterize cohorts according to health insurance coverage and HMO enrollment. The demand-for-services forecasts are based on the population projections, and are estimated for six separate provider settings.2/ This is done by multiplying the population in each cohort by estimates of per capita demands for each type of health service. These per capita demand estimates are based on data from the 1972 Health Interview Survey. Finally, future nursing requirements in each employment setting are estimated by multiplying the projected health service demands for each setting by appropriate nurse staffing ratios.3/ The staffing ratios that are used by the model are intended to reflect the existing practice with respect to the levels of nursing care provided to the population. In the current version of the model, the requirements forecasts are produced only for RNs. However, the model can be easily modified to produce LPN requirements forecasts as well.

The Vector model does not produce nursing supply forecasts. Therefore, the model user must have available independent supply projections in order to derive estimates of future nursing shortages or surpluses. The model builders used recent nurse supply projections made by the Bureau of Health Manpower in a comparison with the model's national requirements forecasts.

Examinations of the effects of health system changes are done by allowing model users to incorporate into the forecasts different assumptions concerning the timing and magnitudes of these changes. For example, in order to examine the effects of a proposed NHI plan on nursing requirements, the model user can specify the values of certain input parameters that define the type of plan being considered, the year in which it is adopted, and the period of time over which it is phased into existence. In a similar manner, the model user can develop forecasts involving higher formation rates for new HMOs, greater use of the nurse practitioner in physicians' offices, adoption of the primary nursing concept in hospital inpatient units, or new roles for clinical nurse specialists. In this way, the Vector model can be used as a flexible planning tool for guiding

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2/ These are: short-term hospital inpatient units; hospital outpatient and emergency units; physicians' offices; nursing care homes; HMO clinics; and home health care.

3/ Nursing requirements forecasts are produced for the following employment settings: short-term hospital inpatient units; hospital outpatient and emergency units; physicians' offices; nursing homes; HMO clinics; community health; non-short-term general hospitals; private duty nursing; and nursing education. Nursing requirements in the latter four settings are estimated independently of the health service demand factors.

nurse supply policies at the state and national levels. Repeated use of the model in this manner is facilitated by the low computer costs associated with each projection. Vector Research has indicated that each state project involves computer costs of only $12.

If the model is used with the existing data bases to address the types of issues for which it was designed, the data requirements associated with operating the model would be limited to values for the previously mentioned scenario-defining input parameters. In order to verify and properly interpret the model's results, personnel who are familiar with nursing trends and health care statistics should be available.

CSF MODEL

The model developed by Community Systems Foundation, Ltd. (CSF) is intended to be used by the Division of Nursing and health care planning agencies as a nurse manpower planning tool at the state and substate levels. The model produces both nursing requirements and nursing supply forecasts, although the model does not provide for the interaction of these two forecasts. The model, nevertheless, can be used to determine the likelihood of future nursing shortages or surpluses in specific geographical planning areas.

The CSF model consists of three types of submodels: a set of submodels that forecast health service utilization in acute care and long-term care settings; two submodels for forecasting nursing requirements in ambulatory care and community and public health care settings; and submodel for producing nurse supply projections. The health service utilization submodels were constructed using multiple regression procedures, and are used to forecast patient days of care in specific types of acute care and long-term care facilities.4/ These facility-specific submodels (such as regression equations) require input data describing the future characteristics of the population and the health care system within the geographical area served by the institution being modeled. The forecasts produced by these submodels are translated into future nursing requirements by multiplying the utilization estimates by the appropriate nurse staffing ratios.

In contrast with the acute care and long-term care submodels, the submodels for ambulatory care and community and public health care settings produce county level forecasts of nursing requirements

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4/ Acute care institutions are classified according to size, control, technology, and teaching status; long-term care institutions are classified according to size and control. The specific submodels that have been constructed are described in more detail in Chapter 3.

directly. These forecasts are made via simple trend projections of historical nurse employment data.

The supply submodel is based on a national model of nurse supply that was developed previously by Research Triangle Institute 5/ and modified to take account of nurse migration at the substate level. This is essentially a flow model of nurse supply that increments the existing stock of nurses each year by taking account of additions to supply (such as new graduates, new foreign nurses, in-migration, and so forth) and subtraction from supply (such as license expirations, out-migration, and so forth). The outputs of this submodel are age-specific forecasts of both the licensed and active supplies of RNs and LPNs for county or multiple-county areas.

While the modeling approach differs for the acute care and long-term care settings, on the one hand, and for the ambulatory care and community and public health care settings, on the other, the concept of nursing requirements is similar. For all settings, the requirements forecasts are intended to represent the number of nurses that would have to be employed to meet future demands for health services, while maintaining current levels of nursing care.

The supply projections can be compared with similarly aggregated nursing requirements projections in order to derive estimates of future nursing shortages or surpluses. However, it should be restated that the requirements and supply forecasts are independent of one another, and do not reflect the interaction of supply and demand in the nurse markets. Therefore, the derived shortages or surpluses are not equivalent to the market-based concepts of excess demand or excess supply. Thus, a projected nursing shortage, for example, would not necessarily correspond to the number of nurses that the market would actually absorb, should they be made available, at existing wage rates.

Finally, it is also important to note that the primary factor in determining both the types of submodels that were constructed, and their forecasting accuracy, was the availability and reliability of data at the substate level. A specific provision of the CSF project was that the development of the model and its use were to rely on data that was already generally available. The American Hospital Association (AHA) and the Hospital Research and Educational Trust data are mainly used for the model development.

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5/ Jones, D.C., et al, Procedure for Projecting Trends in Registered Nurse Supply, Research Triangle Institute, March 1975, (Contract number: NO1-NU-44123). Division of Nursing, Bureau of Health Resources Development, HRA, DHEW. (unpublished report)

The CSF model has been implemented and evaluated at three test sites, 6/ where the model builders found that satisfactory data for model operation were available. However, the amount of historical data and their reliability can be expected to vary substantially among substate areas, and this will influence the amount of effort required in data collection, as well as the accuracy of the model's forecasts. For example, input data required for the health service utilization submodels consist of projections of the characteristics of the population served by specific facilities, but only a few years of detailed Bureau of Census data are likely to be available for most substate areas. Therefore, model users will have to base the projections on data from local sources or use other methods of making the required projections. The utilization forecasts also depend on input data that project over the forecast period various health system characteristics of each substate area. For reasons such as these, the model builders suggest that it would be desirable to take full advantage of the knowledge and experience of local health care planners in verifying and possibly modifying the model's forecasts.

The costs involved in operating the model have not been documented fully. In discussions with the Applied Management Sciences staff, the CSF staff estimated the computer costs per simulation to be $200 to $400. The time required for collection of the data for each area was estimated to be from two to three months.

PUGH-ROBERTS MODEL

The Pugh-Roberts model is developed with an equation system referred to as System Dynamics. The System Dynamics models are variants of the operation research type models and consist of an initial set of variables whose values define the starting point for the model projections. These variables are called level variables. While it is tempting to refer to them as stock variables, they may, in reality, represent flows. To each of these variables is then applied a rate of change that can be, in turn, a function of other model variables. In essence, then, the System Dynamics model is a series of differential equations. The solution of these equations in terms of equation specification and parameter value assignment is handled by a software package called DYNAMO.

The Pugh-Roberts model is a national model and does not concern itself with the distribution of nurses within the country. However, it is concerned with the nurse distribution between employment settings and between the types of educational training. In dealing with these nongeographical distributional problems, the model con-

6/ The CSF model was tested in Washington, D.C., Madison, Wisconsin, and the entire State of New Mexico.

centrates on the relationships showing how various factors affect the number of nurses in each job setting and educational program rather than on refining the classification of them.

The nature of the Pugh-Roberts model allows an examination of a wide variety of issues. However, time and resources did not allow the model builders to run simulations of all possible policy issues. Instead, they have chosen to examine several policy issues, such as the relative impacts on nursing and health care sector of the NHI programs, the imposition of strict utilization control measures, the expanding responsibilities of nurses, the upgrading of nursing education, and the changing structure and level of the average wage of nurses.

The baseline projection of nursing requirements in the Pugh-Roberts model involves making projections of nurse demand and supply, under the assumption that external and other variables will influence the demand and supply in the future in the same manner as indicated in the historical trends. The projected number of nurses required consists of the difference between the projected number of nurses demanded and that of nurses supplied. Clearly, then, the required nurses are equivalent to the excess demand that results from the equilibrating process of the dynamic property of the model. Given the baseline projections, the effects of various policies are examined by modifying or altering these projections according to the changes induced in key variables by the implementation of policies.

There are four sections in the Pugh-Roberts model. They are the nurse education, nurse employment, nurse demand, and demographic (population) sectors. Essentially, each sector represents relationships showing how various factors affect the rate of inflows into and out of the respective sector. For example, the nurse employment sector represents relationships showing how various factors affect the number of nurses entering and leaving the employment sector, whereas the nurse education sector represents relationships showing how various factors affect the number of persons entering the nurse educational programs and the number of graduates and dropouts from them. The demographic sector represents key demographic characteristics of the total population and nurse population and how they affect the other sectors.

Clearly, then, the Pugh-Roberts model is market-oriented in that market demand and supply form the basis of projecting nursing requirements. Furthermore, the key variables chosen by the model such as nurses average wage rate, the demand for health services, the job satisfaction of nurses, and so forth, closely resemble those hypothesized to influence the demand for supply of all types of professional personnel. The relationships between key variables are specified by multipliers. The multipliers in the Pugh-Roberts model are estimated according to the judgment of the Task Force based on a variety of data.

In order to refine the Pugh-Roberts model, four types of validation tests were performed. First, face-validity checks of initial simulation were conducted by the Task Force. Second, the forecast consistency was checked by scrutinizing the simulation results for the first four years of simulation (1972-76), and then by comparing them with any available data for those years. Third, the historical tracking ability of the model was checked by running simulations for the recent past period (1962-72) and by comparing the results with the historical data. Finally, policy-impact forecasts are simulated and examined as part of sensitivity tests.

The Pugh-Roberts model uses DYNAMO III language. It is estimated that the cost per run is about $20. A variety of data is required, such as published surveys of a broad nature, reports of studies directed at particular relationships, and expert judgment. Personnel with some familiarity with computers and health statistics are needed to use the model.

WICHE MODEL

The WICHE model differs from traditional health manpower models in that it does not define structural relationships between the selected model variables. Rather, it presents variables to be included in the model and it guides the construction and estimation of relationships among them. The guides that are present consist of past data on relevant relationships and various factors affecting them.

The model is designed to be a guide for planning, with inputs from a panel of experts. An expert panel plays a pivotal role in making projections according to the process formulated by the model. The key structural relationships of the model are to be defined by the panel through a consensus approach on the basis of the background data and information provided by the model. Therefore, the selection and composition of the panel members largely determine the outcome of projections. The criteria for selecting the panel members are that they possess the requisite expertise in their fields and that they bring with them diverse perspectives. It is recommended that the panel members' backgrounds include nursing education, nursing service, higher education, health planning, and consumer representation.

In order to help model users, the WICHE model provides five types of documents. The main body of the report describing the process is called A Guide for State-Level Planning. The guide is designed to assist state-level decisionmakers in nursing, health planning, and higher education communities. It contains mathematical procedures that may be used to project nursing resources and requirements. The remaining four documents consist of users' manuals for requirement calculation software, resource calculation software, profile data base, and profile report generation system.

In providing a guide for making these projections, the model addresses several broad policy issues. Meeting the state's requirements for total nursing personnel and those for appropriate job-mix for nurses are the two most important issues addressed. The other important issues deal with how to develop the appropriate nursing educational programs and state programs to judiciously influence the inflow and outflow of nurses into and from the state.

The WICHE model emphasizes the importance of achieving the optimum distribution of nursing jobs within the state in terms of employment setting and educational preparations. More than any of the other models, the WICHE model refines the classifications of employment setting. It divides health services to be provided into six broad categories according to provider/practice settings. They are further divided according to the types of services provided into 34 employment settings. The model also provides a guide for projecting LPN requirements and RN requirements of four levels of educational preparations and four categories of nurse job functions. A total of 355 cells of requirements are reported by the model.

The WICHE model's projections of nursing requirements are based on the need concept rather than demand concept. Given the need for providing health services required to treat the projected prevalence of ailments of the state's population, the model asks, "How many and what types of nursing personnel will be required?" The process of projections that serves as the framework for quantifying professional judgment involves a very traditional approach. That is, it involves projecting the state's population by age, race or ethnicity, and income group based on Bureau of Census projections. Then the prevalence rate of ailments of the population cohorts is used as background material as obtained by the opinions of experts in epidemiology. The next step involves estimating the number of nursing personnel required to provide the volume of utilization as determined from the background data. As shown above, the WICHE model's recommended process of projecting the nursing requirements conforms to the traditional method. What is different is that the conversion of one projection into the next one is to be based entirely on the judgments of experts, who are provided with relevant past data to aid them in making the judgments.

The WICHE model's projections of the state's nursing resources are to be made using a traditional injection-leakage method of manpower supply. This method involves estimating the inflows to and outflows from the manpower supply pool. The inflows or injections into the state's nurse supply are expected from three sources: new graduates from nursing schools, inactive nurses becoming active, and immigrating nurses. The outflows or leakages are expected from four sources: retirement, including those becoming temporarily inactive, and death; suspension of licenses; reeducation; and out-migration. The estimations of the rates of inflow and outflows are again to be based on professional judgment.

The WICHE model includes Requirements Calculation Software and Resource Calculation Software written in FORTRAN IV language. Personnel with some familiarity with computers can easily use the software packages by identifying the "assumptions" that specify key relations. Although the cost of a computer run is relatively inexpensive, estimated at $20 per run, the model builders estimate that to collect the necessary data, convene a panel of experts to obtain the assumptions, and to operate the computer programs will take from 6 to 9 months. Although no formal validation tests have been undertaken, face-validity checks were conducted as the panel of experts produced the estimates of key relations. In addition, pilot tests of the model were conducted in six States.

## B. COMPARISON OF THE FOUR MODELS

In this section, the four Division of Nursing models are briefly compared in tabular form in order to offer a synopsized view of the key features of each model. Figure 2.1 shows that a variety of policy issues were targeted by the four models. The Vector and Pugh-Roberts models designed to examine the effects of a variety of health policies, whereas the CSF and WICHE models were designed to be concerned mainly with projecting future nurse shortages or surpluses. As for geographic coverage, Figure 2.1 shows that the Pugh-Roberts model is a national model, whereas the WICHE and Vector models 7/ are state models. However, the WICHE model can be used to make projections at substate levels, and the Vector model is also capable of producing national forecasts by aggregation. The CSF model generates institution-specific forecasts for the most part, but produces county, multicounty, and state levels of forecasts via aggregration of the institution-specific forecasts.

Finally, Figure 2.1 displays a wide variety in the nurse requirements concept used by the models. The concept used by the Pugh-Roberts model is market-oriented, with nurse requirements measured as the difference between nurse demand and nurse supply so that the concept is close to that of a market shortgage or surplus. The other three models, however, do not employ market-oriented concepts, at least not in a direct sense. For example, both CSF and Vector employ nurse requirements concepts that establish nurse staff ratios via the current market situation. Future nurse requirements are then based on the desirability of maintaining these staffing ratios. The WICHE model, however, embodies a concept of desirable staffing goals in its nurse requirements projections, with only a limited reference to the feasibility of obtaining such goals.

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7/ As stated earlier and as will be described in more detail below, Vector Research actually produced two models--a national model and a state model--but both are similar in structure and will be described as a single entity for convenience of exposition.

FIGURE 2.1: TARGET POLICY ISSUES, GEOGRAPHICAL COVERAGE, AND REQUIREMENTS CONCEPT USED BY EACH OF THE FOUR DIVISIONS OF NURSING

| | Target Policy Issues | Geographic Coverage | Requirements Concept Employed |
|---|---|---|---|
| VECTOR MODEL | Model users may simulate various scenarios involving:<br><br>1. the implementation of NHI<br>2. expanded enrollment in HMOs<br>3. role reformulation on the part of nurses | National and state versions of the model have been developed. The state model is also capable of producing national requirements forecasts by aggregation, or by using national input level. | Nurse staffing ratios are applied to projections of health service demands. The requirements forecasts are intended to represent the number of nurses that would have to be employed in order to meet the projected service demands, and to maintain current levels of nursing care. |
| CSF MODEL | The model provides independent nursing demand and supply projections for substate areas, thus enabling model users to estimate future nursing shortages or surpluses. Suggested use as a planning tool for health systems agencies, hospital associations, and so forth | Institution-specific nursing requirements for acute care and long-term care settings; county-level projections for other provider settings. County-level forecasts of nurse supply. County, multiple-county, and state levels of aggregation possible | For acute care and long-term care settings: nursing demand factors (such as full-time equivalent nursing personnel per annual patient-day) applied to projected utilization measured in patient days. Projection of historical nurse employment trends for other provider settings |
| PUGH-ROBERTS MODEL | 1. Relative sectorial effects of NHI<br>2. Relative sectorial effects of utilization control<br>3. Effects of expanding nurses' responsibilities<br>4. Effects of upgrading nursing education | National | Difference between nursing supply projections and the demand for nurses projections |
| WICHE MODEL | 1. Meeting the state's requirements for total nursing personnel<br>2. Meeting the state's requirement for the appropriate staffing patterns<br>3. Developing the appropriate nursing educational programs | State | Number of nursing personnel needed to meet the model user's stipulated health care goals |

As Figure 2.2 shows, a distinctive modeling technique is used by each of the four models. The Vector model makes forecasts by using a series of ratios. For example, the service-demand projections are made by multiplying the population cohort projections by estimates of per capita health service demand. Then, nurse requirements projections are made by multiplying the health service demand projections by nurse staffing ratios. On the other hand, the CSF model relies on step-wise regressions to estimate the functional relationships of health services utilization submodels. These submodels produce institution-specific forecasts of health service utilization in acute and long-term care settings. Then, like the Vector model, nurse staffing ratios are used to forecast nursing requirements. That is, the health service utilization forecasts are multiplied by nurse staffing ratios to produce nurse requirements projections.

The Pugh-Roberts modeling technique is shown in Figure 2.2 as consisting of a series of differential equations and as a variant of the operations research type models. The model views the working of the health and nursing sector as a dynamic process whose structure is defined by differential equations. Nurse requirements and nurse supply projections are then based on the solution of the equation set. In contrast, the WICHE model differs from traditional health manpower models in that it does not define structural relationships between the selected model variables. Rather, it presents variables to be included in the model to a panel of experts, and guides the construction and estimation of relationships among them. The guides consist of the past data on relevant relationships and the presentation of an array of factors that may affect them. Given the guides and procedures, nurse requirements and resource projections are then made on the basis of the opinions and judgments of the expert panel.

As expected from the diverse approaches taken by the four models, the nurse supply forecasts (as opposed to requirements forecasts) also differ as to both coverage and type. Figure 2.3 shows that the Vector model does not generate nurse supply projections at all. On the other hand, the CSF model produces the nurse supply forecasts at the substate level based on the Research Triangle Institute's national model; the Pugh-Roberts model generates projections of nurse supply at the national level; and the WICHE model generates supply forecasts at either the state or the substate level. While only the Pugh-Roberts model uses its supply forecasts in an interactive fashion with its demand forecasts, Figure 2.3 shows that each of the three models that produce nurse supply forecasts uses variants of the injection-leakage model of manpower supply. The CSF model bases its nurse supply forecasts on the flow in and out of nurse supply estimated by age-specific activity rates and survival probability. The Pugh-Roberts model makes nurse supply forecasts by estimating the number of new graduates, immigrating nurses, nurses returning to work, those quitting nursing jobs, and those becoming inactive. The WICHE model provides a procedure that

FIGURE 2.2: MODELING TECHNIQUES USED BY THE FOUR DIVISIONS OF NURSING MODELS

| | |
|---|---|
| VECTOR MODEL | Estimates of the size and composition of the future U.S. population are based on Bureau of Census projections. These population cohort projections are then multiplied by estimates of per capita health service demands by provider setting. The resulting health service demand projections are multiplied by appropriate nurse staffing ratios to produce forecasts of nursing requirements by employment setting. The structure of the model also permits model users to specify the values for certain input parameters that define various "scenarios" they may wish to examine. |
| CSF MODEL | Step-wise multiple regression procedures were used to estimate equations (submodels) for producing institution-specific forecasts of health service utilization in acute care and long-term care settings; that is, each equation forecasts patient days of care for a specific type of acute care or long-term care facility. These health service utilization forecasts are then multiplied by appropriate nurse staffing ratios to produce estimates of future nursing requirements in each facility. For ambulatory care and community and public health care settings, historical trends in nurse employment data are simply projected over the forecast period. |
| PUGH-ROBERTS MODEL | The Pugh-Roberts model is a System Dynamic model, which is a series of differential equations expressed in DYNAMO language. The model includes an initial set of variables whose value defines the starting point for the model forecast. These variables are called "level" variables to each of which a rate of change is applied. The rate of change can be, in turn, a function of other model variables. |
| WICHE MODEL | The WICHE Model provides a guide for planning by presenting the procedure model users may use to project nursing requirements and resources. Given the procedure, it is up to the model users to make the projections based on the opinions and judgments of experts. |

FIGURE 2.3: NURSE SUPPLY COVERAGES OF THE DIVISION OF NURSING MODELS

| | |
|---|---|
| VECTOR MODEL | The Vector model provides only nurse requirements forecasts, so the model user must have available independent supply projections in order to derive estimates of future nursing shortages or analyses. In the final report of the Vector project, nursing requirements forecases under various scenarios are compared with recent nurse supply projections made by the Bureau of Health Manpower. However, the authors of the model do compare their requirements forecasts with recent nurse supply projections made by the Bureau of Health Manpower. These comparisons are discussed in the final report of the Vector project. |
| CSF MODEL | The CSF model includes an independent nurse supply submodel for forecasting both the active and licensed supplies of RNs and LPNs at the substate level. This submodel is a modified version of a national model of licensed nurse supply developed previously by Research Triangle Institute. Inputs to the submodel are the following: age-specific activity rates and survival probabilities; and projections of new graduates, new foreign nurses, reinstatements, new endorsements, license expirations, and nurse migration. Outputs of the submodel are the supply of full-time equivalent LPN and RN personnel. |
| PUGH-ROBERTS MODEL | The nursing employment sector of the Pugh-Roberts model consists of specifying how key variables chosen determine the number of licensed nurses, including new graduates, who are employed or seeking employment who are willing to take available jobs at each job setting; the number of nurses quitting to take other than nursing jobs; the number of nurses retiring or becoming inactive; and the number of immigrant nurses. Determination of the above would enable model users to project the effective rate of nurses' supply at each point in time. |
| WICHE MODEL | The WICHE model's projection of nurse resource is based on an injection-leakage model of nurse supply. Given the number of active nurses in the base year, the supply projection is to be made by adding the estimated number of nurses expected to enter the supply pool, and then subtracting the number of those expected to leave the pool. The inflows or injections are expected from three sources: new graduates from nursing schools; inactive nurses becoming active; and immigrating nurses. The outflows or leakages are expected from four sources: retirement, including those becoming temporarily inactive, and death; suspension of license; reeducation; and outmigration. |

can be used to project the number of people entering the active nurse supply pool, as well as those leaving it, so that nurse supply forecasts can be made on the basis of these projections.

Figure 2.4 was prepared to show that the demographic coverages among the four models are similar, except that the Pugh-Roberts model includes fertility and death rates in addition to age categories. The other three models all include age, race or ethnicity, and income, with the Vector model adding family status. Care should be taken, however, to point out that the demographic coverage relevant to the CSF model is the service area of each of the institutions for which employment or requirements are to be projected, whereas for the other three models the relevant geographic coverage is the political area under consideration (such as an HSA, a state, or the nation).

The two final summary comparison figures are closely related. Figure 2.5 displays the types of nursing personnel handled by each of the models, whereas Figure 2.6 shows a comparison of the variety of employment settings addressed by the models. In neither set of comparisons should the conclusion be drawn that because more nursing types or more employment settings are addressed by a given model, it is better in relation to the other models. The amount of detail included in the forecast is only one of several dimensions by which a model must be judged, and reliance on this dimension for a judgment in the absence of other dimensions, such as accuracy, cost of implementation, and so forth, is not advocated.

In examining both final figures, it must be pointed out that the assignments of coverage in many instances is only approximate because of the differences in definitions among the models. At the same time, the array of "x" for each model describes only the marginal distribution of coverage and not joint distributions. That is, an indication of coverage of both RNs and LPNs, and an indication of coverage by a variety of nursing specialties (or educational background or employment setting) does not indicate that both RNs and LPNs are projected by these specialties (or educational background or employment setting). For this level of detail, reference must be made to the descriptions in Chapter 3.

Figure 2.5 shows that all models are capable of providing forecasts of RNs as well as LPNs. In addition, all models except Pugh-Roberts are designed to forecast nursing aide requirements. Only the Pugh-Roberts and WICHE models track nurses by educational background, while only these two plus the Vector model track nurses by type of position or functional role in the job market. The last manpower type category on Figure 2.5 is patient care specialties. A number of specialties are covered among the models, although only ambulatory care nurses are included in all four models. Many of the specialties indicated herein were determined by implication from the employment settings indicated in Figure 2.6, so some inconsistencies

FIGURE 2.4: DEMOGRAPHIC COVERAGES OF THE DIVISION OF NURSING MODELS

| | |
|---|---|
| VECTOR MODEL | The Vector model includes a population module that projects the future U.S. population in terms of the type of health insurance coverage offered to individuals in specific age/sex/family income/family status cohorts. This module consists of four submodels: (1) A population submodel that projects the future U.S. population in terms of age, sex, family income, and family status groupings. This submodel merges Bureau of Census projections of the distribution of age and sex cohorts over time with Census statistics on the income distribution of the population. (2) An HMO submodel that projects the number of persons enrolled in HMOs by age and sex in each year. (3) A health insurance submodel that describes the fraction of each population cohort that is eligible for health insurance plans. (4) A health consumer submodel that combines the outputs of the first three submodels to produce the output of the population module. |
| CSF MODEL | The CSF model uses census tract or county level data as inputs to the submodels that forecast health service utilization in acute care long-run care institutions. These data characterize the population in terms of age, sex, ethnicity, and income and are adjusted to provide approximate coverage of each institution's patient service area. |
| PUGH-ROBERTS MODEL | The demography sector of the Pugh-Roberts model presents the Nation's population in terms of its total size and distribution among 10 age categories, and the fertility rates and death rates for members of each age category. The number and age distribution of immigrants is also presented. |
| WICHE MODEL | In the WICHE model, population is to be projected by three age groups, three races or ethnicities, and two income groups. |

FIGURE 2.5: DIVISION OF NURSING MODEL FORECASTS OF NURSING REQUIREMENTS BY NURSING MANPOWER TYPES

| | VECTOR MODEL | CSF MODEL | PUGH-ROBERTS MODEL | WICHE MODEL |
|---|---|---|---|---|
| **TYPES OF PERSONNEL** | | | | |
| Registered Nurse | X | X | X | X |
| Licensed Practical (vocational) Nurse | X | X | X | X |
| Nursing Aide, Orderly, and Attendant | X | X | | X |
| **EDUCATIONAL BACKGROUND (RNs)** | | | | |
| Associate Degree | | | X | X |
| Diploma | | | X | X |
| Baccalaureate | | | X | X |
| Postbaccalaureate | | | X | X |
| **TYPE OF POSITION** | | | | |
| Administrator | | | | X |
| Consultant | | | | X |
| Researcher | | | | X |
| Instructor | | X | X | X |
| Quality Control Specialist (patient assessment, utilization review, and so forth) | | | | X |
| Patient Care | | | | |
| General Staff Nurse | | X | X | X |
| Clinical Specialist | | X | | X |
| Nurse Practitioner | | X | | |
| **PATIENT CARE SPECIALTIES** | | | | |
| Ambulatory Care Nurse | X | X | X | X |
| Critical Care Nurse | | | | X |
| Emergency Care Nurse | | X | | X |
| Geriatric Nurse | | | | |
| Home Health (visiting) Nurse | | X | X | X |
| Industrial Nurse | | | X | X |
| Medical/Surgical Nurse | X | | | X |
| Maternal-and-Child Health Nurse | | | | |
| Mental Health (psychiatric) Nurse | X | | | X |
| Nurse Anesthetist | | | | |
| Nurse-Midwife | | | | |
| Obstetrical/Gynecological Nurse | X | | | X |
| Office Nurse | | X | X | X |
| Oncological Nurse | | | | |
| Pediatric Nurse | X | | | |
| Private Duty Nurse | | X | X | X |
| Public Health Nurse | | X | X | X |
| School Health Nurse | | | X | X |

FIGURE 2.6: DIVISION OF NURSING MODEL FORECASTS OF NURSING REQUIREMENTS BY EMPLOYMENT SETTING

| | VECTOR MODEL | CSF MODEL | PUGH-ROBERTS MODEL | WICHE MODEL |
|---|---|---|---|---|
| INPATIENT FACILITY | | | | |
| Hospital | X | X | X | X |
| General hospital | X | X | X | X |
| Medical/surgical unit | X | | | X |
| Pediatric unit | X | | | X |
| Intensive/coronary care unit | | | | X |
| Maternity unit OB/GYN | X | | | X |
| Nursery | | | | X |
| Other specialty unit (psychiatry) | X | | | X |
| Psychiatric hospital | X | | | X |
| Chronic disease hospital | X | X | X | X |
| Other specialty hospital | X | | | X |
| Nursing care and related home | X | X | X | X |
| Skilled nursing facility | X | | | X |
| Other nursing care home | X | | | X |
| NONINPATIENT SERVICE OR FACILITY | | | | |
| Hospital emergency department | X | X | | X |
| Hospital outpatient department | X | X | X | X |
| Freestanding ambulatory care facility | X | | X | X |
| Home health service | X | X | X | X |
| Public health or welfare agency | X | X | | X |
| Physician's office (private and nonprepaid group practice) | | X | X | X |
| Prepaid group practice or HMO | X | X | X | X |

among the specialty definitions of the models may be anticipated due to varying definitions with regard to the employment settings among the models.

Figure 2.6 indicates a fairly consistent coverage of employment settings among the models, although with somewhat less detail exhibited by Vector and Pugh-Roberts, particularly with respect to units within hospitals. Figure 2.6 produces only a rough guide to the comparability of the four models with respect to coverage, however. Reference to the details of Chapter 3 will reveal further differences as the definitions and schemes of categorization are identified. A very large number of potential comparisons is possible, with the number limited only by the interests of the investigator. Therefore, rather than try to anticipate each of them, and in the process introduce potential misunderstanding through attempts to reconcile the varying definitions and categorization schemes among the models, it is clear that it is more efficient for the interested reader to make his/her own comparisons from the details of Chapter 3.

## III. APPLICATION OF THE FRAMEWORK OF ANAYSIS TO THE FOUR DIVISION OF NURSING MODELS

In the preceding chapter, the four Division of Nursing models have been briefly described in an overview that summarizes the significant features of each. This chapter describes the models in terms of the major components of the analytical framework and is organized into four sections. In the first section, the four models are described in terms of the policy issues they were designed to address and are capable of addressing prospectively, their geographical coverages, and the nursing requirements concepts they utilize. In the second section, the models are described in terms of the comprehensiveness of their coverage of specific elements of the nursing and health care sectors. In the third section, the theoretical considerations underlying the development of each model are discussed. The last section describes the resources required for implementing the models. Table 3.1 presents an outline of this framework of analysis as it will be applied to the four models. The descriptive format will include indepth narrative discussions of each model's characteristics accompanied by diagrammatic presentations. As an aide to the reader, Table 3.2 is also included and presents the location of each of the descriptions referenced in Table 3.1. With the information contained in Table 3.2, this chapter may be employed by the reader either to obtain a fully structured and detailed description of each of the models or to develop comparative references between two or more of the models.

### A. PURPOSE AND USES

All four models were developed for the Division of Nursing in order to provide estimates of future nursing requirements, but each model focuses on different issues and different aspects of the requirements estimation problem. In this section, three key features of the Division of Nursing models will be described in order to provide a clear statement of the original purposes and objectives of each model. These descriptions will assist potential model users in identifying additional uses and application areas for each model by clarifying the types of forecasts each model was designed to produce and the types of policy issues that have been examined with each of the models. In particular, each model will be examined with respect to:

- geographical coverage
- the policy issues initially designed to be addressed
- the concept of nursing requirements adopted

#### VECTOR MODEL

The original purpose of the Vector project differed somewhat from that of the other three projects sponsored by the Division of

TABLE 3.1: OUTLINE OF THE FRAMEWORK OF ANALYSIS

A. PURPOSE AND USE

- Target policy issues
- Geographical coverage
- Requirements concept

B. COMPREHENSIVENESS

- Characteristics of the population
- Nurse employment settings
- Types of nursing personnel

C. THEORETICAL CONSTRUCTION

- Descriptions by module or sector

D. OPERATIONAL FEASIBILITY AND COSTS OF IMPLEMENTATION

- Computer and personnel requirements for implementation
- Data requirements

TABLE 3.2: PAGE REFERENCES TO MODEL DESCRIPTIONS

| Description Item | Model | | | |
|---|---|---|---|---|
| | VECTOR | CSF | Pugh-Roberts | WICHE |
| PURPOSE AND USE | 3.4 | 3.9 | 3.12 | 3.17 |
| Target Policy Issues | 3.5 | 3.10 | 3.15 | 3.19 |
| Geographical Coverage | 3.8 | 3.11 | 3.16 | 3.21 |
| Requirements Concept | 3.8 | 3.12 | 3.17 | 3.22 |
| COMPREHENSIVENESS | 3.23 | 3.27 | 3.33 | 3.35 |
| Population Characteristics | 3.23 | 3.28 | 3.33 | 3.36 |
| Employment Settings | 3.26 | 3.28 | 3.33 | 3.37 |
| Types of Personnel | 3.27 | 3.30 | 3.35 | 3.38 |
| THEORETICAL CONSTRUCTION | 3.43 | 3.53 | 3.59 | 3.72 |
| Description by Module | 3.43 | 3.54 | 3.60 | 3.72 |
| OPERATIONAL FEASIBILITY | 3.75 | 3.79 | 3.82 | 3.84 |
| Resource Requirements | 3.77 | 3.79 | 3.82 | 3.85 |
| Data Requirements | 3.78 | 3.80 | 3.83 | 3.85 |

Nursing. In the case of the WICHE, CSF, and Pugh-Roberts projects, the objective was the development of nurse manpower forecasting models that could be used on an ongoing basis by the Division of Nursing and other health care planning agencies. In the case of the Vector project, on the other hand, the Division of Nursing was concerned primarily with obtaining a one-time assessment of the impact of anticipated changes in the health care system on future requirements for registered nurses. The final report of the Vector project therefore consists of a discussion and interpretation of various scenarios involving specific changes in the health care system and the expected impact of these changes on nursing requirements. However, in order to undertake this analysis, Vector Research developed a large and comprehensive model of the nursing sector, and this model has subsequently been delivered to the Division of Nursing. 1/ In this section, the additional uses to which the Vector model can be put will be described in more detail.

Target Policy Issues--Vector Model

Vector Research was given a very specific mandate regarding the issues to be addressed by the project. The Vector model was, therefore, specifically designed to examine three types of health system changes:

- the implementation of selected NHI plans
- expanded enrollments in HMOs
- the possible reformulations of nursing roles

The implementation of NHI is expected to increase the amount demanded of health services by decreasing the perceived price of these services from the point of view of the consumer. The measure of price used by the model is the effective coinsurance rate (that is, the average fraction of expenses paid directly out-of-pocket by the consumer). This coinsurance rate serves to define the type of NHI plan being considered. Thus, in order to examine the effects of a NHI plan on nursing requirements, the model user can specify a parameter value that corresponds to the coinsurance rate under the plan. This coinsurance rate is then used to compute the price effects on per capita amounts demanded resulting from implementation of the plan and the corresponding effects on nursing requirements. The model user can further define the type of NHI plan by specifying the year in which it is adopted and the period of time over which it is phased into existence.

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1/ Although the discussion will be carried on as if there was a single Vector model produced, two models were actually prepared. See the discussion under Geographical Coverage, below, for the reasons for this approach.

The effects of HMO enrollment growth on nursing requirements can also be estimated with the Vector model. In order to examine a particular enrollment growth scenario, the model user can specify an HMO formation rate (the number of HMOs that become operational each year) that is used to compute the number of HMO enrollees for each year of the forecast period. The growth in HMO enrollments will influence nursing requirements in hospital inpatient departments and HMO clinics 2/ because of differences in the per capita health service demands of HMO enrollees and those of non-HMO enrollees. Therefore, different HMO formation rates will result in different nursing requirements forecasts for the hospital inpatient and HMO clinic settings.

Various nurse role reformulation scenarios can be simulated with the Vector model in a manner similar to that for the other two health system changes. That is, the model user can specify values for input parameters that are intended to measure the degree of acceptance of three types of role reformulation concepts: institution of primary nursing, new role for clinical nurse specialists, and expansion of the nurse practitioner role. In this case, the model produces separate results that estimate the effect of role reformulation on requirements for LPNs and aides as well as for RNs in new and traditional roles.

In addition to these three issues, which the Vector model was specifically designed to examine, the model is capable of addressing other related issues as well. Since the model estimates the changes in health services demands on the basis of changes in the price of these services to the consumer, this provides a means of examining the effects of future trends in the type and extent of private health insurance coverage, as well as the implementation of NHI. For example, if trends in private health insurance are toward introducing greater amounts of deductibles while lowering the coinsurance rate, then it is expected that the price effect will result in changes in the rate of utilization of health services. Thus, by providing the model with the appropriate price input data, it can be used to forecast the direction and magnitude of such changes. Also, since the model includes inpatient and nonpatient settings, it is expected that the model will be able to estimate the impact of changing the amount of deductibles and coinsurance on the relative utilization rate of inpatient care versus noninpatient care.

One of the most important issues of health care today is the question of the optimum mode of delivery of health care in terms of its effect on health care costs. In relation to this issue, since the Vector model specifically examines the effect of increasing

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2/ It is assumed that HMO enrollees use outpatient services in the HMO clinic, rather than in hospital outpatient departments or physicians' offices.

enrollment growth, the model can be used to examine the whole issue of fee-for-service and capitation payments, as it relates to the pattern of health care utilization and the costs of health services. For example, some of the Nation's labor unions and employers are negotiating with insurance carriers on the mode of payment to the providers of health services. If an increasing number of providers accept payment on a capitation basis, the model can be used to estimate the effect on health care costs and the pattern of healthcare utilization. This can be done by providing the model with data on the number of individuals expected to be covered by health care plans involving payment on a capitation basis.

These are, of course, only two examples of the ways in which the Vector model can be extended to address additional issues. These two examples are intended to be suggestive only, since the nature of the model is such that a wide range of potential applications is possible.

In summary, it can be seen from this discussion that the structure of the Vector model enables model users to incorporate into the forecasts their own assumptions concerning the timing and magnitudes of the health system changes referred to previously. That is, the model user can choose values for certain input parameters of the model that define the types of health system changes being considered. In this way, various scenarios can be simulated with the model, and the resulting effects on nursing requirements can be estimated.

### Geographical Coverage--Vector Model

In order to examine the effects of these specific health system changes on nursing requirements at both the national level and the state level, two separate versions of the Vector model were developed. Both versions of the model address the same policy issues and are the same in all respects except for the level of geographical coverage and the sources of input data. In fact, the model builders point out that the state-level forecasts have been aggregated to national totals that were in close agreement with the forecasts produced by the national model. In this sense, the state model "supersedes" the national model, and it is the state version that is intended to be used on an ongoing basis by the Division of Nursing and other health care planning agencies. Since the state and national models differ only with respect to the level of aggregation, all discussions will apply equally well to both versions of the Vector model.

### Nursing Requirements Concept--Vector Model

The Vector model produces nursing requirements forecasts for six different employment setting by applying nurse staffing ratios (for example, the number of RNs per unit of service) to projected health service demands for each setting. The resulting forecasts are intended to represent the number of nurses that would have to be employed to meet the projected health service demands and to "retain the current level or maintain the current trends in the amount of nursing care provided to the population". 3/ As a result, the staffing ratios used by the model are based on actual employment data and reflect existing practices in providing nursing care.

By employing this definition of nurse requirements, the Vector model produces forecasts "without regard to any concomitant or exogeneous constraints on the availability of nursing resources to meet these requirements". 4/ There is no concept of market equilibrium adjustment contained in this definition, and nurse supply is considered to be completely elastic. Of course, Vector Research recognizes that this assumption is unrealistic, but it believes that it allows reasonable forecasts of nursing requirements to be produced, against which independent supply forecasts can be compared in order to guide national supply policies.

CSF MODEL

The overall objective of the CSF project was to produce a nurse manpower forecasting model to be used as a planning tool at the substate (such as county and multiple-county) level. In addition, the model was to incorporate demand and supply factors on an independent basis into a framework for estimating future nursing shortages or surpluses, and was to focus on institutional settings as far as data availability permitted.

Target Policy Issues--CSF Model

The model was designed to be of general use to HSAs and other planning agencies concerned with the distribution and availability of nursing resources within the state. Given the structure of the model, it is possible to identify several issues that it is capable of addressing. As will be explained below, the forecasts of nursing demand in acute care and long-term care settings depend on certain intermediate forecasts of health service utilization in these settings. These utilization forecasts depend, in turn, on input data provided by the model user that describe the characteristics of the population and the health system of the substate area over the forecast period. By providing appropriate values for these input data, the model user can examine, for example, the effects of different trends in the age or income distribution of the population, the number of hospitals and nursing homes, mortality rates,

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3/ The Impact of Health Care System Changes on the Nation's Requirements for Registered Nurses in 1985, Vector Research, Inc., Ann Arbor, Michigan.

4/ Ibid, p.1.

and so forth. The resulting nursing demand forecasts can then be compared with independent nurse supply projections, also produced by the model, in order to determine the likelihood of future nursing shortages or surpluses.

In the case of the nurse supply forecasts, the model user must provide input data that describe several major determinants of change in the future supply of nurses, such as new graduates, activity rates, nurse migration, and so forth. Therefore, to the extent that nursing education and other programs can be expected to influence these supply determinants, the model can also be used to examine the likely effects of various proposed nursing supply policies.

Geographical Coverage--CSF Model

The original intention of the CSF model builders was to develop individual submodels capable of producing institution-specific forecasts of nursing demand, which could then be aggregated to the county, multiple-county, or, possibly, state levels. However, because of limited data availability, this approach was not entirely feasible. Institution-specific nurse demand submodels were constructed for two of the four employment settings covered by the model (acute care and long-term care settings). The county level is the smallest geographical unit for which nurse supply forecasts are produced. Therefore, in order to derive estimates of future nursing shortages or surpluses, the nurse demand forecasts for the acute care and long-term care settings must be aggregated to the county level as well.

By working from these county-level forecasts, it is, of course, possible to aggregate to the multiple-county or state levels. However, since state-level forecasts would require that institutional forecasts be produced for every acute care and long-term care institution within the State, the required data preparation and analysis would make implementation impractical.5/ In addition, it was anticipated at the outset of the project that the model would produce only gross estimates of nursing demand at the institutional level, and this was confirmed through testing and evaluation. Therefore, based on tests of the model at three sites, 6/ the model builders suggest that optimal application of the model would be at the Standard Metropolitan Statistical Area (SMSA) or multiple-county planning levels.

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5/ Should a computationally efficient model for state-level forecasts be required, the model builders recommend that the existing data base be used to create county or state-level nursing demand models.

6/ The CSF model was implemented at sites in New Mexico, Washington, D.C., and Madison, Wisconsin.

Nursing Requirements Concept--CSF Model

The nursing demand or requirements forecasts referred to above are produced for four types of nurse employment settings: acute care, long-term care, ambulatory care, and community and public health care. For the acute care and long-term care settings, the nursing requirements concept adopted corresponds to the number of nurses that would have to be employed to meet projected levels of health service demand in these settings, 7/ while maintaining current standards of nursing care. That is, the model applies nurse staffing ratios to the projected number of patient days of care demanded in acute care and long-term care institutions that are based on existing practices in the specific types of institution being modeled. For the ambulatory and community and public health care settings, a different modeling approach was used because of the lack of adequate data on the utilization of health services in these settings. However, the requirements concept is similar to that used for the acute care and long-term care settings in that the forecasts of nursing requirements are based on projections of historical nurse employment data.

PUGH-ROBERTS MODEL

The Pugh-Roberts model consists of a set of causal relationships represented by a set of equations in the DYNAMO simulation language. These relationships fall into four interrelated and interdependent sectors:

(1) Nurse education sector - represents relationships showing how various factors affect the number of students in each major type of educational program for nurses, the graduation rates from these programs, and the number of nursing school faculty required

(2) Nurse employment sector - represents relationships showing how various factors affect the number of nurses employed in each setting and various characteristics of employment in each setting, such as nurses' wages and nurses' roles

(3) Demand sector - represents relationships showing how various factors affect the health care provided in each sector of the health care delivery system, the nursing needs, and nursing jobs available in each employment setting

(4) Demographic sector - represents key demographic characteristics of the total population and nurse population and how they affect the other sectors of the model, principally the demand sector

7/ These health service demand projections are produced by separate submodels included in the CSF model. See below.

Figure 3.1 provides a schematic view of the model. The key population characteristics specified in the demographic sector influences the health care need of the Nation's population and, therefore, the demand for health services. This, in turn, influences the demand for nurses. On the supply side, the population characteristics influence the number of applicants to nursing education programs, and thereby influence the supply of nurses. The difference between the demand for and the supply of nurses becomes the net nursing requirements.

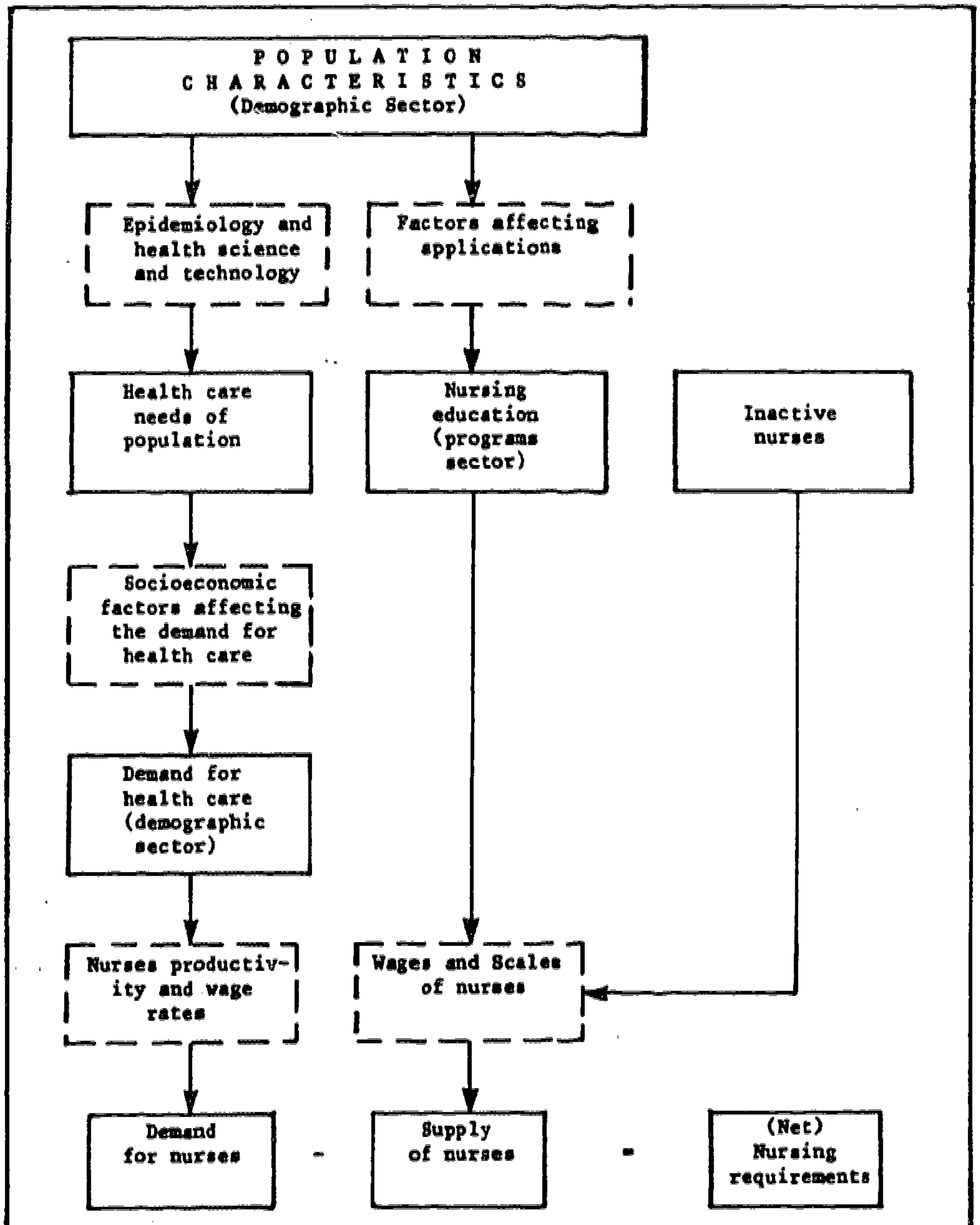
Whereas earlier modeling efforts projected requirements or supply separately, the Pugh-Roberts model specified the relationships between demand and supply factors in each sector jointly. Thus, the model represents nursing and health care sectors more realistically as they exist now and as they are likely to be over the next few years. In portraying nursing and health care sectors in the future, certain developments are built into the model's baseline assumptions and others are treated as policy variables, the effects of which are to be analyzed by simulations. The primary objective of the Pugh-Roberts model is to provide a tool to analyze the effects of policy variables on the Nation's supply, requirements, and distribution of nurses across employment settings. In this subsection, the major policy issues addressed by the model will be discussed, and the requirements concept used by the model will be clarified.

Target Policy Issues--Pugh Roberts Model

The Pugh-Roberts model is not addressed to specific policy issues. Rather, it is designed to examine and analyze a wide variety of issues. Its strength lies in its ability to evaluate and conduct comparative analyses of the relative effects of alternative policies. There are some issues the model has specifically examined because it is thought that these issues are important and can be analyzed effectively by the model. Important issues addressed and examined by the Pugh-Roberts model are:

- relative effects of the NHI programs on the demand for hospital and nursing home care versus ambulatory and home care and their resulting effects on the demand for nurses in these settings
- effects of the imposition of strict utilization controls on the demand for hospital and nursing home care versus ambulatory and home care and their resulting effects on the demand for nurses in these settings
- effects of expanding nurses' responsibilities (such as autonomy and complexity of tasks) on staffing patterns of RNs in hospitals and nursing homes versus in other settings and on the composition of nurses' educational preparations

FIGURE 3.1: A SCHEMATIC VIEW OF THE REQUIREMENT CONCEPT OF THE PUGH-ROBERTS MODEL*




* As interpreted and simplified by Applied Management Sciences.

- effects of expanding nursing involvement in ambulatory care, home health and public health settings on the labor mix in the production of health services, as represented by RN-MD and RN-physician associated ratios

- effects of upgrading nursing education on the educational composition of nurses in various employment settings

- effects of increasing nursing personnel input per output, represented by RN-patients and RN-office visit ratios, on the demand for nursing personnel

- effects of an increasing rate of population growth on the demand for nursing personnel

- effects of changing structure of nurses' wage rates, by educational preparations and employment settings, on the occupational distribution of nurses.

As can be seen from the above listing of issues, the Pugh-Roberts model can estimate, through simulations, the effects of a wide variety of possible new developments and policy interventions on the demand for and the supply of nurses at each employment setting. For example, the model can be used to analyze the effects on the demand for nurses of the implementation of a national hospital cost control program as it affects the demand for and supply of hospital services. Another potential use of the model will be to analyze the combined effects on health and nursing sector of the NHI program coupled with the imposition of utilization and cost controls of hospitals. Since the Pugh-Roberts model consists of differential equations, its strength lies in being able to estimate the partial impacts on nurse supply and demand of various policy issues jointly implemented.

Geographical Coverage--Pugh-Roberts Model

The Pugh-Roberts model is a national model. It forecasts the nurse demand and supply at the national level. The model analyzes the effects of various policies on the Nation's health care and nurse sector over time. It is not concerned with the geographical distribution of nurses. However, the Pugh-Roberts model deals with the nurse distribution between employment settings and between educational programs.

Nursing Requirements Concept--Pugh-Roberts Model

The Pugh-Roberts Model, illustrated in Figure 3.1, incorporates a dynamic, market-oriented requirement concept. The model differentiates among the need for nursing personnel (the desirable number for serving the population's health care needs), the demand for nursing personnel (positions made available by employers in response to actual use, perceived need, and nurses' wage rates), and supply. Supply--the number of nursing personnel actually employed or available for employment--is influenced by the number of positions available, the nature of nursing education programs, the nurses' willingness to accept positions, and wage rates. The net nursing requirement is the difference between demand and supply. Given the baseline assumptions, the demand for nursing personnel (positions made available) and the supply of nurses (those actually employed) in various employment settings can be projected through simulation techniques. The impacts of various policies can be examined by modifying the projections in terms of changes in the key variables. Thus the net nursing requirement, or the difference between demand and supply in the nursing market, indicates not only the additional number of nurses required to bring the market into equilibrium but also the implied actions required to increase the supply.

WICHE MODEL

The WICHE model is a process that can be used to make projections of nurse requirements and resources. The model is designed to be a guide for nurse manpower planning at the state and substate level. The process designed by the model serves as a planning guide not only because it enables the model users to make nurse manpower projections in a systematic way, but also because the steps to be taken to use the process calls for inputs of a panel of experts on a variety of issues. In fact, such a panel plays a pivotal role in arriving at projections and in clarifying the various issues involved in making projections according to the WICHE process.

The key feature of the WICHE model is its reliance on the "assumptions" to be made in making various projections. The assumptions are estimates of the relationships between key variables. The primary function of a panel of experts is to make these estimates through mutual consultation and discussion using background data and information provided by the model. In this respect, the outcome of the model projections is a direct function of the selection and composition of the panel members who are controlling the process. The panel members are selected so that they bring with them diverse perspectives: nursing education, nursing service, higher education, health planning, and consumer interests. Emphasis is on the first three.

A rationale for relying on the judgment of a panel of experts in making projections lies in the fact that these experts are likely to be the people who will also be involved in local and state planning. By involving these people in obtaining the assumptions and projections, therefore, the model enables them to make planning decisions in a more systematic and informed way. Another rationale for the reliance on expert judgment is that, of all health professionals, registered nurses are likely to be performing tasks that tend to underutilize nursing as a manpower resource. At the same time, the variation in educational preparation within nursing is likely to result in a substantial variation in the degree to which many given tasks are performed relative to the ideal. The degree of underutilization of nursing resources in terms of the types of tasks undertaken is largely a function of management trends and evaluation, whereas the mean performance of nurses on individual tasks is largely a function of the level of educational preparation provided to nurses. Given the qualitative and subjective nature of these trends and these relationships to nursing performance (and nursing requirements), a climate is created whereby expert judgment can be most effectively used in a panel approach to the generation of nurse requirements.

Target Policy Issues--WICHE Model

There are three broad issues to which the WICHE model is addressed. They are:

- meeting state requirements for total nursing personnel
- meeting state requirements for the appropriate staffing patterns of nurses in terms of job settings
- developing the appropriate nursing educational programs to meet state required staffing patterns.

The first policy issue is the most important issue addressed by the WICHE model. The model approaches this issue by raising the question: "How many nurses are required to provide the volume of health services needed to treat the projected prevalence of illness of the state's population, and will the number of the nurses forthcoming match that required?" The WICHE model attempts to answer this two-part question by providing policymakers with systematic procedure for making projections of nursing requirements and resources.

For making requirements projections, the model postulates that the volume of health services required to treat a given prevalence of illness of the state's population is to be decided by model users according to their stipulated health care goals. Then, given the required volume of health services thus obtained, model users can project the number of nurses required to provide this amount of health care based on estimates of future nurse staffing ratios (say, through historical trend projections). On the nurse supply side, the WICHE model proposes an injection-leakage method of forecasting nurses supply in the state. The requirements and resources projections together will provide policymakers with forecasts of either nurse shortages, surpluses, or optimum supplies. This would enable them to take appropriate actions according to their stipulated health care goals.

The WICHE model goes further than simply providing policymakers with tools to make forecasts of nurse shortage or surplus. Thus, by discussing and providing the data on the factors affecting the number of the graduates from nurse education programs, the interstate migration of nurses, the decision to retire or reenter nursing profession, as well as other factors, the model helps policymakers to systematically formulate strategies to influence nurse supply.

The WICHE model addresses the issue of insuring appropriate distribution of nurses among different employment settings by providing policymakers with a tool to forecast nursing requirements and resources in each of the 33 employment settings that the model specifies. In making the nurse-requirements forecast by employment setting, service-specific projections of health care need are necessary. Because the mix of nurse employment setting is determined by specifying the process of projecting service-specific volume of health services required, the model enables model users to forecast the nursing requirements by employment setting and by the type of nursing personnel needed. Given the projections of nursing requirements by employment setting, the WICHE model helps policymakers to formulate policies designed to meet these requirements by discussing and providing data on the factors influencing nurses' education and job choices.

In order to achieve the optimum mix of types of nursing personnel, nurse educational programs that will provide the appropriate skill-mix for their graduates must be developed. The WICHE model addresses this issue by providing a procedure to forecast the number of persons graduating from each of the five levels of nurse education programs. Again, the model helps policymakers develop appropriate nurse education programs in terms of achieving the optimum skill-mix of their graduates by discussing and providing data on the factors affecting the number of applicants to each program and that of places available. Given the information about the decisionmaking process involved in entering a specific nurse education program, the policymakers will be better able to formulate strategies to insure the appropriate skill-mix of the graduates of the nurse education programs.

The most fruitful potential uses of the WICHE model lie in providing policymakers with general information about the nursing sector and what is involved in making nurse manpower projections. The user's manual for generating the data profile, for example, provides valuable information for planners about what kind of data are needed to make projections of nurse requirements and resources and where such data may be found.

Geographical Coverage--WICHE Model

The WICHE model is designed to serve as a guide for planning at the state level. However, the process can be used for making projections in any substate level. The geographical coverage at substate levels depends on the model users' interests and objectives. Health planning at the substate level is usually conducted by an HSA and the model will be well suited to be used for nurse manpower planning at that level. The model is extremely flexible in terms of its geographical coverage.

Nursing Requirement Concept--WICHE Model

Requirements in the WICHE model refers to the number of personnel that will be needed to meet the user's stipulated health care goals. The goals are set on the basis of projections of the health services required to treat illnesses in age-race and ethnicity-income specific population projections.

This is a goal-oriented, or normative, concept of requirements, which should be distinguished from the market demand concept. According to the latter concept, the number of nurses required to meet the demand for nurses is determined by the consumers' demand for health services, which in turn is determined by the consumers' perception of the need to receive health care and their ability and willingness to pay for this care.

A normative concept of nurse requirements is based on the community's perceived need of health services according to a stipulated health goal. Given the volume of health care needed to meet the goal, nurse requirements may be projected on the basis of a stipulated nurse staffing ratio.

## B. COMPREHENSIVENESS

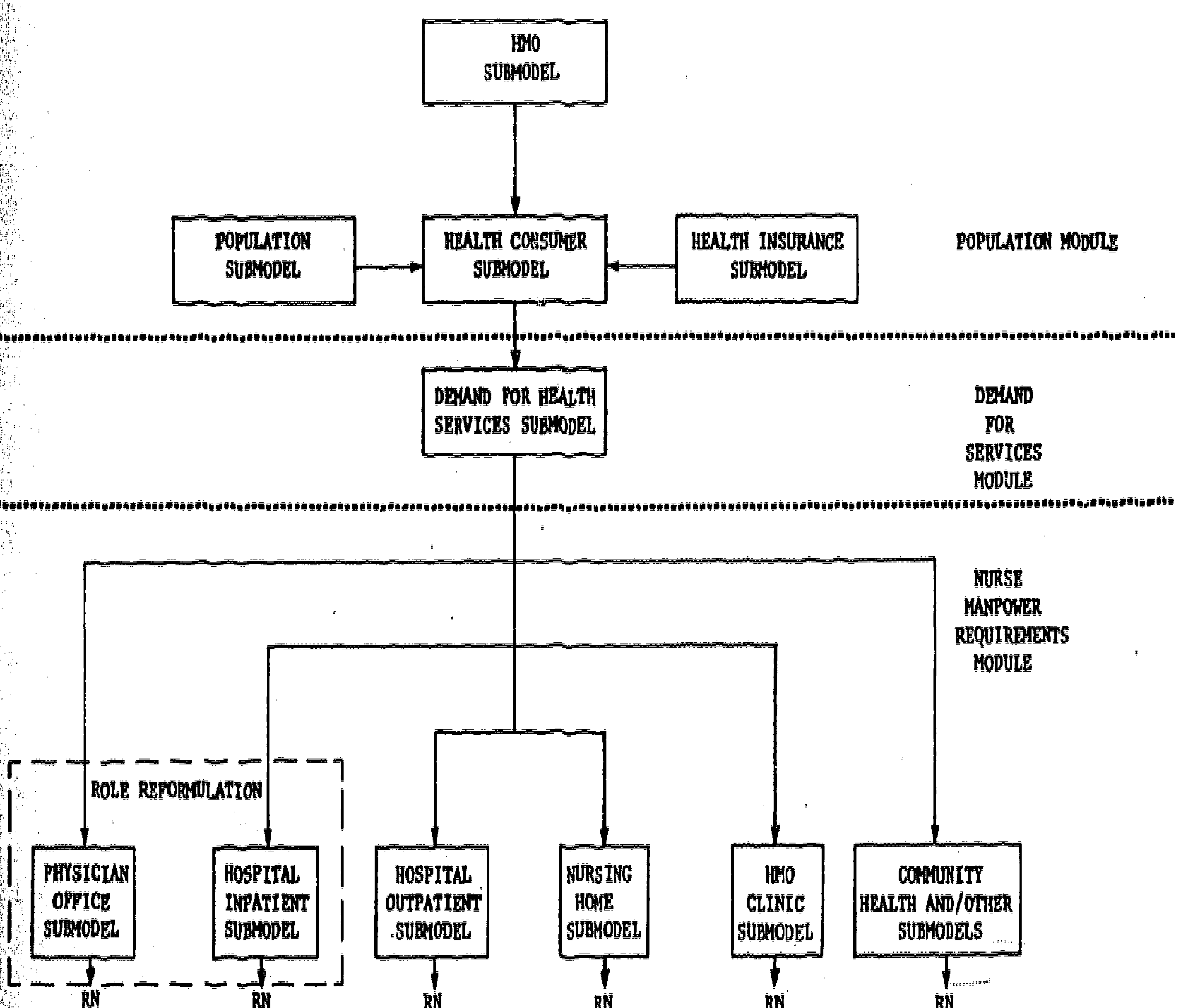
In this section, the Division of Nursing models will be described in terms of the comprehensiveness of their coverage of the nurse market and related health care sectors. A brief description of each model's overall structure will be provided in order to indicate the various sectors of the health care system which are represented by each model. Then, the specific inputs and outputs of the models will be identified in order to focus on five specific categories of model coverage:

- demographic characteristics of the population
- nurse employment settings
- types of nursing personnel

VECTOR MODEL

As indicated in Figure 3.2, the Vector model consists of three modules: a population module, a demand-for-services module, and a nurse manpower requirements module. The following discussion will

FIGURE 3.2: THE STRUCTURE OF THE VECTOR MODEL



describe the outputs of each of these modules as shown in Table 3.3 and will focus on the model's coverage of the population, nurse employment settings, and types of nursing personnel.

Characteristics of the Population--Vector Model

Projections of the future populations of health care consumers are produced by the population module, which consists of four submodels as shown on Figure 3.2: a population submodel, an HMO submodel, a health insurance submodel, and a health consumer submodel. The outputs of these submodels are combined to produce projections of the future population as characterized by age, sex, family income, family status, and health insurance coverage (including HMO enrollment) cohorts.

The population submodel essentially merges Bureau of Census projections of the distribution of age and sex cohorts over time with census statistics on the 1972 income distribution of the population. The output of this submodel is a projection of the future population in terms of age, sex, family income, and family status. The HMO submodel projects the annual number of people enrolled in HMOs by age and sex for each year of the forecast period. These projections of HMO enrollment growth depend on an assumed HMO formation rate, which is an input to this submodel that must be specified by the model user. The health insurance submodel describes for each population cohort, the proportion of the population eligible for health insurance benefits under the types of insurance plans being considered. Finally, as indicated in Figure 3.2, the health consumer submodel uses the outputs of the first three submodels to produce the output of the population module described in Table 3.3.

Nurse Employment Settings--Vector Model

Nursing requirements by employment setting are estimated largely on the basis of the outputs of the demand-for-services module. This module computes the demand for health services by provider setting for each year of the forecast period. This is done by applying a large array of per capita demands to the projected numbers of individuals estimated from the population module. For each population cohort, the projected population is multiplied by the appropriate projected per capita demand for each type of health service. These health service demands are then aggregated over population cohorts to produce the total demand for health services in each of the provider settings listed in Table 3.3.

Notice that Table 3.3 lists six separate settings in which health service demands are estimated; yet, it also lists nine employment settings for nursing requirements. This is because nursing requirements in the community health, non-short-term general hospital, private duty, and nursing education settings are estimated independently of the outputs of the demand-for-services module.

TABLE 3.3: FORECASTS PRODUCED BY THE VECTOR MODEL

Output of the Population Module

Projections of future population cohorts in terms of:

1. Age (0-16, 17-24, 25-44, 45-64, 65+)
2. Sex
3. Family income (<3K, 3K-5K, 5K-7K, 7K-10K, 10K-15K, >15K)
4. Family status (unrelated, in family)
5. Insurance coverage (current public/private plans, national health insurance, HMO enrollment)

Output of the Demand-for-Services Module

Projections of health service demands in the following provider settings:

1. Non-Federal short-term hospital inpatient units
2. Hospital outpatient and emergency units
3. Physicians' offices
4. Nursing care homes
5. HMO clinics
6. Home health care

Output of the Nurse Manpower Requirements Module

Projections of requirements for nurses in the following employment settings:

1. Non-Federal short-term hospital inpatient units
2. Hospital outpatient and emergency units
3. Physicians' offices
4. Nursing homes
5. HMO clinics
6. Community health (home care, boards of education, occupational health, other community health)
7. Non-short-term general hospitals
8. Private duty and other
9. Nursing education

Nursing requirements in these settings are based on projections of historical employment data. For the other settings, separate submodels in the nurse manpower requirements module estimate the number of nurses that would have to be employed in order to meet the projected health service demands. These nurse requirements estimates are in terms of both full-time equivalent positions and total numbers employed.

## Types of Nursing Personnel--Vector Model

As indicated above, nursing requirements by employment setting are estimated in the six submodels contained in the nurse manpower requirements module. These submodels can be used to forecast requirements for either RNs or LPNs.8/ The Vector Model does not explicitly distinguish RN requirements according to the level of educational preparation. However, although not indicated in Figure 3.2, the model does estimate the requirements for RNs in three types of extended roles. Specifically, the model estimates the additional requirements for RNs in primary nursing, clinical specialist, and nurse practitioner roles. The requirements for RNs in primary nursing and clinical specialist roles are estimated for the hospital inpatient setting and the requirements for RNs in the nurse practitioner role are estimated for the physicians' office setting. Also, in addition to estimating the effect of role reformulation on RN requirements, the model is capable of presenting separate results that estimate the effect on requirements for LPNs and aides as well.

## CSF MODEL

In order to describe the comprehensiveness of the CSF model in terms of the coverage of the forecasts produced by the model, it is necessary to indicate that the model's overall structure is inherently different from those of the other models. The forecasts are in large part institution-specific rather than population group-specific. That is, requirements forecasts of the model are based on forecasts of the demand for health services for several specific types of acute care and long-term care institutions (to be described in more detail below). These forecasts are based on input data describing the population and health system characteristics of each institution's patient service area. The institutional demands for nursing personnel are then found by applying the appropriate nurse staffing ratios to the health service utilization forecasts for the institutions.

Because of the institutional approach to forecasting used by the CSF model, the population groups of interest vary by institution type, and can assume most any set of characteristics combination deemed necessary for the institution, although typical characteris-

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8/ As explained below, the state version of the Vector model is not operational for LPN requirements forecasts.

tics, such as age, race or ethnicity, and income were used. These population characteristics are inputs to the model. Thus, the focus of this discussion will be on the population of institutions rather than health care consumer, and we can proceed directly to the discussion of employment settings for the CSF model.

Nurse Employment Settings--CSF Model

The institutional focus of the CSF model is apparent from Figure 3.3, where two of the four demand submodels are based upon analyses of institutions rather than populations (the remaining two demand submodels of ambulatory care and community and public health care settings use trend projections to get directly to nurse forecasts, without working through forecasts of service utilization). For the acute care and long-term care settings, the CSF model produces both health service utilization forecasts and nurse demand forecasts for specific types of institutions. That is, the model user can select a submodel corresponding to the particular type of acute care or long-term care institution for which forecasts are desired. Moreover, for acute care institutions, these forecasts are further divided into four clinical specialty areas within the institution: medical/surgical, OB/GYN, pediatric, and psychiatric.9/

The CSF model includes 20 submodels for acute care institutions and 8 submodels for long-term care institutions. As indicated in Table 3.4, acute care institutions were classified according to four characteristics (size, control, technology, and teaching status) and long-term care institutions were classified according to two characteristics (size and control). On the basis of this classification scheme, the 20 acute care utilization submodels and 8 long-term care utilization submodels were constructed as listed in Table 3.5. Thus, model users can select from these 28 submodels in order to generate health service utilization and nurse demand forecasts for specific acute care and long-term care institutions in each substate area.

As mentioned earlier, the acute care and long-term care nursing demand forecasts are produced for specific institutions, whereas the nursing demand forecasts for the other two settings are produced at the county level. Therefore, the institutional forecasts must be aggregated to the county (or multiple-county) level, so that the nurse demand forecasts for all four employment settings can be combined to produce the total nurse demand for the substate area being considered. Since the nurse supply submodel also produces county (or multiple-county) level forecasts, the county level is the smallest geographical area for which estimates of future nursing

9/ The model also forecasts the number of operating room procedures. However, separate forecasts of operating room demand for nurses are not provided because of lack of available nurse staffing data.

FIGURE 3.3: STRUCTURE OF THE CSF MODEL

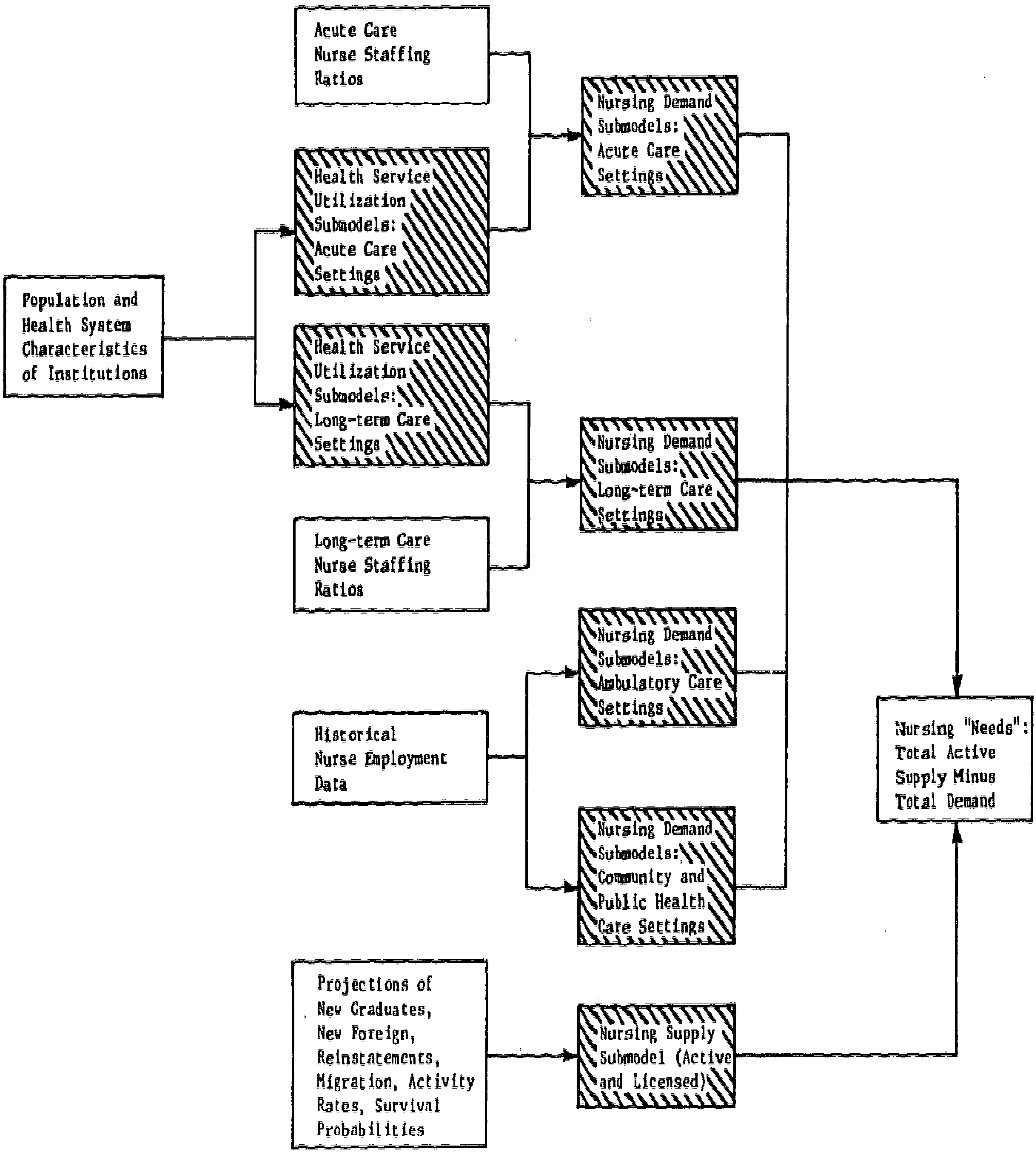

TABLE 3.4: CLASSIFICATION OF ACUTE CARE AND LONG-TERM CARE INSTITUTIONS

| Acute care setting | Long-term care setting |
|---|---|
| **Size** | **Size** |
| 1: 0-49 beds | 1: 3-24 beds |
| 2: 50-149 beds | 2: 25-49 beds |
| 3: 150-299 beds | 3: 50-99 beds |
| 4: 300+ beds | 4: 100-199 beds |
| | 5: 200-299 beds |
| | 6: 300+ beds |
| **Control** | **Control** |
| 1: Government/non-Federal | 1: Proprietary |
| 2: Nongovernment/not-for-profit | 2: Not-for-profit |
| 3: For-profit | 3: Government |
| 4: Government/Federal | |
| **Technology** | |
| 1: Low technology | |
| 2: Medium technology | |
| 3: High technology | |
| **Teaching status** | |
| 1: Teaching | |
| 2: Nonteaching | |

TABLE 3.5: SUBMODELS FOR ACUTE CARE AND LONG-TERM CARE INSTITUTIONS

Acute Care Institutions

| Submodel | Bed Size | Control | Technology | Teaching Status | Specialty Area |
|---|---|---|---|---|---|
| 1 | 0-49 | All | All | All | Med/Surg |
| 2 | 50-149 | 2-4 | Low | Nonteaching | Med/Surg |
| 3 | 50-149 | 2-4 | 2-3 | Nonteaching | Med/Surg |
| 4 | 50-299 | All | All | Teaching | Med/Surg |
| 5 | 50-299 | 1 | All | Nonteaching | Med/Surg |
| 6 | 150+ | 2-4 | All | Nonteaching | Med/Surg |
| 7 | 300+ | All | All | Teaching | Med/Surg |
| 8 | 0-49 | All | All | All | OB/GYN |
| 9 | 50-149 | 2-4 | All | Nonteaching | OB/GYN |
| 10 | 50-299 | All | All | Teaching | OB/GYN |
| 11 | 50+ | 1 | All | Nonteaching | OB/GYN |
| 12 | 150+ | 2-4 | All | Nonteaching | OB/GYN |
| 13 | 300+ | All | All | Teaching | OB/GYN |
| 14* | 0-49 | All | All | Nonteaching | Pediatric |
| | 50-149 | 1 | All | Nonteaching | Pediatric |
| 15 | 50-149 | 2-4 | All | Nonteaching | Pediatric |
| 16 | 50-299 | All | All | Teaching | Pediatric |
| 17 | 150+ | All | All | Nonteaching | Pediatric |
| 18 | 300+ | All | All | Teaching | Pediatric |
| 19 | All | All | All | All | Psychiatric |
| 20 | All | All | All | All | Operating Room |

Long-term Care Institutions

| Submodel | Bed Size | Control |
|---|---|---|
| 1 | 3-24 | 1 |
| 2 | 25-49 | 1 |
| 3 | 50-99 | 1 |
| 4 | 100-199 | 1 |
| 5 | 200+ | All |
| 6 | 3-199 | 3 |
| 7 | 3-49 | 2 |
| 8 | 50-199 | 2 |

*Two similar types of institutions were combined in order to assure complete coverage over all characteristics and maintain mutually exclusive groups.

"needs" (that is, the difference between nursing supply and demand) can be made. 10/

Types of Nursing Personnel--CSF Model

For each of the four types of nurse demand submodels shown in Figure 3.3, forecasts are produced for three types of nursing personnel: RNs, LPNs, and aides. (These forecasts are expressed in terms of full-time equivalent positions.) An original objective of the CSF project was to provide RN demand forecasts classified by the level of educational preparation. However, workload estimates for RNs categorized by educational level were not available and this classification was not undertaken.

The nurse supply submodel uses the inputs listed in Figure 3.3 to produce forecasts of both the licensed and active supplies of nursing personnel. However, the types of personnel covered by this submodel include only RNs and LPNs. The supply of nursing aides and assistants is a personnel recruitment problem for a specific institution rather than a problem of nursing planning and policymaking at the substate level.11/

PUGH-ROBERTS MODEL

The Pugh-Roberts model contains four sectors: education, employment, demand, and demographic. The comprehensiveness of the model in terms of its coverage of population demographic characteristics, nurse employment settings, and the types of nursing personnel depends on the classifications used in these four sectors.

Characteristics of the Population--Pugh-Roberts Model

The Pugh-Roberts model describes the Nation's population in terms of its total size and age distribution. The population is distributed among 10 age categories, and the model estimates the fertility rates and death rates for members of each age category. The number and age composition of immigrants is also estimated. The model does not differentiate the Nation's population by race or ethnicity, sex, or any other demographic characteristics. The primary function of the demographic sector is to project the effects of changing population size and age composition on the demand for health services, which, in turn, affects the employment and education sectors.

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10/ It was noted earlier that the most appropriate use of the model would be at the SMSA or multiple-county levels of aggregation.

11/ CSF. A Micro Model for Assessing Nursing Demand and Supply, Final Report; page 7-5. Contract No. 321-75-0814 (P). July, 1977. (National Technical Information Service HRP-0023567.)

Nurse Employment Settings--Pugh-Roberts Model

The employment settings considered by the model are classified according to the institutional setting, the type of service provided, and job category. These consist of 7 employment settings, 3 of which are further divided, so that the total number of employment settings, including the subcomponents, equals 12. The following shows how the model classifies the employment settings:

(1) Hospitals
- short-term
- long-term

(2) Ambulatory care
- physicians' offices and group practices
- outpatient departments
- community health centers and mental health centers

(3) Long-term care facilities (nursing homes)

(4) Home care agencies

(5) Nursing schools

(6) Public health settings
- public health agencies (excluding nurses providing home care)
- occupational health
- school health

(7) Private duty and other

Those nurses with licenses who are "not employed in nursing" are classified into those who are considering employment (the unemployed) and those who are not (the inactive). Finally, the model includes inactive nurses who have not renewed their licenses, so that all nurses are classified into one of 15 categories, according to employment setting, employment or labor force status, and licensure status. 12/

Types of Nursing Personnel--Pugh-Roberts Model

The Pugh-Roberts model tracks RNs and LPNs at several levels of educational preparation as they move among the various employment settings, licensure status, and labor force status combinations.

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12/ Twelve employment settings for the employed, the unemployed, the licensed inactive, and the unlicensed inactive.

The level of educational preparation for RNs is measured according to the following four types of programs:

- Associate degree
- Diploma
- Baccalaureate degree
- Advanced degree

Thus, 60 is the total number of matrix cells for the employment settings, employment and licensure status, and educational preparations of RNs. Nurses are not classified according to their function, such as direct health care or administration, which reflects a focus on factors that affect movements of nurses among the current cells, rather than on an expansion of employment settings.

WICHE MODEL

The WICHE model is a process for projecting nursing requirements and resources that serves as a guide for planning. The process can be used for making projections at the state and substate level, depending on the model users' objectives and interest. Likewise, the coverage of requirements and supply forecasts depends on the model users' intentions. The model provides the process and a great deal of background materials for forecasting 355 categories of nurses employment settings, functions, and educational preparations. As mentioned previously, the process allows various levels of aggregations.

In describing the process involved in making projections of nursing requirements and supply, however, the WICHE model provides a guide for specifically projecting the following: population by age, race or ethnicity, and income; the prevalence of ailments for each population cohort; health services needed to treat the ailments; and nurse staffing requirements to provide the health services needed. This section will describe the characteristics of the population, the nurse employment settings, nurse functions, and levels of educational preparation that are specifically included in the model's requirements and supply projections.

Characteristics of the Population--WICHE Model

The WICHE model differentiates a state's (or substate's) population according to those characteristics that are hypothesized to best differentiate among the prevalence rates of ailments in the population. The projection of a state's need for health services is then based on the application of projected prevalence rates to projections of that state's population. Nursing requirements are then projected by applying required staffing patterns to the projections of needed health services.

The population characteristics chosen by the model are age, race or ethnicity, and income. There are 3 age categories: under 17 years, 17 to 64 years, and 64 years. Although the model presents data on three categories of race or ethnicity and two income groups as background information, the model uses only age groups in its guide for requirements projections.

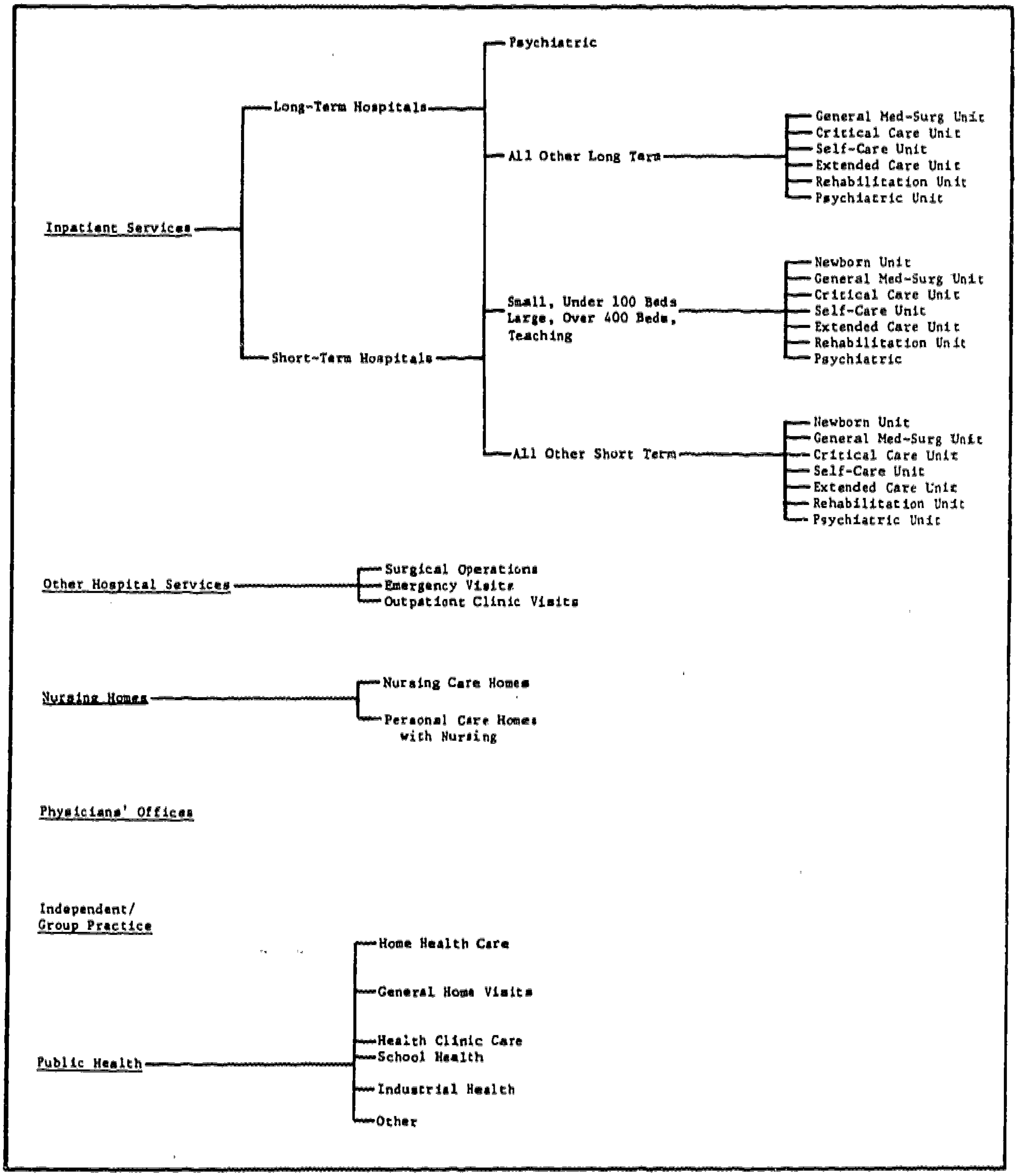
The model provides data on the relationship between the health needs/health status of the population and race or ethnicity. Based on these data, the user of the model can estimate the incidence of 38 categories of illness by race or ethnicity. These estimates, however, are not used directly in projecting the utilization rate of health services. Instead, they are to be used as background information by the panel of experts in arriving at the assumptions about the relationship between the incidence of illness and population characteristics.

Nurse Employment Settings--WICHE Model

As shown in Figure 3.4, the nurse employment settings for which the requirements projections are to be made are classified according to provider/practice settings and the types of health services provided. The WICHE model divides health services into six broad categories: inpatient services that are to be provided at long-term hospitals or at short-term hospitals; other hospitals; nursing home care; physician's office care; independent/group practice care; and community health services. Inpatient services provided at long-term hospitals are further divided into those provided at psychiatric hospitals and those provided at all other long-term hospitals. Inpatient services provided at short-term hospitals are further divided into those provided at small (under 100 beds) hospitals; large (over 400 beds) hospitals, or teaching hospitals; and those provided at all other short-term hospitals. For the above three types of hospitals, excluding long-term psychiatric hospitals, nurse employment settings are further classified by departments: six for non-psychiatric long-term hospitals; and seven, including newborn units, for each category of short-term hospitals. Thus, a total of 21 employment settings for inpatient care are provided by the model when including long-term psychiatric care.

There are three categories of services included in other hospital services for which nursing requirements are projected: surgical operations, emergency visits, and outpatient clinic visits. At the same time, there are five categories of services included in community health (public health), and two in nursing home care. Thus, when counting physicians' offices and independent/group practice each as one setting, there are 34 total employment settings considered by the WICHE model, as shown in Figure 3.4.

FIGURE 3.4: EMPLOYMENT SETTINGS OF THE WICHE MODEL ACCORDING TO THE TYPES OF SERVICES TO BE PROVIDED



According to the "worksheet" of the WICHE model, the employment settings dictate the method of projecting the nursing requirements. For example, for the provision of inpatient services and nursing home care, the projection of nurse requirements is based on the projected number of patients or residents; this, in turn, is based on estimated occupancy rates and targeted bed-population ratios. For other hospital services and independent/group practice services, the required number of nurses is projected from the volume of services to be provided; this, in turn, is determined from a target number of services per population. The number of nurses required in physicians offices is projected from the projected number of physicians and the targeted RN/MD ratios. Finally, the number of nurses required to provide community health services is projected from target nurse-population ratios that vary by the age composition of the population.

Types of Nursing Personnel--WICHE Model

The WICHE model provides for nursing requirements projections of five levels of education preparation: doctoral, masters, baccalaureate, associate, and diploma programs. Direct client care, administration, teaching, and "others" constitute the four categories of nurses' functions also covered by the model.

As shown in Figure 3.5, the nursing requirements for the provision of direct client care 13/ are projected for each of the above five levels of educational preparation and 34 job settings, where each of the hospital departments offering inpatient services is considered as a separate job setting.14/ Thus, there are 170 matrix cells for education and employment settings for RNs in the direct client category care alone. LPNs and nursing aides in direct client care are projected for each of the 34 job settings only. These LPN projections are based on the number of RNs projected for each setting. The choice of LPN/RN and aide/RN ratios is determined by the model users based on professional judgment. There are no projections for LPNs or aides for functions other than these direct client care categories.

Requirements projections for nurses in administrative roles are made for 11 separate institutional settings and 5 levels of educational preparation. Furthermore, nurse administrators are bifurcated into executive administrators and mid-level administrators. Thus, the total number of matrix cells for education and institutional settings for nurses in administrative positions is 110.

13/ Which temporarily excludes private duty nursing.

14/ A taxonomy of employment settings was presented in Figure 3.4.

## FIGURE 3.5: TYPES OF NURSING PERSONNEL--REQUIREMENTS PROJECTIONS BY THE WICHE MODEL

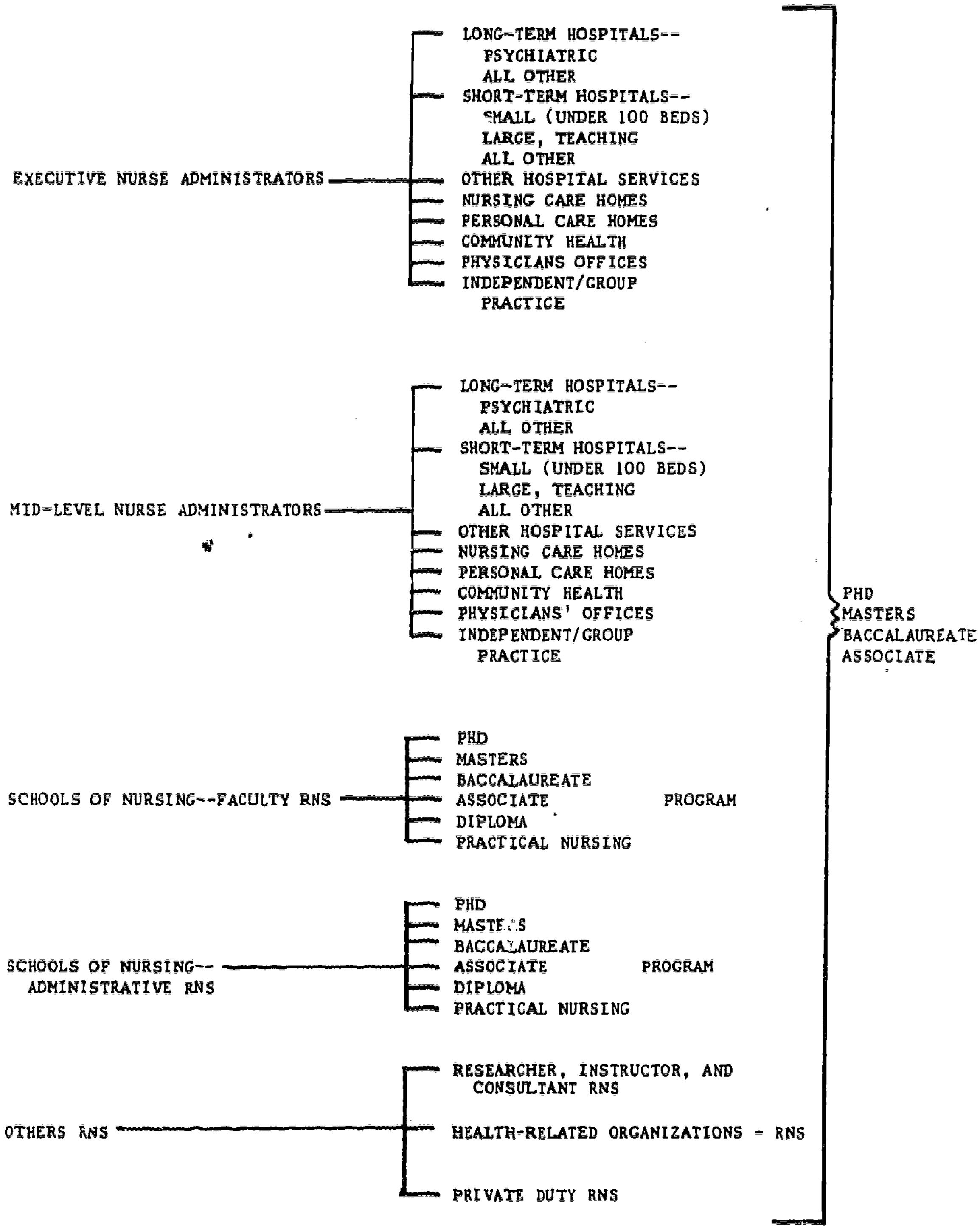
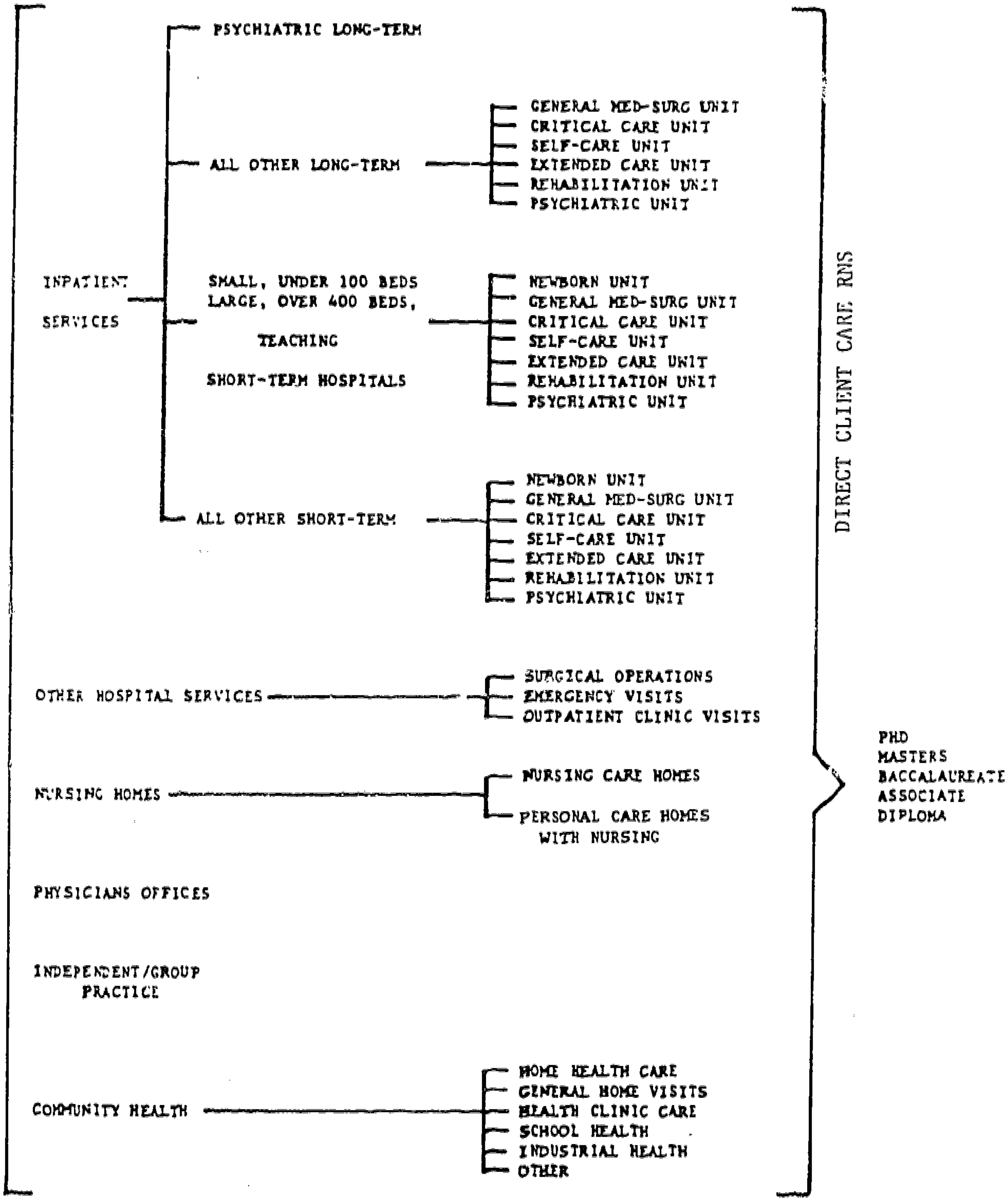


FIGURE 3.5: TYPES OF NURSING PERSONNEL--REQUIREMENTS PROJECTIONS BY THE WICHE MODEL



Nursing requirements for education are projected separately for faculty and administrators of nursing schools. Educational nurse requirements are projected for six separate types of educational programs and five levels of educational preparation for both faculty and school administrators. The six types of educational programs consist of the aforementioned five basic RN programs plus a practical nursing program. Thus, there are 60 cells in the function and program matrix for nurse educators.

The remaining RNs are classified into: researchers, instructors, and consultants; nurses in health-related organizations; and private duty nurses. These "other RNs" are further distinguished by the five levels of educational preparation, so that there are 15 matrix cells for "other RNs" in the model.

When the matrix cells for nurse functions, education, and job settings are combined, a total of 355 cells are represented: 170 for nurses in direct client care, 110 for those in administration, 60 in teaching, and 15 for the others. Figure 3.5 presents a complete listing of the entire matrix.

## C. THEORETICAL CONSTRUCTION

In the previous section, the overall structure of each model was decribed in terms of the submodels, and the specific outputs of these submodels. This section will describe in more detail the approaches used in constructing each of the Division of Nursing models, as well as the assumptions underlying the development of each. The focus will be on those factors affecting nursing requirements that have been explicitly incorporated into each model, and the manner in which each factor is modeled to influence nursing requirements in each of the models. This will require a close examination of the inputs to each model and the relationships structured among the inputs and outputs. The discussion in this section will therefore be somewhat more technical in nature than in other sections of this chapter.

### VECTOR MODEL

Earlier, in Figure 3.2, it was noted that the Vector model includes three modules: a population module, a demand-for-services module, and a nurse manpower requirements module. The demand-for-services module uses the projections from the population module to produce projections of health service demands by provider setting. The nurse manpower requirements module uses these projected health service demands to estimate future nursing requirements by employment setting. In the following discussion, the construction of each module will be described in more detail, with the discussion focusing on the input data (that is, the independent variables) used to generate the forecasts and the methods used to estimate the values of parameters and technical coefficients.15/ The discussion will also identify those assumptions that describe the conditions under which nursing requirements are estimated in the model, and which thereby affect the interpretation of the model's results.

The Vector model was developed for the purpose of assessing the effect of specified health system changes on future nursing requirements, as discussed earlier. This is done by comparing the requirements forecasts generated under scenarios involving selected health system changes (such as, implementation of NHI) with a forecast that assumes that no substantial changes in the health system occur over the forecast period. This latter forecast is referred to by the model builders as the "norm" scenario, and it is the baseline against which other forecasts are compared. In this way, the model user can estimate the additional requirements for nurses that would result, for example, solely from an increase in the formation rate of new HMOs. The effect of other specific changes, or combinations of such changes, can also be examined in the same way.

In addition to the "no change" assumption behind the norm or baseline forecast, there are two other implicit assumptions that underlie all of the forecasts produced by the model. These assumptions essentially exclude from consideration certain potential influences on nursing requirements that are beyond the scope of the modeling effort. The forecasts produced by the Vector model do not, for example, take into account the possible effects of changes in wage rates on nursing requirements. More precisely, it is assumed that the relative wages of nursing personnel remain the same as in the base year throughout the forecast period. This implies that the nursing requirements forecasts do not reflect changes in staffing patterns that might occur because of changing relative wages.

The requirements forecasts are also based on the assumption that the supplies of health system goods and services are perfectly elastic. That is, as the demands for health services increase, the capacities of health service providers are assumed to increase pari passu, so that the (relative) price of these services remains constant. This assumption removes from consideration any constraints on nursing requirements associated with the availability of health care facilities or the production of other health care services. Thus, for those forecasts involving a sudden and dramatic increase in the requirements for nurses (such as the adoption of a virtually "free" NHI plan), the estimated number of required nurses would likely exceed the number that would actually be used because of constraints on the available supply.

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15/ The Vector model can be used to forecast requirements for either RNs or LPNs. The description provided here is concerned with the data needed to produce forecasts of RN requirements.

It has been noted in previous sections that both a national version and a state version of the Vector model were developed. The only significant structural difference between the state and national models is in the specification of the equation used to forecast requirements for nurse educators. In the national model, the required number of nurse educators depends on the projected number of graduates from RN and LPN training programs. In the state models, the required number of nurse educators is assumed to be a constant proportion of the number of nurses employed in the state.16/ With this exception, the following discussion will apply to both versions of the Vector model.

The Population Module--Vector Model

The population module uses as input four types of data: projections of the future U.S. population in terms of age, sex, and family status cohorts; statistics on the income distribution of the population; health insurance coverage fractions for each population cohort; and an HMO formation rate. These data are used by the module to produce forecasts of the future U.S. population that characterize cohorts in terms of health insurance coverage and HMO enrollment. The first two types of data were obtained from the Bureau of Census, 17/ and were combined to produce population projections in terms of age/sex/family status/family income cohorts. The third type of data describes the population in terms of the fraction of each cohort eligible for benefits under the types of health insurance plans being considered. The coverage fractions for current public/private insurance plans were estimated using National Center for Health Statistics (NCHS) data from the 1972 Health Interview Survey. Under proposed national health insurance plans, these coverage fractions would become 100 percent.

The fourth type of data describes the HMO formation rate, which is the number of HMOs that become operational in each year. This is an input parameter that is to be specified by the model user in order to examine the effects of different HMO enrollment growth scenarios. Based on an analysis of data from Wetherville and Nordley, 18/ the rate of growth in the number of HMO enrollees is

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16/ This assumption is reasonable for the purposes of the state model, since the number of nurse educators is small, in relation to the total number of employed nurses, and can be approximated.

17/ Bureau of Census, "Population Estimates and Projections," Current Population Reports, Series P-25, No. 541, February 1975; and Bureau of Census, "Income in 1973 of Families and Persons in the United States," Current Population Reports, Series P-60, No. 97, January 1975.

18/ Wetherville, R.R., and Nordby, J.M., "A Census of HMOs, July 1975," and previous editions, Minneapolis, Interstudy.

assumed to decline exponentially with the age of the HMO. The rate of growth is assumed to be approximateldy 52 percent during the first year, 26 percent during the second year, 13 percent for the third year, and 7 percent thereafter. Given the assumed HMO formation rate and these HMO enrollment growth rates, the Vector model then computes the total number of HMO enrollees for each year of the forecast period.

The Demand-for-Services Module--Vector Model

The demand-for-services module requires as input projected per capita health service demands for each of the population cohorts projected by the population module. These input data consist of sets of per capita demands that characterize the consumption of health services by individuals enrolled in HMOs and by individuals covered by different types of health insurance plans. Estimates of the per capita demands of HMO enrollees for the hospital inpatient and HMO clinic settings are assumed to be proportional to the per capita demands of their non-HMO enrollee cohorts. 19/ For other settings, the demands of HMO enrollees are assumed to be the same as for the general population.

The per capita demands of individuals covered under current public/private health insurance plans were estimated on the basis of data from NCHS, the Bureau of Health Manpower, and other sources. The effect of a NHI plan on per capita demands is determined by estimating the change in the price of health services to the consumer resulting from implementation of the plan. The measure of price that is used is the effective coinsurance rate, which is the average fraction of expenses paid out-of-pocket by the consumer. This coinsurance rate is an input parameter specified by the model user to characterize the type of national health insurance plan being considered. Using the results of previous studies on the price elasticity of demand for health services, 20/ the effect of

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19/ For hospital inpatient services, the proportionality factor is estimated to be .439; for outpatient services, it is estimated to be .856.

20/ Heaney, Charles T., and Riedel, Donald C., From Indemnity to Full Coverage: Changes in Hospital Utilization, The Blue Cross Association, Chicago, 1970; and Newhouse, J.P., and Phelps, , C.E., Price and Income Elasticities for Medical Care Services, presented at a Conference of the International Economics Association, Tokyo, April 1973. For the hospital outpatient and physician office settings, data from Scitovsky, Anne A., and Snyder, N.M., "Effect of Coinsurance on Use of Physician Services," Social Security Bulletin, June 1972.

changes in the coinsurance rate (or the type of plan) on health service demands is then computed by the model.

By applying the appropriate set of per capita demands to the projections from the population module, the Vector model simulates the effects of changes in the population's health insurance coverage and in the number of HMO enrollees on health service demands in each provider setting. These health service demands are then used by the nurse manpower requirements module to estimate the impact of these two health system changes on requirements for nurses.

The Nurse Manpower Requirements Module--Vector Model

The nurse manpower requirements module produces forecasts of nursing requirements by employment setting. There are six submodels contained in this module, and they correspond to the following employment settings: physicians' offices, hospital inpatient units, hospital outpatient units, nursing homes, HMO clinics, and community health and other settings.

The physicians' offices submodel forecasts the number of RNs employed in them in each year, in a three-step procedure. 21/ First, the number of physicians in private practice is projected on the basis of 1963-73 data from the American Medical Association (AMA). 22/ Second, the number of nonphysician personnel employed per physician is projected on the basis of the projected number of office visits demanded, which is an output of the demand-for-services module. Finally, estimates of the fraction of nonphysician personnel that are RNs are used to produce forecasts of future RN requirements in the physicians' offices setting. 23/

The effect of expansion of the nurse practitioner role is also estimated in the physicians' offices submodel. In this submodel, requirements for nurse practitioners are based on an estimate of the excess demand for office visits; that is, the difference between the number of visits demanded in office practice and an estimate of the maximum number of visits a physician can profitably supply without extender personnel. The estimate of the maximum number of visits a physician can supply without extender personnel is based on an

21/ Requirements for LPNs are also estimated by these submodels in a manner similar to that for RNs.

22/ Five types of office practice are distinguished: general practice, OB/GYN, pediatrics, medical specialties, and surgical specialties.

23/ The values for the fraction of nonphysician personnel that are RNs were estimated from data in American Medical Association, Profile of Medical Practice, annual publication, various editions.

analysis of production functions developed by Reinhardt. 24/ The fraction of the excess demand for office visits satisfied by nurse practitioners is an input parameter that is to be specified by the model user. The value of this fraction is intended to measure the degree of acceptance of nurses in practitioner roles.

The hospital inpatient submodel forecasts the number of RNs employed in non-Federal short-term hospital inpatient units in each year. These forecasts consist of three components: the number of RNs employed in the intensive care units (ICUs), the number of RNs employed in the Department of Nursing Service, and other hospital inpatient RNs. The first component is based on a projection of the number of ICU beds and an estimate of the average number of RNs per ICU bed. The number of ICU beds is projected by fitting a trend line to historical data from the AHA. The second component is based on projections of the number of RNs employed in the Department of Nursing Service per patient day. These projections are made by extrapolating historical data from the Bureau of Health Resources Development and the AHA. The number of patient days demanded is an output of the demand-for-services module. The third component is an empirically derived constant based on data from the Bureau of Health Resources Development. 25/ The sum of these three components is the total number of RNs employed in hospital inpatient units for each year of the forecast period.

The hospital inpatient submodel also estimates the effect of two types of role reformulation on nursing requirements: the institution of the primary nursing concept and the expansion of the clinical nurse specialist role. Primary nursing in the hospital inpatient setting has the effect of replacing nursing assistants, aides, and orderlies with either RNs or LPNs. In the hospital inpatient submodel, the effect of primary nursing on nursing requirements is estimated by using data on average RN/aide and LPN/aide ratios in

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24/ Reinhardt, U.E., An Economic Analysis of Physicians' Practices, unpublished Ph.D. Dissertation, Yale University, 1970. The analysis by Reinhardt indicates that solo physicians can profitably use no more than four nonextender personnel. Thus, assuming that physicians have at most four employees, Reinhardt's production function can be used to estimate the number of visits that can be supplied.

25/ Bureau of Health Resources Development, Nursing Personnel in Hospitals, 1968, 1970, 1972: Survey of Hospitals Registered with the AHA, 1970, 1972, 1974.

primary nursing units.26/ The fraction of inpatient units with primary nursing and the fraction of such units using only RNs are input parameters to be specified by the model user, and are intended to measure the degree of acceptance of the primary nursing concept.

The effect of expanded roles for clinical nurse specialists on RN requirements is estimated by assuming that, to the extent that clinical nurse specialist and RN responsiblities do not overlap, additional RNs will be required as nurses acquire MS degrees and move into new clinical nurse specialist roles. The estimate of additional RN requirements is therefore based on projections of the number of MS graduates in clinical practice in hospitals.27/ This number is then multiplied by the fraction of MS nurses that assumed new roles in each year (an input parameter specified by the model user) in order to determine the additional requirements for RNs as a result of expanded roles for clinical nurse specialists.

The forecasts of RN requirements in the hospital outpatient, nursing home, and HMO clinic submodels are based on health service demand projections from the demand-for-services module. In the hospital outpatient submodel, the projected number of outpatient visits in each year is multiplied by an estimate of the average number of RNs per outpatient visit. The estimate of the average number of RNs per outpatient visit is based on an analysis of data from the Division of Nursing and the AHA. The projected number of outpatient visits is an output of the demand-for-services module.

In the nursing home submodel, an estimate of the number of RNs per day of care is multiplied by the projected number of nursing home care days demanded, which is an output of the demand-for-services module. Similarly, in the HMO clinic submodel an estimate of the number of RNs per visit is multiplied by the projected number of HMO visits by enrollees, which is also an output of the demand-for-services module.

The community health and other submodel is actually a set of submodels that are grouped together because they are, with one ex-

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26/ Manthey, M., "Primary Nursing is Alive and Well in the Hospital," American Journal of Nursing, 73, No.1, January 1973, p. 86; Manthey, M., and Kramer, M., "A dialogue on Primary Nursing," Nursing Forum, IX, No. 4, 1970, p. 361; Logsdon, A., "Why Primary Nursing," Nursing Clinics of North America, 8, 1973, pp. 283-291; and Felton, G., "Increasing the Quality of Nursing Care by Introducing the Concept of Primary Nursing: A Model Project," Nursing Research, 24:27-32, January-February 1972.

27/ Estimates of the future number of MS graduates were derived from extrapolations of historical data from American Nurses' Association, Facts About Nursing: 1972-73, 1974.

ception, independent of the projections from the demand-for-services module.28/ This submodel estimates future nursing requirements in the following subsettings: community health, all non-short-term general hospitals, private duty nursing, and nursing education. The requirements for nurses in these subsettings are based on trend lines fitted to historical employment data.

From this discussion, it can be seen that, with the exception of the community health and other submodels, the basis approach used in estimating future nursing requirements in the Vector model is one of applying empirically derived nurse staffing ratios to projected health service demands for each employment setting. The nurse staffing ratios and other inputs are derived from analyses of data from various sources, and the projected health service demands are outputs of the demand-for-services module.

CSF MODEL

In this section, the methods used in constructing the individual submodels of the CSF model will be described, along with the types of data required as inputs. Since different approaches were used in constructing the submodels, it will be convenient to provide separate discussions according to the following classification:

- the health service utilization and nursing demand submodels for acute care and long-term care settings
- the nursing demand submodels for ambulatory care and community and public health care settings
- the nurse supply submodel

Before discussing these submodels, however, an important point should be made concerning the limited availability of data at the institutional and substate levels. This was cited by the model builders as the key problem area, both in developing and in using the model. It was noted above that the development and use of the CSF model were to rely solely on data that were already available. However, because of the limited availability at the substate level, this proved to be a major constraint faced by the model builders, and one that limited both the types of submodels constructed and their forecasting accuracy.

Acute Care and Long-Term Care Submodels--CSF Model

The number of nursing personnel required in acute care and long-term care institutions is determined by forecasting the levels

28/ The number of home health nurses (part of the community health requirements) is proportional to the number of home care visits, which is an output of the demand-for-services module.

of health service utilization in these settings and then applying nurse staffing ratios to the utilization forecasts. As mentioned earlier, utilization forecasting submodels were constructed for specific types of acute care and long-term care institutions; these are listed in Table 3.4. Each submodel is a single equation that predicts the utilization of health services in each type of institution in terms of variables of two types: demographic and economic characteristics of the population served by the institution and health system characteristics of the substate area in which the institution is located. Step-wise multiple regression procedures were used to select from a list of potential independent variables those that best explain the utilization of health services. A detailed discussion of the resulting equations is presented in the final report of the CSF project and will not be repeated here. However, there are certain considerations that bear on the accuracy and interpretation of the utilization and nursing demand forecasts that the model user should be aware of and these are discussed.

The first point has to do with the overall "goodness of fit" of the individual regression equations. The reported $R^2$ values for the 20 acute care regression equations and the 8 long-term care regression equations indicate that, for many of these equations, the independent variables account for only a small proportion of the variation in the dependent variables (such as patient days of care). It was therefore expected that these regression equations would provide only gross estimates of future nursing demand at the institutional level, and this was confirmed by the model builders during evaluations of the model conducted at three test sites. However, aggregation of the individual institutional forecasts improves their overall forecasting accuracy, so that the model builders suggest that the most appropriate use of the acute care and long-term care submodels would be made by aggregating to the county or multiple-county level. Aggregating to the multiple-county area is suggested in the case of heavily populated metropolitan areas where there can be significant flows of nursing personnel and patients among counties.

Another consideration has to do with the nurse staffing ratios that are used to convert the utilization forecasts into estimates of future nursing demand. Two points should be made concerning these staffing ratios. First of all, these ratios are input data that must be provided by the model user. The user's manual accompanying the CSF model includes estimates of RN, LPN, and aide staffing ratios that are classified according to the type and size of the institution and the region of the county, so that the model user can select the appropriate staffing ratios for the particular type of institution being modeled. However, these estimates are average ratios and may differ appreciably from those for the particular institution being modeled.

A final consideration involves the availability of historical data for the independent variables used in the regression equations. The model builders found that on the basis of their experience during the testing and evaluation phase of the project, only limited amounts of historical data for the independent variables were available at the substate level. They concluded that only simple linear projections of the independent variables were possible. While linear projections based on only a few historical data points may accurately predict trends in census data, this may not be the case for data that describe future characteristics of the health care system of the substate area.

Ambulatory Care and Community and Public Health Care Submodels--CSF Model

The problem of data availability mentioned above also accounts for the different approaches used in constructing the submodels for acute care and long-term care settings and ambulatory care and community and public health care settings. As noted above, in the case of the acute care and long-term care settings, the demand for nursing personnel is based on forecasts of utilization of health services in these settings. For the ambulatory care and public health care settings, however, this approach was not feasible because of the lack of adequate data.

The approach that was adopted for the ambulatory care and community and public health care settings involved forecasts of nurse demand using linear projections of historical nurse employment data. These projections are intended to reflect historical trends in the demand for nurses in these settings. However, the extent to which they do so will depend on the number of data points upon which the projections are based, and the validity of the linearity assumption. In those substate areas where only a small number of data points are available, it may not be possible to establish accurate historical trends using this method. Also, where major new programs requiring additional nursing services are adopted, historical trends may be disrupted and future nursing demand would not be accurately forecast using this linear projection method. On the basis of considerations such as these, the model builders suggest that this would be another area in which it would be desirable to take advantage of the experience of local health care planners in verifying, and possibly modifying, the model's forecasts on the basis of professional judgment.

Nurse Supply Submodel--CSF Model

The nurse supply submodel is based on an approach developed by Research Triangle Institute for making national projections of nursing supply.29/ However, since the CSF model is concerned with supply projections for substate areas, the RTI approach was modified to take account of nurse migration. A formal statement of the model is as follows:

$$(1) \quad S(t) = \sum_{j=1}^{n} a_j (t) L_j (t)$$

$$(2) \quad L_j (t+1) = P_j L_j(t) + G_j(t) + FN_j(t) - MO_j(t)$$

where

$S(t)$ = the number of nurses in year t (that is, the active supply)

$L_j(t)$ = the number of licensed nurses age j in year t

$a_j(t)$ = the activity rate for nurses age j in year t (that is, the ratio of employed nurses to licensed nurses)

$P_j$ = the one year probability of survival for nurses age j

$G_j(t)$ = the number of new graduates age j licensed in year t

$FNj(t)$ = the number of new foreign, new endorsements, and reinstated nurses age j in year t

$MO_j (t)$ = the number of nurses age j who leave the area or whose licenses expire and are not renewed in year t

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29/ Jones, D.C., et al., Procedure for Projecting Trends in Registered Nurse Supply, Research Triangle Institute, March 1975, (Contract number: NO1-NU-44123). Division of Nursing, Bureau of Health Resources Development, HRA, DHEW. (unpublished report)

This is a flow model for a substate area that is based on the supply pool of licensed nurses. It can be seen from equation (2) that the supply of licensed nurses is estimated on a yearly basis by taking account of new graduates, new foreign nurses, reinstated nurses, new endorsements, nurses who leave the area or whose licenses expire, and one-year survival probabilities. The active supply of nurses, equation (1), is then determined by multiplying the (age-specific) supply of licensed nurses by the (age-specific) activity rate.

Projections of each of the components of the supply submodel must be provided by the model user. It should be noted that the availability and reliability of these required data will vary among substate areas. For example, reasonably accurate forecasts of new graduates can be based on data from annual publications from the National League of Nursing. These publications provide data on the number of graduates that will be produced by each nursing program in a substate area. On the other hand, the net migration of nurses for a specified substate area is a more difficult input variable to accurately forecast. For this reason, the model builders suggest that in the absence of county level nurse migration data, an alternative method be used for estimation purposes. This consists of using equation (2) above, without the nurse migration term, to project nurse supply over a period for which actual historical data on nurse supply are available (for example, from 1966-72). Then, by comparing the projected supply with the actual supply at the end of that period, an estimate can be obtained of the net migration for the substate area. The number of foreign nurses and reinstated nurses are other variables whose values may be difficult to project. Therefore, as in the case of nursing demand, the accuracy of the supply forecasts will depend, to a large extent, on the availability and reliability of local data sources.

## PUGH-ROBERTS MODEL

The Pugh-Roberts model is developed with a set of techniques or equations referred to as System Dynamics. This provides a framework within which to view the internal microoperation of a system in a coherent and orderly manner. The model views the health care system in terms of two major types of constructs: levels and rates. A level is a number that represents the state of some part of the system. A rate defines the amount by which a level will change. The changes taking place are influenced by other model variables. The Pugh-Roberts model consists of relationships among these three categories of variables expressed in DYNAMO simulation language.

As mentioned before, the Pugh-Roberts model consists of four sectors: nurse education, nurse employment, demand, and demographic. The nurse education sector forecasts the number of yearly graduates from each program. The nurse employment sector makes projections of the number of nurses employed in each employment setting. The demand sector forecasts the demand for nurses based on the projection of the demand for health services. Finally, the demographic-sector represents key demographic characteristics of total and nurse population and how they affect other sectors of the model. Each sector will be discussed individually, followed by a brief discussion of the intersections among these four sectors.

Nursing Education Sector--Pugh-Roberts Model

The nursing education sector of the Pugh-Roberts model consists of specifying how the selected variables determine the number of non-nurse applicants to nursing education programs, the number of nurse applicants to nursing education programs, the number of available places in nursing education programs, and the dropout rate from such programs. The establishment of the above relationship allows the projection of the number of graduates each year, given an age-specific population projection. As shown in Figure 3.6, a schematic view of the nursing education sector of the Pugh-Roberts model as interpreted by Applied Management Sciences is presented.

The total number of applicants is a measure of the demand for nursing education, while the number of available places is a measure of the supply of nursing education. The number of entering students is then determined by the interaction of these demand and supply measures. Given the number of entering students, the number of graduates at the end of required years of schooling is determined applying dropout rates. Yearly graduates from nursing schools constitute a major source of nurses entering the employment sector (see Figure 3.6). In the following, the structure of the nursing education sector is presented in terms of the determinants of the demand for, and the supply of, nursing education, along with the dropout rates. The demand for nursing education by non-nurses in the Pugh-Roberts model may be expressed as:

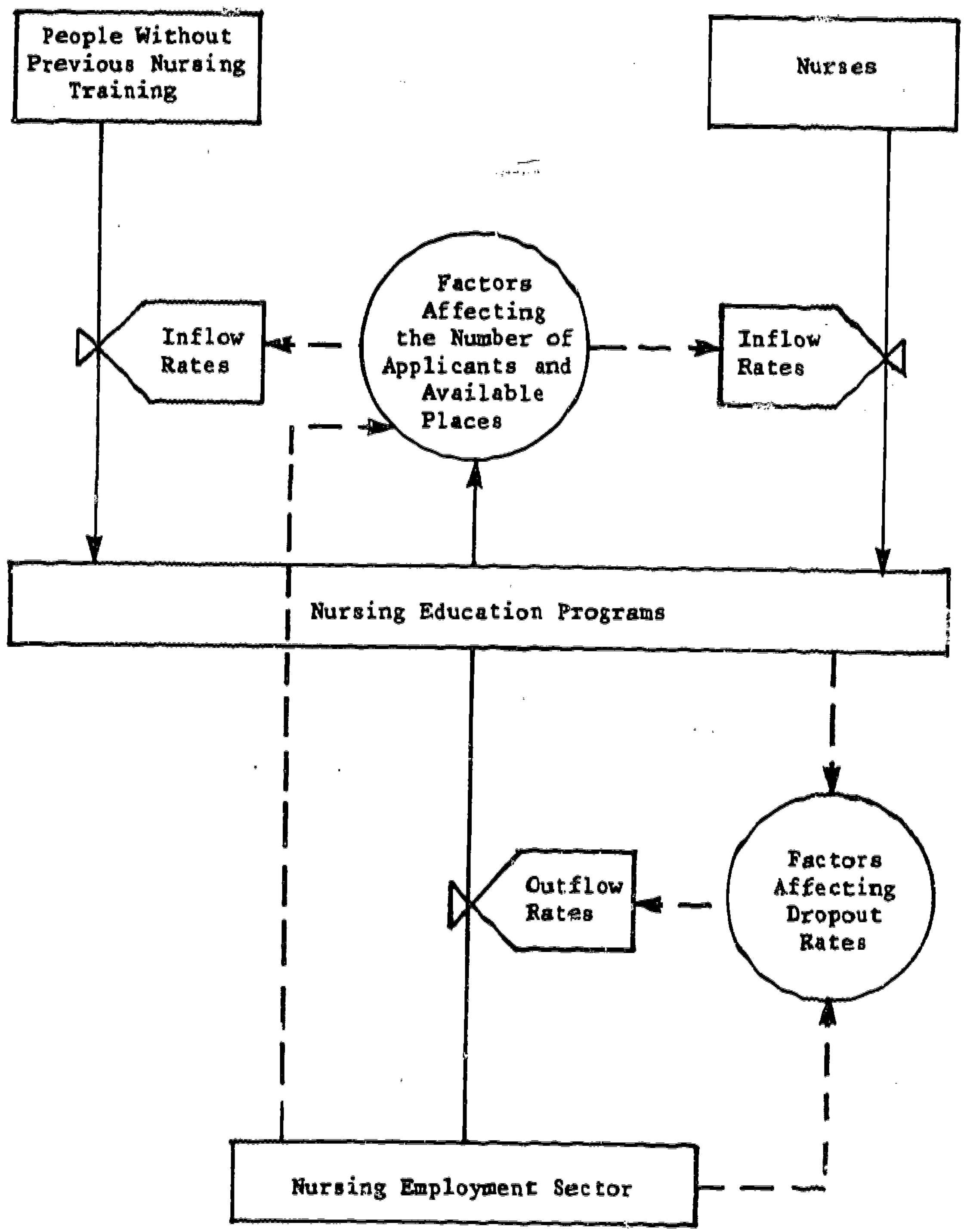
$$NAEP = f(NPAE, PAJA, W, CBNR, ASL, OFDE) \qquad (1:1)$$

where

NAEP = number of people without previous training applying to each type of nursing education program

NPAE = number of places available in each type of educational program, represented by the ratio of the number of places available at each point in time to that in 1972

FIGURE 3.6: SCHEMATIC VIEW OF THE NURSING EDUCATION SECTOR OF THE PUGH-ROBERTS MODEL*




*As interpreted by Applied Management Sciences

PAJA = perceived availability of jobs in nursing at each level, represented by the ratio of nurses employed and considering employment to available jobs at each level over the 1972 ratio

W = nurses wages as represented by the ratio of real wages at each level to 1972 wages for personnel at that level

CBNR = changes in the breadth of nurses responsibilities, as represented by a dimensionless index in which a value of 1.0 represents the breadth of responsibilities of nurses at each level in 1972

ASL = availability of scholarships and loans as represented by the fraction of costs covered by scholarships and loans for the average student

OFDE = other factors affecting the demand for nursing education, such as perceived availability of jobs in other professions, changes in average tuition levels, and the perceived job satisfaction of nurses

The effects of these independent variables on the demand for nursing education is expressed by multipliers that increase or decrease the value of dependent variables by specified proportions. These multipliers are often determined from the consensus judgment of the Task Group rather than by correlation estimation.30/ Since the values of the multipliers change according to the magnitude of changes in the independent variables in a complicated nonlinear and possibly nonsystematic way, one cannot represent them as the usual demand parameters.

An estimation of multipliers presented in appendix B of the final report indicates that the Task Group considered the perceived availability of nursing jobs as the most important factor affecting the demand for nursing education, followed by nurses wages, the availability of scholarships and loans, available places in each educational program, and changes in the breadth of nursing responsibilities. The judgment of the Task Group, as expressed by the values given for the multipliers, closely conforms to the results of several past correlation studies of the parameters of demand for professional education that they considered in forming their judgments.

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30/ In response to a concern that the model be an accurate representation of nursing and its role in health care, a National Model Task Force was formed and played a central role in the work. The Task Force consists of nine members who brought with them diverse perspectives.

The demand for nursing education by nurses (continuing education) is similar to that exhibited by non-nurses. Fc bvious reasons, however, there are some variations in the af...ting variables used. For example, the relative availability of nursing jobs at higher levels replaces the perceived general availability of jobs in nursing; and wage differentials among levels of nursing positions replaces the general levels of nurses wages. The total demand for nursing education is then measured by adding the total demand by non-nurses to that of nurses who wish to return to nursing schools.

On the supply side, the total supply of nursing education may be expressed as follows:

$$NPAE = f(NAEP_t/NAEP_{72}, PAJA, FPF, OFSE) \qquad (1:2)$$

where

NPAE = number of places available in each type of nursing education program

$\frac{NAEP_t}{NAEP_{72}}$ = number of applicants relative to existing places as represented by the ratio of applicants to programs at each level to the 1972 appli-ants

PAJA = perceived ilability of jobs in nursing as represen' oy the ratio of nurses employed and cons..ering employment at each level to jobs available at ea level over the 1972 ratio

FPF = availability of qualified faculty as represented by the fraction of faculty positions filled

OFSE = other factors affecting the supply of nursing education, such as financial pressures on schools and constraints on the availability of clinical exposure

The demand for and supply of nursing education, as specified above by equations (1:1) and (1:2), determine the number of students entering into each type of nursing education program. Then, the number of graduates at each type of educational program is determined by subtracting the number of dropouts from entering students following the required years of schooling. The Pugh-Roberts model projects the number of dropouts by:

$$FNSD = f(CSL, OFDR) \qquad (1:3)$$

where

FNSD = fraction of nursing students dropping out of each type of educational program

CSL = changes in the availability of scholarships and loans

OFDR = other factors affecting dropout rates, such as more stringent academic standards in some programs

Thus, the number of yearly graduates is determined as:

$$NGS_{t+n} = NSEN_t - (NSEN_t \times FNSD) \quad (1:4)$$

where

$NGS_{t+n}$ = number of students graduating from each type of nursing education program at the year t+n, where t denotes the base year and n the number of required years of schooling

$NSEN_t$ = number of students entering into each type of program at the base year t

FNSD = fraction of nursing students dropping out of each type of educational program during the n year of schooling

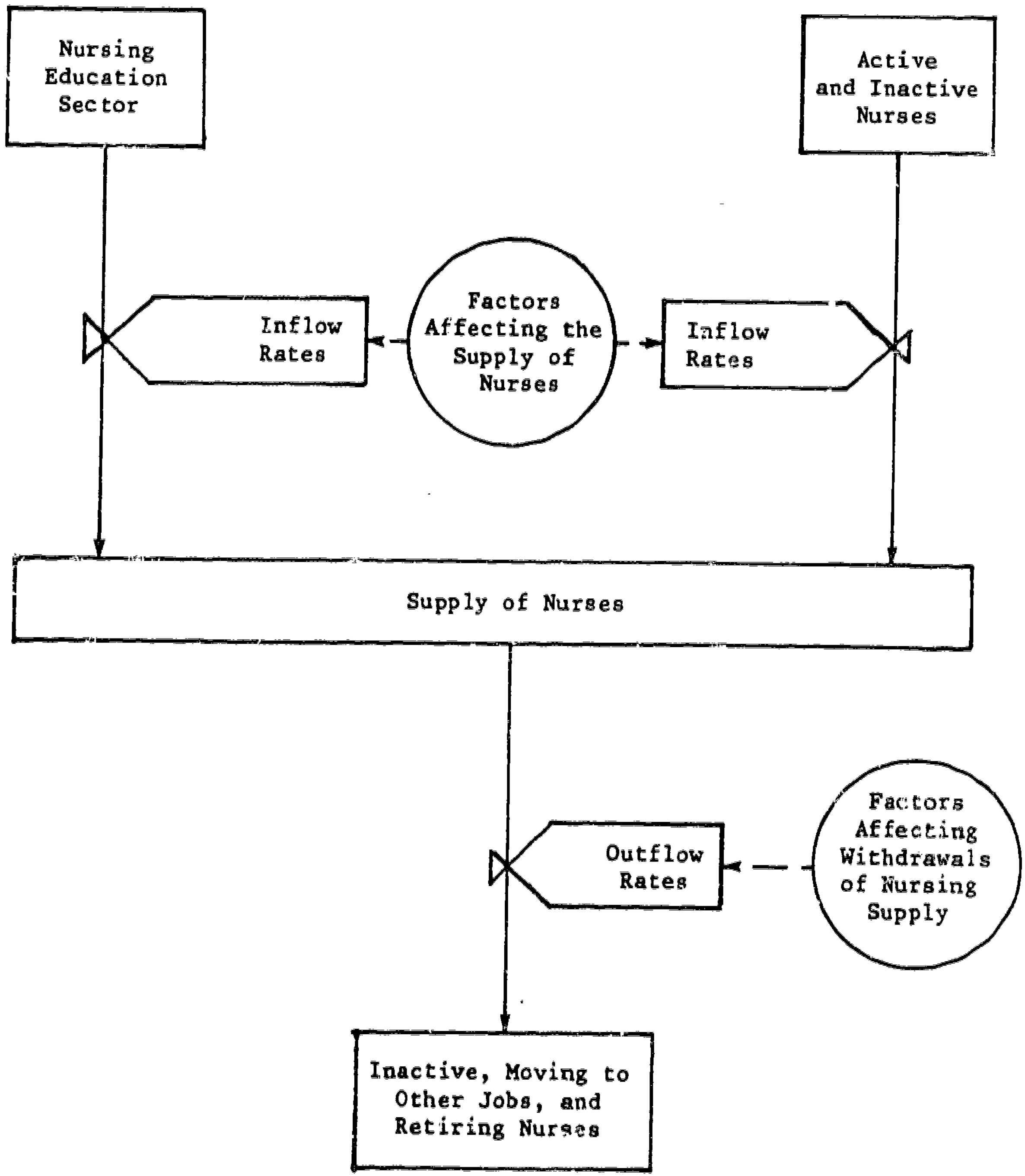
The projection of the number of yearly graduates from each type of nursing education program, as determined by equations (1:1) through (1:4), completes the function of the nursing education sector of the Pugh-Roberts model.

Nursing Employment Sector--Pugh-Roberts Model

As shown in Figure 3.7, the nursing employment sector of the Pugh-Roberts model consists of specifying how the chosen variables determine: the number of licensed nurses, including new graduates, who are employed or seeking employment and who are willing to take available jobs at each job setting; the number of nurses not employed or inactive but willing to take available jobs; the number of nurses quitting to take other nursing positions; the number of nurses retiring or becoming inactive; and the number of nurses immigrating to the country. Determination of the above would enable model users to project the effective rate of nurses supply at each point in time.

The Pugh-Roberts model's specification of the factors affecting the supply of nurses from both the nursing education sector and active nurses may be expressed in the following way:

FIGURE 3.7: SCHEMATIC VIEW OF THE SUPPLY OF NURSES OF THE PUGH-ROBERTS MODEL*




*As interpreted by Applied Management Sciences

FNWECE = f(PAJAS, W, BNR, EFOT) (1:5)

where

FNWECE = fraction of nurses at each educational level who are employed or are willing to consider employment

PAJAS = perceived availability of jobs at each level as presented by the ratio of the number of jobs available for nurses at each level to the total number of jobs for nurses at each level

W = nurses wages as represented by the ratio of wages of personnel at each level to 1972 wages for personnel at that level

BNR = breadth of nurses responsibilities as represented by a dimensionless index in which a value of 1.0 represents the breadth of nurses responsibilities in 1972

EFOT = changes in overall economy over time

In terms of the values of impact multipliers given by the Task Group, by far the most important factor influencing the supply of nurses is nurses wages. Other factors are judged to exert relatively insignificant impacts on the nurses supply.

In the Pugh-Roberts model, the movements of nurses between employment settings are determined by the differences between employment settings in the factors influencing the willingness of nurses to take employment in a particular setting. The factors affecting the willingness of nurses to take employment in a particular setting are relative availability of jobs in each setting, relative wage rates, and relative inherent attractiveness that reflects the relative breadth of responsibilities of nursing personnel.

As mentioned above, the Pugh-Roberts model also considers the factors affecting the withdrawal of nurses from the supply. The model assumes that the decision of nurses to quit nursing employment, either to take jobs outside of nursing or to become inactive, are influenced by the availability of jobs in the nursing sector versus those in other sectors and by changes in the demographic statuses of nurses.

In addition to specifying what variables and how they influence the supply of nurses, the model considers how these variables are determined. For example, the model specifies the variables influencing the spread of collective bargaining in hospitals, changes in nurses wage rates, and the relationship between the two.

Demand (for Nurses) Sector--Pugh-Roberts Model

Given the supply of nurses as determined in the nursing employment sector, the demand for nurses needs to be determined in order to arrive at projections of nursing requirements. The Pugh-Roberts model determines the demand for nurses at each educational level, for each of the seven major employment settings in its "demand sector." Factors that affect the demand for nurses differ somewhat according to the employment settings. Since the majority of nurses are employed in hospitals, and because a set of factors that influence the demand for nurses in hospitals approximates the general set of factors that influence demand in most of employment settings, the determinants of the demand for nurses in hospitals are discussed here as representing the demand sector of the Pugh-Roberts model.

Factors affecting the demand for nurses in hospitals, as represented by the number of jobs available in hospitals, may be expressed as:

$$NEDH = f(WH, FSH, CBH, BNRH, INPNH, TCEFH) \qquad (1:6)$$

where

NEDH = number of nurses at each educational level demanded in hospitals

WH = nurses wages as represented by the ratio of average wages of nurses in hospitals adjusted for inflation to 1972 average ages

FSH = hospital's financial situation as represented by an index measuring the degree of difficulty hospitals have in passing along increased costs

CBH = collective bargaining as represented by the fraction of hospitals with collective bargaining agreements

BNRH = breadth of nurses responsibilities in hospitals as represented by a dimensionless index for which a value of 1.0 represents the breadth of responsibilities of nurses in 1972

INPNH = average intensity of patient needs for nursing services as represented by a combined index reflecting average length of stay and preadmission screening

TCEFH = technological change and other exogenous factors

According to the values assigned to the multipliers, the Task Group considered the intensity of patient needs for nursing services, and nursing wages, as the two most important factors influencing the demand for nurses in hospitals. It projected a 20 percent decrease in the number of jobs available in hospitals, with a 40 percent increase in nursing wages. On the other hand, the Task Group projected a <u>decrease</u> in the demand for nurses of five percent, with an <u>increase</u> in the patient-need-intensity index of 10 percent. It is also interesting that the Task Group expected technological changes and other exogenous factors to increase the demand for nurses by 20 percent by 1992.

<u>Demographic Sector--Pugh-Roberts Model</u>

The demographic sector of the Pugh-Roberts model estimates the nation's population in terms of both total size and the distribution among 10 age categories, as well as the fertility rates and death rates for members of each age category. The number and age distribution of those immigrating to the country are also included in the model.

For the 10 age groups, the rates of change of the population (per month) due to births, deaths, and immigration for each age category are derived from the "series E" census projections. The rate of immigration is held constant at 400,000 people per y[illegible] is distributed among various age categories. The model au[illegible]cally "ages" the population each month by moving a fractio[illegible]n age group to the next-older age group. Female death rates, [illegible] are somewhat different from those reported for the total population, are used in computing the rates of deaths of nurses in each age category for each educational level.

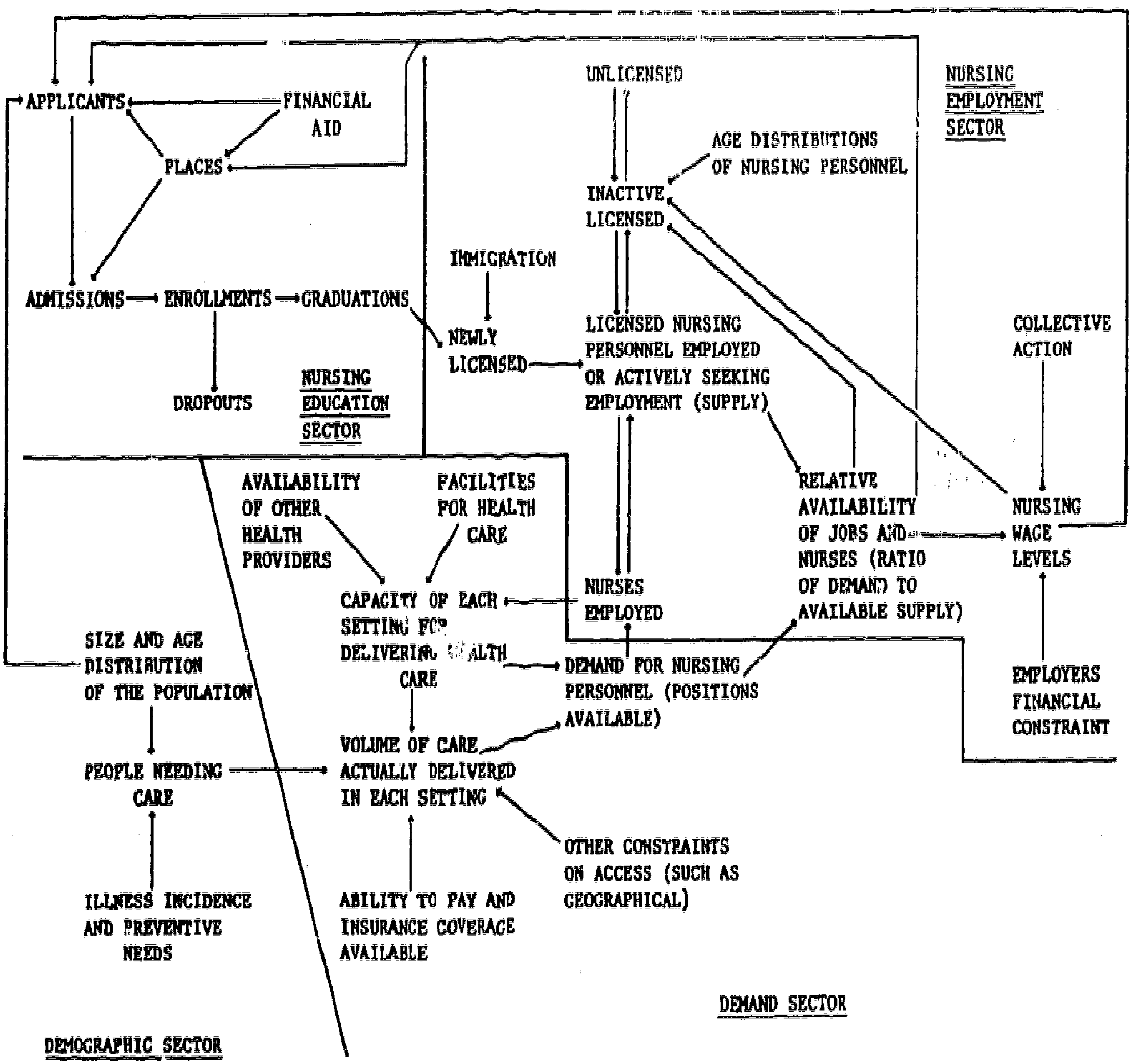
The objectives of the demographic sector are twofold. One is to provide a basis to calculate the age-specific incidence of illness in the population and, thereby, the magnitude of the population's need for health services. This enables the model to project the demand for nurses in the demand sector. The other is to provide a basis for projecting the number of applicants for each nursing education program. This, in turn, provides a basis for projecting the supply of nurses from the nursing education sector.

<u>Integration of the Four Sectors--Pugh-Roberts Model</u>

For each of the four sectors of the Pugh-Roberts model (nursing education, nursing employment, demand, and demographic), the model construct is separately described above. This subsection discusses how these four sectors fit together to make projections of the demand for, and supply of, nurses.

The interrelationship between the four sectors of the Pugh-Roberts model is explained by Figure 3.8. As shown in this figure,

FIGURE 3.8: OVERVIEW OF INTERRELATIONSHIPS BETWEEN THE FOUR SECTORS OF THE PUGH-ROBERTS MODEL



the primary role of the demographic sector is to provide a basis for estimating the prevalance rate of illness and, thereby, the need of the Nation's population for health services. This enables the demand sector to project the demand for health services and, subsequently, the demand for nurses. The secondary role of the demographic sector is to provide the nursing education sector with a basis for projecting the supply of the applicants to nursing education programs.

The role of the nursing education sector is to consider the demographic factors, along with other factors, affecting the supply of applicants (or the demand for nurse education), and the factors affecting the demand for students (or the supply of nursing education). Then it projects the number of the yearly new graduates at each level of education for the nurse employment sector.

The role of the demand sector is to provide projections of the magnitude of the demand for health services estimates of the need for health services provided by the demographic sector and other factors affecting the demand for health services. Then it considers, along with other factors, how the demand for health services affects the demand for nurses. This provides the employment sector with a basis for projecting the number of nurses demanded in each employment setting.

The role of the nursing employment sector is to consider and synthesize projections of the demand for health services provided by the demand sector with the projections of the yearly new graduates provided by the nursing education sector. Then, on the basis of these and other factors affecting the demand for and the supply of nurses, it projects nursing employment in each setting.

## WICHE MODEL

The WICHE model differs from the other health manpower models in that it does not define structural relationships between the selected model variables. Rather, it presents variables to be included in the model and it guides the construction and estimation of relationships among them. The guides that are presented consist of past data on relevant relationships and the identification of various factors affecting them. The panel of experts determine the assumptions or estimates according to the process provided in the model on the basis of the background data and information provided. The assumptions are estimated according to a consensus approach where all panel members agree on the estimates in the course of mutual consultation and discussion. Since these panel members are likely to be those who will be involved in planning, the model builders consider this process of obtaining the final relationships extremely important. Note that as previously stated, all panel members are selected to bring diverse perspectives to the process. In this section, the model's structure, the process of estimation, and the assumptions underlying the model's development are discussed in greater detail.

## Requirements Projections--WICHE Model

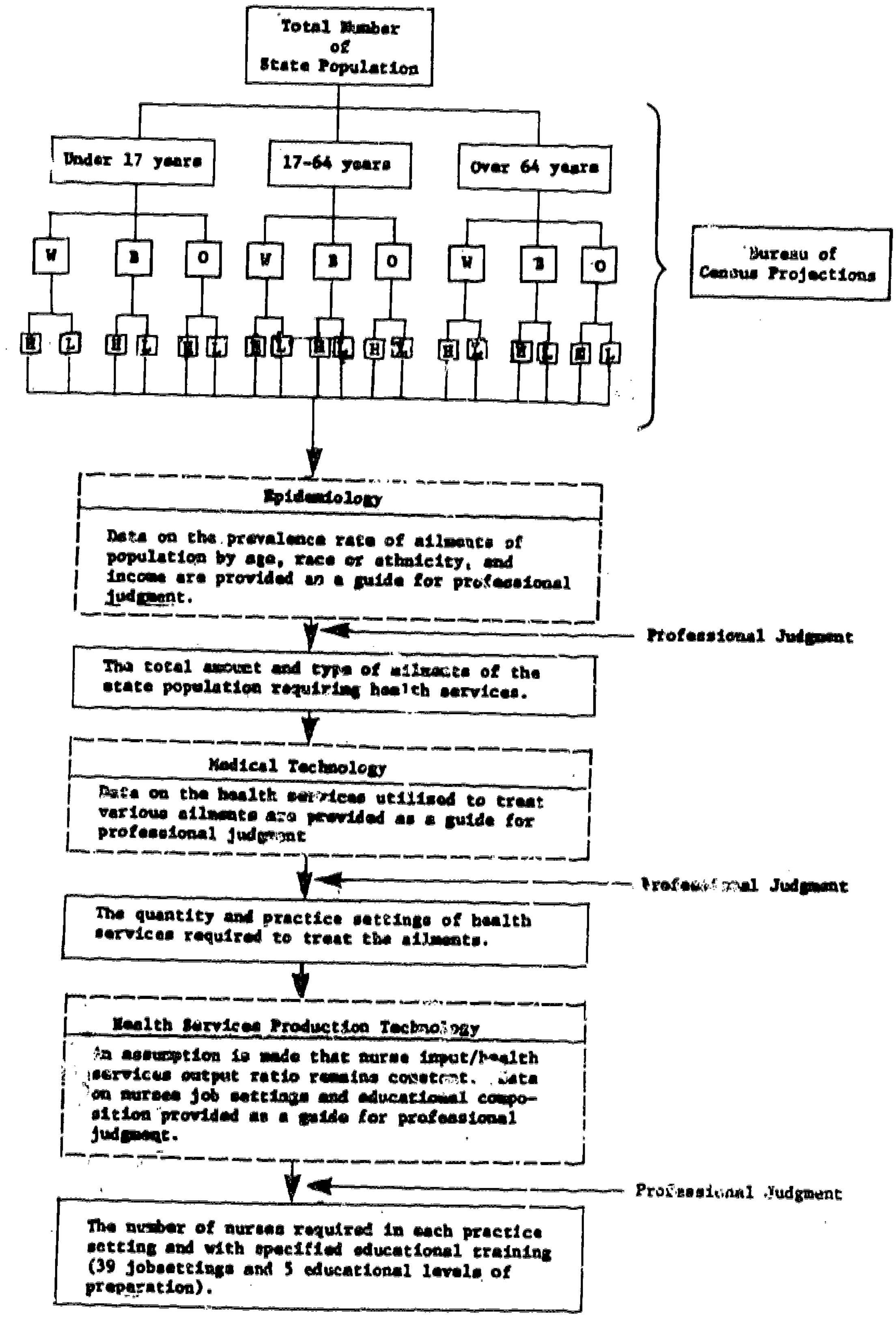
The WICHE nursing requirements projections involve: population projections by age group, race or ethnicity, income-group; the projection of the age-race/ethnicity-income specific illness prevalence rates; projections of the quantity and types of health services required to treat the projected prevalence of ailments; and projections of the number of nurses required to provide the needed health services.

Figure 3.9 shows the Applied Management Sciences' interpretation of the conceptual structure of the WICHE model as it pertains to the requirements projections. First, the projections of state populations by age, race or ethnicity, and income are based on Bureau of Census projections. Second, given the projected composition of the population according to the above groupings, the prevalence rate of ailments of the state population is estimated from past data on the basis of the judgments of experts in epidemiology. Third, given the estimated prevalence rates of ailments of the population, the quantity and types of health services required for treatment is projected from data on the disease-specific utilization rates of health services. The conversion of the estimated prevalence of illnesses into required health services is also based on professional judgment. Finally, given the projected quantity and types of health services required, the required number of nursing personnel is projected for each job setting and level of educational preparation. These last projections are also made on the basis of historical staffing pattern data and data on the educational attainment of nurses by using professional judgment.

## Resource Projections--WICHE Model

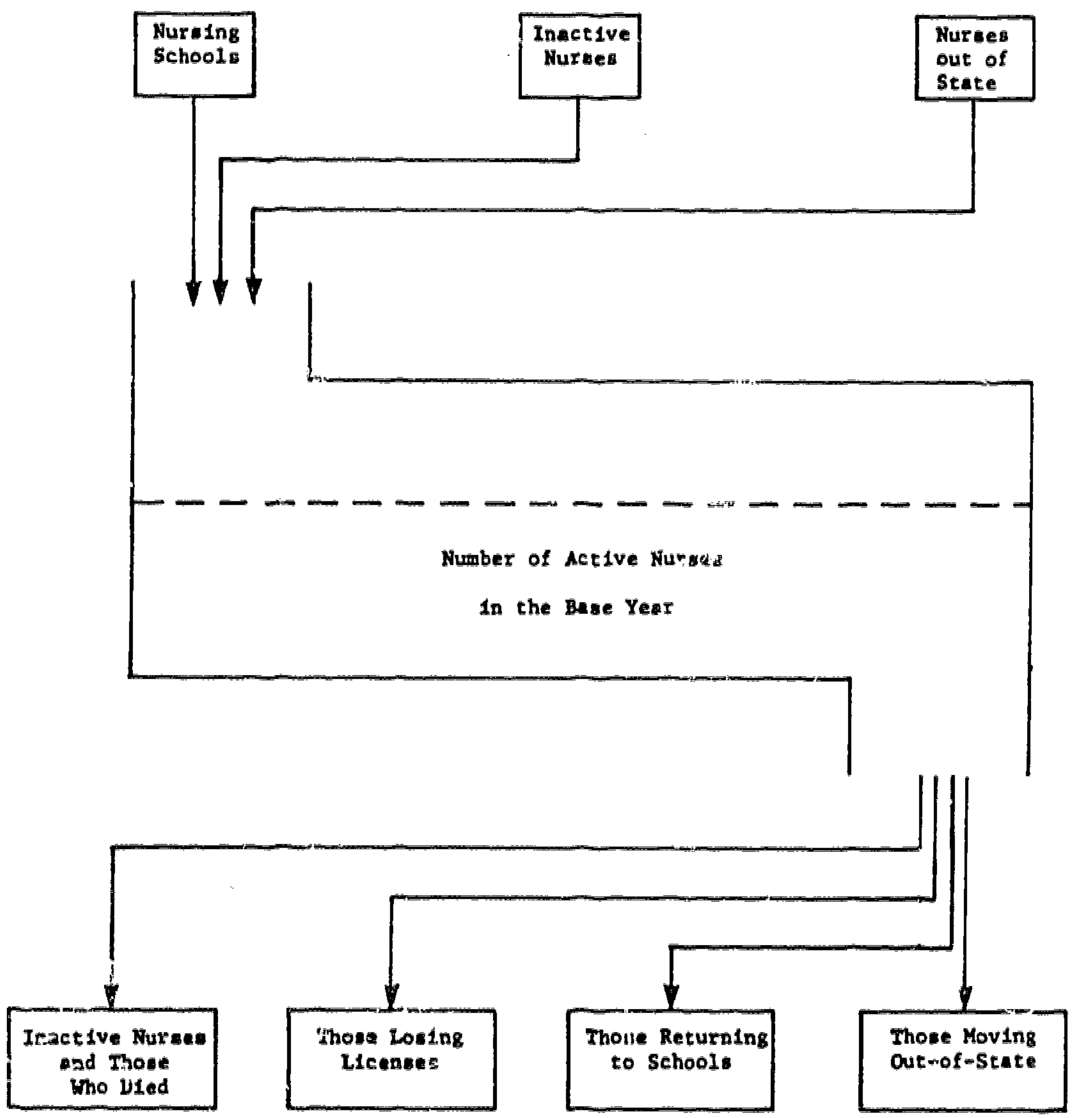
The nursing resource projections are made using an injection-leakage model of nurse supply. Given the number of active nurses in the base year, a resource projection is made by adding the estimated number of nurses expected to enter the supply pool, and subtracting the number of those expected to leave the pool. The inflows or injections into nurse supply are expected from three sources: new graduates from nursing schools, inactive nurses becoming active, and immigrating nurses. The outflows or leakages are expected from four sources: retirement, including those becoming temporarily inactive, and death; suspension of licenses; nurses returning to schools; and outmigration. Figure 3.10 presents a graphical interpretation of the injection-leakage model suggested by Applied Management Sciences for the resource projections of the WICHE model.

FIGURE 3.9: PROCESS OF MAKING NURSING REQUIREMENTS PROJECTIONS--WICHE MODEL




KEY: W - White, B - Black, O - Other
H - High Income, L - Low Income

FIGURE 3.10: INJECTION-LEAKAGE DIAGRAM FOR NURSING RESOURCE PROJECTIONS--WICHE MODEL



The WICHE model of resource projection and planning consists of presenting the relevant data and defining the factors affecting the rates of the inflows and the rates of the outflows of the types mentioned above. Estimation of the coefficients necessary to convert the current enrollment of nursing schools into the number of yearly graduates, the number of inactive nurses into the number of those returning to work, and the number of active nurses into the number of those moving out of state, as well as other factors, are arrived at through the deliberations of the members of the expert panel.

## D. OPERATIONAL FEASIBILITY

Information as to the resources required to operate each of the four Division of Nursing models is provided to assist potential model users in determining the feasibility of implementing each model by allowing comparisons with the resources available to the model user. These resource requirements include the computer hardware and software, the types of personnel required to operate the model, and the data required as inputs.

### VECTOR MODEL

The Vector project produced both a national model and a state model, and both versions are operational. However, as noted earlier, the state model supersedes the national model in that it can also be used to produce national level forecasts. Therefore, only the computer tapes containing the data bases and program files for the state model have been delivered to the Division of Nursing.

### Computer and Personnel Requirements--Vector Model

The computer programs for the Vector model are coded in FORTRAN language, and are designed to run on medium-to-large-scale computer systems.31/ Since most such systems are equipped with FORTRAN compilers, installation of the model should not present any difficulties for most users. In the case of users with non-IBM compatible equipment, however, they should expect that modifications of the computer programs will be necessary, and this will require personnel with programming skills. The computer costs pe lation for a State are estimated to be about $12.

The Vector model is programmed to operate in an interactive mode, so that only minimum levels of modeling skills would be

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31/ The Vector model was developed and run on the University of Michigan's Amdahl 470/6 computer system.

required of personnel using the model. However, users would be expected to be familiar with health care statistics and trends in nursing so that appropriate input data are supplied to the model, and the resulting outputs are properly interpreted. For example, in order to produce forecasts involving role reformulation on the part of nurses, the user must supply input data describing the expected degree of acceptance of primary nursing and of nurses in practitioner and clinical specialist roles. While the model builders have suggested values for these data to be used at the national level, separate state-level estimates should be made to reflect the differences in role reformulation among the States. Similar considerations would be involved in using the model to forecast the effects of changes in health insurance coverage and HMO enrollments at the state level.

Data Requirements--Vector Model

There are three major types of data used by the Vector model: projections of the future U.S. population that are derived from Bureau of Census publications; per capita health service demands that are derived largely on the basis of data from NCHS 32/; and nurse staffing ratios and employment data that are derived from reports of the American Nurses' Association, AHA, and the Bureau of Health Manpower.33/ All of these data have been collected and are available in the data bases supplied with the Vector model.34/ Therefore, if the user exercises the model with the existing data bases, the only additional inputs required would be values for the parameters that define the various scenarios to be examined. The values for these inputs can be chosen by the model user so as to reflect different assumptions concerning the timing and magnitude of the health system changes considered by the model.

Finally, in order to make the Vector model operational for producing LPN requirements forecasts, additional data are required.

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32/ Per capita demands for home care visits were estimated on the basis of data from Bureau of Health Manpower, 1972 Survey of Public Health Nursing, (HRA)76-8, November, 1975, and from Hurtado, A.V., Greenlick, M.R., and Lauvard, E.W., Home Care and Extended Care in a Comprehensive Prepayment Plan, Hospital Research and Educational Trust, Chicago, 1972.

33/ The number of nurses per HMO visit was derived from data in Gorby, J.T., and Associates, Special Report on Prepaid Group Practice Plans, 1974.

34/ An exception is the data required for LPN requirements forecasts.

These data consist primarily of LPN staffing ratios and employment data used in the nurse manpower requirements module. The LPN data that were required for the role reformulation scenarios have been collected, but these data are used only for the hospital inpatient settings. Therefore, the necessary data for the other employment settings would have to be provided by the user.

CSF MODEL

The documentation accompanying the CSF model includes both a system manual and a user's manual. The system manual is intended for programmer/analyst personnel, and describes the machine configuration requirements and procedures for installing the model software. The user's model describes the input data requirements and the system commands to be used to generate forecasts and output reports. The information provided in these manuals will be summarized here, along with additional information obtained in discussions with the model builders.

Computer and Personnel Requirements--CSF Model

The CSF model software is a collection of FORTRAN IV programs developed for use on the National CSS Corporation's time-sharing system, although the model can, of course, be installed and operated on other computer systems having a FORTRAN compiler. Also, although the model software was designed as an interactive system, it can be operated in a batch mode by constructing data and "RUN" files prior to execution. In this connection, it should be noted that the model was designed for interactive use because it was originally expected that the model would be used primarily at individual health care facilities, and the data processing requirements would be thereby minimized. However, as the project progressed, it became clear that the most appropriate users of the model would be HSAs or other health planning agencies. Thus, because of the greater data processing requirements involved at this level of analysis, the model builders suggest that most efficient use of the model would be obtained by operating in a batch mode.

The total costs involved in operating the model have not been documented by the model builders; however, in discussions with the Applied Management Sciences' staff, they did suggest that the computer costs per simulation at a specific site should be expected to be $200 to $400. In addition to these computer costs, costs for clerical personnel would also be incurred in connection with necessary data collection activities. The time required for collection of the necessary data was estimated to be approximately 2 to 3 weeks.

Finally, although actual operation of the model would not require personnel with special technical skills, it would be desirable to have available personnel who are capable of properly interpreting and evaluating the model's results. As noted earlier, in those cases where the model's forecasts are based on limited amounts of historical data or simple trend projections, these forecasts should be verified and possibly modified by personnel familiar with the health system characteristics of the substate area being modeled.

Data Requirements--CSF Model

There are several types of data that are required as inputs to the CSF model, and these data are generally available at the substate level. However, a few exceptions should be mentioned, in addition to certain other considerations that will affect the time and effort involved in constructing the data base for the model.

In the case of the nursing demand submodels, the data requirements will differ according to the type of employment setting being considered. For the ambulatory care and community and public health care settings, the only data required are several years of historical nurse employment data. For the acute care and long-term care settings, however, two types of data are required. First, nurse staffing ratios for specific types of acute care and long-term care are needed. Estimates of these staffing ratios are provided in the user's manual and can be selected by the model user; but, in terms of improving the forecasting accuracy of the model, it would very likely be preferable to obtain the staffing ratios actually used by the specific institutions being modeled.

The second type of input to the acute care and long-term care submodels consists of data that describe the characteristics of the health care system and the population of each institution's patient service area. These data are the independent variables for the health service utilization regression equations. The health system data (numbers of physicians and hospitals, mortality rates, and so on) are generally available on an annual basis from publications of the AHA, AMA, and state health agencies, as well as others. The population data (age, sex, and income distributions of the population) can be obtained at the tract or county level from Bureau of Census publications. However, the most recent detailed census data for substate areas are likely to be available only for 1970. Therefore, the composition of the population for subsequent years (and over the forecast period) will have to be estimated using data from other local sources.

Another point should be made concerning these inputs to the acute care and long-term care submodels. These data (or independent variables) are projected over the forecast period using a simple trend projection technique, and these projections provide the basis for the resulting health service utilization and nursing demand forecasts. Therefore, care should be taken to insure that the projections are realistic, particularly in cases where only a few historical data points are available or where future values of the independent variables may not follow a linear trend.

In the case of the nurse supply submodel, the required input data consist of several major determinants of the future supply of nurses. These include: new graduates, new foreign nurses, new endorsements, reinstated nurses, nurse migration, and license expirations. In general, the model builders found that satisfactory data were available for operation of the model at the three test sites where the model was implemented (Washington, D.C., Madison, Wisconsin, and New Mexico). 35/ The single exception was data on county level nurse migration, which was unavailable at all test sites. Therefore, the alternative method of deriving this data as described earlier was used.

PUGH-ROBERTS MODEL

The final report of the Pugh-Roberts model lists data sources and data needs, and the documentation accompanying it includes a list of model equations and variables. In addition, the User's Manual of DYNAMO III describes the computer programs for the Pugh-Roberts model. Information contained in the documents and additional information obtained in discussions with the model builders will be summarized there.

Computer and Personnel Requirements--Pugh-Roberts Model

The Pugh-Roberts model uses DYNAMO III software, which is written mainly in FORTRAN language. The computer programs for the model are designed to run on medium to large-scale computer systems with at least 400K of memory. The software can be operated as an interactive system and also in a batch mode. The cost of operating the model is estimated at about $20 per simulation run.

Since the computer program for the Pugh-Roberts model is designed to be operated in an interactive mode, it requires personnel with a modest level of skills in modeling and some familiarity with computers. However, if one wishes to change the structure of the model, personnel with a higher level of modeling skills are required.

Data and Personnel Requirements--Pugh-Roberts Model

Three types of data are required to perform the simulations of the Pugh-Roberts model. The first is to provide the measures to

35/ A list of the data sources used in implementing the model at these test sites is provided in the final report of the CSF project.

represent the variables of the model at the initial points in the simulations. The second type is to represent the multipliers, which are quantification of the relationships among the variables. The third and final type is needed to represent the exogenous variables that are external to the model, but affect its behavior. The first and third types of data are relatively easy to obtain. The second type of data needed to quantify the relationships among the variables is difficult to find and sometimes does not exist.

Since the model requires various types of data, many different data sources must be consulted. As the primary source of data on the nursing system, the model builders used the American Nurses Association's Inventory of Registered Nurses and Facts About Nursing and the Division of Nursing's Source Book: Nursing Personnel. For nursing education sectors, the National League for Nursing's longitudinal study supported by the Division of Nursing, From Student to RN and RNs One and Five Years After Graduation, was used. For the nursing employment sector, The Inventory of Registered Nurses, Facts About Nursing, and a study done by the Research Triangle Institute, Trends in Registered Nurse Supply, were used. For the demand sector, because of the complexity of data required, several data sources have to be consulted. As the principal data source, the model builders used AHA's Hospital Statistics; the Division of Nursing's, Survey of Registered Nurses Employed in Physicians' Offices and Nursing Personnel in Hospitals; and the Bureau of Health Manpower's, Health Resources Statistics: Health Manpower and Facilities, 1974, and The Supply of Health Manpower: 1970 Profiles and Projections to 1990.

Because of the diverse nature of data required, personnel required for data collection and activities should have training in mathematics and statistics. They should also be familiar with health and nursing sector statistics. Where data are not available, the model requires estimates based on the judgments of experts. Therefore, the model users should be able to solicit and obtain such expert help.

WICHE MODEL

There are four sets of technical documents accompanying the main body of the final report of the WICHE model. They are user's manuals for the requirements calculation software; the resources calculation software; the profile data base; and the profile report generation system. The software manuals are designed to aid in the generation of a range of requirements and resources projections for nursing personnel based on various combinations of assumptions. These manuals provide the necessary information and instructions to input assumptions and produce sets of projections with minimal effort. The manual for the profile data base provides the necessary information and instructions to produce the individual nursing and health care profile file report using the profile data base and the computerized profile report generation system. The following subsection on the operational feasibility of the WICHE model is prepared on the basis of the information contained in these manuals, and additional information obtained in discussions with the model builders.

Computer, Personnel, and Other Resources Requirements--WICHE model

The requirements and resources calculation softwares of the WICHE model are a series of FORTRAN IV programs. These softwares can be operated in a batch mode by inserting a series of instructions concerning the assumptions made by model users as specified in the user's manuals. Assumptions consist of estimates of the bed-population ratio, the supply of MDs, the volume of outpatient visits per population, occupancy rates, and so forth. These assumptions determine the projections according to the formula specified by the softwares. Preparing the instruction cards and operating the softwares in general requires a person with some technical background in computer systems and data processing. The cost per computer run is estimated at about $20. The model builders estimate that it will take from 6 to 9 months for a State to collect all the necessary background data, convene a panel of experts, make forecasts based on the panel's judgment (formulated with the help of the background data), and then produce the nurse requirements and resources projections based on these forecasts. Most of the background data can be updated annually by those who were familiar with the data sources.

Data Requirements--WICHE Model

Three types of data are required to use the WICHE model. The first type contains the demographic data that are required as the direct inputs for making projections of the number of required RNs in public/community health. These data consist of the State's population divided into three age categories, and the number of live births and infant deaths from birth to 1 year of age. The age-specific population data of an individual State are obtained from the Bureau of Census. The birth and infant death statistics are obtained from NCHS.

The second type of data contains those used to make the key assumptions upon which rests the final projections. These data consist of the historical and current statistics on the bed-population ratio, occupancy rates, the volume of outpatient services and surgical operations per population, the number of MDs, the number of visits to independent/group practices, and the composition of nursing education programs, as well as other data.

The third and final type of data contains those that the model user is urged to consult as background information in making projections. These consist of data on the socioeconomic characteristics of the State's population, health needs/health status of the population, health care facilities and services, nursing personnel, nursing education, and licensure statistics. The data sources for the second and third types of data include NCHS' Vital Statistics and Master Facility Inventory data, the Division of Nursing's Survey of Public Health Nursing and Survey of Nursing Personnel in Hospitals, the American Nurses' Association's Inventory of Registered Nurses and Inventory of Licensed Practical Nurses, and the National League for Nursing's Nurse Faculty Census. Since all three of these types of data are essential in making the projections according to the procedures stipulated in the WICHE model, personnel who have considerable skill in collecting and organizing the above data are required to use the WICHE model.

# IV. MODEL VALIDATION

The objectives of this chapter are threefold. First, it will identify and describe the validation efforts that have already been undertaken by each of the model builders. Second, it will discuss how these past efforts may be extended in the most fruitful way in terms of furthering the initial objectives of these efforts. Finally, it will examine what types of other validation techniques may be applied to each of the four models. However, no validation test will actually be conducted; rather, such tests will be designed as deemed most suitable for later implementation.

Reflecting the diverse modeling approaches embodied in the four models, the validation efforts undertaken by the model builders are substantially different among the models, not only in technique, but also in concept. In fact, different techniques are often used for a single model, as in the case of the Pugh-Roberts model where four different methods of validation were employed. In order to identify the various methods used for each of the four models, Applied Management Sciences obtained information from the model builders directly, as well as from the documents accompanying the model reports. A careful examination of the various validation efforts undertaken by the model builders then revealed that the differences in the validation approaches adopted have resulted mainly from the differences in validation requirements. This chapter will attempt to suggest ways in which these efforts may fruitfully be extended, if and when resources become available for the future validation activities.

With this goal in mind, Applied Management Sciences examined the full range of validation approaches available. A taxonomy of all the validation tests is not presented; rather, all relevant validation approaches were considered and, on the basis of this review, the most suitable approach for each of the four models in terms of its theoretical soundness and resource efficiency was developed.

The variety of validation techniques considered for possible adoption fall into several generic categories. Probably, the most often used is the determination of the "goodness of fit" of the model over the historical period from which the model parameters were originally estimated. While not a sufficient condition for achieving forecasting validity, accurate historic tracking is a necessary condition, so that this type of validity check is a very useful and strong test of the model. In fact, only when a structural change is indicated (such as when the estimated parameters have undergone a change indicating a modification in the relationships among variables) will the examination of the historical tracking ability of the model not provide implications as to the accuracy of the model's forecasts. In addition, the examination of historical tracking will identify any diverging or cyclical behavior of the model's forecasts, as well as any tendency for single equation errors to accumulate over time.

The goodness of fit of a model can be ascertained via a number of techniques. One such technique is regression analysis, which simply involves regressing the actual values of the endogenous variables on the predicted values and testing whether the equations that result have zero intercepts and slopes that are not significantly different from one. There are several variations of this technique, but a particularly informative approach was that developed by Theil, as described by Dhrymes et al.:

> By regressing predicted values on actual values and actual values lagged one period, Theil is ... able to investigate whether or not predicted changes tend to be biased toward recent actual changes. Theil's inequality coefficient and its decomposition into elements of bias, variances, and covariance is very closely related to this type of analysis and offers a great deal more information including some information on the tendency of the model to make turning point errors. 1/

Another technique that can be used for evaluating a model's predictive capabilities is spectral analysis. As with regression analysis, there are several variations on this method. For example, one can generate estimated spectra in a simulation experiment and compare these spectra with those generated from actual data. In addition, cross-spectral analysis can also be used to examine the differences between actual and simulated data and to conduct statistical tests of the relationships that exist.

There are numerous other measures that can be used in the evaluation of model validity. Dhrymes et al. 2/ provide a convenient list of the range of descriptive measures that can be used. These nonparametric measures include:

- Single-variable measures
  - mean forecast error
  - mean squared error
  - the level or variability of the variable being predicted
  - a measure of acceptable forecast error for alternative forecasting needs and horizons

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1/ Dhrymes, Phoebus, et al. "Criteria for Evaluation of Econometric Models." Annals of Economic and Social Measurements. New York: National Bureau of Economic Research, 1, No. 3, July 1972.

2/ Ibid., pp. 314-315.

- Tracking measures
  - .. number of turning points missed
  - .. number of turning points falsely predicted
  - .. number of under or over predictions
  - .. rank correlation of predicted and actual changes
  - .. various tests of randomness
- Error decompositions
  - .. bias and variance of forecast error
  - .. errors in start-up position versus errors in the predicted changes
  - .. identification of model subsectors transmitting errors to other sectors
- Comparative errors
  - .. comparison with various "naive" forecasts
  - .. comparison with "judgmental", "consensus", or other noneconometric forecasts
- Cyclical and dynamic properties
  - .. impact and dynamic multipliers
  - .. frequency response characteristics

Of course, the application of these measures and techniques is not limited to historical tracking. They apply equally as well to comparisons of forecasts with postestimation historically generated data. Moreover, in the latter instance, charges of circular reasoning cannot be attributed to the validation approach. It may be considered inefficient though to avoid using the most recent data in the model estimation process in order to be able to immediately apply a forecasting validity check (that is, without a considerable lapse of time). Generally, the model builder uses as much data as possible to estimate the model (particularly the most recent data) in the presumption that the precision thereby gained will reduce forecast inaccuracies to those that are largely the result of inaccurate forecast conditions (that is, the erroneous specifications of the future values of variables that are exogenous to the model), rather than those resulting from inaccuracies in the structural relationship estimates.

Face validity of forecasts often can be ascertained even in the absence of historical data. For example, forecasts of negative wages, graduates, employment levels, and so forth cause some concern for the validity of the forecast. By the same token, a forecast of employment for industrial nurses as high as that for hospital nurses should cause some concern to both the model builder and potential model user. While these types of forecasts can be the result of inconsistent forecast conditions, they can also indicate that the model does not perform well outside of the range of data used in its estimation. Such face validity problems may even identify invalid underlying model assumptions or inappropriate baseline simulation assumptions. At the least, face validity problems necessitate further careful, and often microscopic, examination of one or more specific sectors of the offending model.

Closely related to the face validity checks are forecast consistency checks. These occur where the policy forecasts typically generated as part of the model sensitivity tests are examined for consistency with the economic theory that is supposed to be underlying the equations of the model. While this test is most often used to isolate keypunching errors, data coding errors, and other errors, it is also useful in testing model validity when the model is either highly recursive, or largely simultaneous but estimated with OLS rather than a multistage process. For example, if a large demand subsidy experiment is implemented (such as medicare), and ceteris paribus the model predicts a decline in the prices of factors for which there are derived demands, then either a keypunching error has yet to be discovered or the model has a serious consistency (validity) problem. In the following, the most suitable validation technique for each of the four models will be presented on the basis of the consideration of the types of available validity tests discussed above.

## Validation Tests Conducted--Vector Model

Four types of nurse requirements projections were made by the model builders for each year from 1972 to 1985, for each of the 50 States. These nurse requirements projections were made under four different scenarios: baseline scenario, NHI scenario, HMO scenario, and nurses role reformulation scenario. Under the baseline scenario, the forecasts were also made for six separate provider settings as described earlier. The validation tests conducted consisted mainly of face validity checks of those projections.

There is one main reason why the validation efforts of the model were so limited. The number of nurses required cannot be measured by the actual data, because these nursing requirement forecasts are intended to represent the number of nurses that would have to be employed to meet projected levels of health service utilization while maintaining existing staffing ratios. This concept of nursing requirements does not necessarily correspond to the number of nurses actually employed. Therefore, a comparison of these forecasts with actual nurse employment data would be inappropriate.

Extension of and Proposed New Validation Tests--Vector Model

Since the number of nurses required is not observable, extensions of the validation efforts will have to be limited to consistency checks of health services utilization forecasts.3/ Such consistency checks can be conducted by comparing projections of each State's health services utilization with the actual data between 1972 and the last year for which the data are available.

An additional test of the Vector model can be performed by comparing the model's forecasts for the State of New Mexico with similar forecasts developed by the CSF model. Since these forecasts have already been made, it would require very little additional effort on the part of the Division of Nursing to conduct such tests. Although their modeling techniques differ, both models forecast health service utilization in acute care and long-term care settings, 4/ and the nursing requirements concepts are similar. The Pugh-Roberts model forecasts of the Nation's nurse requirements under conditions of no interaction between supply and demand provide another basis for intermodel comparison. The Vector model's projections are at the state level, but the model builders have also aggregated them to the national level. Thus, the two forecasts can easily be compared.

Finally, the values of impact parameters representing the relative magnitudes of the effects of health care system changes on the health services utilization can be evaluated. The parameters representing the size of the effect of the NHI program on the health services utilization correspond to the price elasticities of demand for health services, where the price of health services is represented by consumers' total out-of-pocket expenses. For example, under the first NHI scenario, it was assumed that the average inpatient coinsurance rate would decrease from 10 to 5.3 percent, and that for ambulatory service would decrease from 60 to 39 percent. These correspond to a 47 percent decrease in the price of inpatient care to consumers, and about a 35 percent decline in the price of ambulatory care. Under the second NHI scenario, it was assumed that there would be no coinsurance, which amounts to a price decline of

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3/ In the making of consistency checks, the objective is to identify models which produce outlier forecasts for further examination, and not to suggest that the best forecast is average of the distribution observed. The outlier forecast may, in fact, be the most accurate forecast.

4/ In the case of the Vector model, these would correspond to the hospital inpatient and nursing home settings, respectively.

100 percent. Given these price declines, and the Vector model's projections of the resulting increases in health services utilization, the relevant literature can be consulted to see whether the Vector model's estimates are realistic. 5/

If time and resources are made available, empirical studies of the effects of changes in the coinsurance rates on health services utilization can be made to validate the Vector model's forecasts under the NHI scenarios. The most beneficial methods of such studies would involve multivariate analyses of the effects of changes in the average coinsurance rate of the residents of the SMSAs on the per capita utilization rate of acute inpatient services. For such studies, data must be available on the coinsurance rate, health services utilization, and other factors affecting the health services utilization for a sufficient number of SMSAs over several years, preferably 1972-77. If multiple regression analyses were used, the magnitude of the coinsurance rate coefficient, where the dependent variable is the utilization rate of acute inpatient services, can be compared with the Vector model's forecasts of the impacts of the NHI scenarios on the health services utilization.

The Vector model's projections of the magnitudes of the impacts of the growth of HMOs on health services utilization can also be examined to ascertain whether these projections are realistic. Under the first HMO scenario, it was assumed that the total number of new HMOs for all States was 34 per year. Under the second HMO scenario, an average of 65 new HMOs per year was assumed, indicating a growth in coverage of from 2.4 percent of the Nation's population in 1972 to 10.6 percent in 1985.

What effects HMOs have on the utilization rate of health services compared with the fee-for-service mode of delivery is an unsettled issue. One thing appears to be certain. It is that HMO enrollees in general have a lower rate of utilization of inpatient care. The efforts to validate the Vector model's estimates of the effects of different rates of the growth of HMOs should, therefore, be in the direction of checking for plausibility of the model's forecasts of inpatient care utilization under the two HMO scenarios.

Validation Tests Conducted--CSF Model

Two types of validation tests were performed for the CSF model as

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5/ Some of the relevant literature are Richard N. Rossett (Editor), The Role of Health Insurance in the Health Services Sector, (New York: National Bureau of Economic Research, 1976); Lien-fu Huang and Elwood W. Shomo, "Assessment and Evaluation of the Impact of Archetypal National Health Insurance Plans on U.S. Health Manpower Requirements," HEW publication No. (HRA) 75-1, July 1975; and Anne A. Scitovsky and N.M. Snyder, "Effect of Coinsurance on Use of Physician Services," Social Security Bulletin, June 1972.

a part of the testing and evaluation procedure. The first type consisted of the goodness of fit tests conducted for the health services utilization submodel for the acute care and long-term care facilities. The second type consisted of forecast consistency checks conducted for health services utilization and nurse supply submodels.

In order to examine the relative performance of the institution specific submodels, the goodness of fit tests were conducted using regression analysis. Twenty step-wise regressions were run on data for long-term care facilities in the Madison, Wisconsin region. Patient days were used as the dependent variable in all regressions. The difference between equations was reflected in the choice of independent variables and the grouping of hospitals. Hospitals were grouped according to size and control for the long-term care facilities, and according to three additional classification variables (technology, teaching, and service) for the acute care facilities. The independent variables included a variety of measures representing age, race, income, mortality rate, physical supply, and hospital beds.

Two types of statistics were generated from these utilization submodel regressions to be used in the goodness of fit tests: $R^2$ and the standard error of the estimate. As shown in Tables 4.1 and 4.2, $R^2$ values ranged from .34 to .76 among the 20 acute care equations, and .50 to .87 among the 8 long-term care equations, respectively. For several of these equations, a large proportion of the total variation in the dependent variables remained unexplained by the independent variables as specified. Consequently, it was expected that the equations would provide only gross estimates of health service utilization at the institutional level for both types of facilities. This was confirmed by the forecast consistency check, conducted at the same Madison, Wisconsin test site, where a comparison of the regression forecasts with actual institutional data indicated large percentage errors in many cases.

The consistency checks were conducted with the actual data for the 1975 forecasts of patient days and nurse supply for all acute and long-term care facilities aggregated to the multiple-county level at the three test sites: the Madison, Wisconsin region, the Washington, D.C. area, and the State of New Mexico. Table 4.3 shows the results of the consistency checks of the forecasts of patient days in which the predicted patient days are close to the actual 1975 values in most cases. The differences between the predicted and actual values are largest for acute care facilities in both Washington and New Mexico. 6/ The closeness between predicted and actual patient days

6/ Further analysis of the New Mexico results revealed that the higher level of error resulted from a lower average occupancy rate (65) and a higher concentration of hospitals in the small size category (50-145 beds) in New Mexico than the national average.

TABLE 4.1: CSF MODEL $R^2$ AND STANDARD ERROR OF ESTIMATES FROM STEP-WISE REGRESSIONS OF ACUTE CARE FACILITIES IN THE MADISON, WISCONSIN REGION

| Model Number* | $R^2$ | Standard Error of Estimate |
|---|---|---|
| 1 | .394 | 2632.7 |
| 2 | .624 | 5599.9 |
| 3 | .564 | 5932.1 |
| 4 | .533 | 14395.3 |
| 5 | .696 | 10580.0 |
| 6 | .767 | 11915.9 |
| 7 | .704 | 27660.6 |
| 8 | .458 | 249.5 |
| 9 | .491 | 949.0 |
| 10 | .573 | 2550.0 |
| 11 | .453 | 1453.4 |
| 12 | .578 | 2883.0 |
| 13 | .416 | 5366.2 |
| 14 | .501 | 435.5 |
| 15 | .403 | 1115.3 |
| 16 | .387 | 7888.9 |
| 17 | .555 | 2922.7 |
| 18 | .578 | 8104.8 |
| 19 | .341 | 7828.9 |
| 20 | .738 | 1760.5 |

*Dependent variable is patient days. Model equations differ according to the combinations of independent variables specified and the groupings of hospitals.

TABLE 4.2: CSF MODEL $R^2$ AND STANDARD ERROR OF ESTIMATES FROM STEP-WISE REGRESSION OF LONG-TERM CARE FACILITIES IN THE MADISON, WISCONSIN REGION

| Model Number* | $R^2$ | Standard Error of Estimate |
|---|---|---|
| 1 | .503 | 1342.8 |
| 2 | .734 | 1505.7 |
| 3 | .787 | 2894.0 |
| 4 | .610 | 6324.6 |
| 5 | .850 | 14602.7 |
| 6 | .878 | 7259.2 |
| 7 | .863 | 1473.4 |
| 8 | .674 | 7217.6 |

*Dependent variable is patient days. Model equations differ according to the combinations of independent variables specified and the groupings of hospitals.

TABLE 4.3: CSF MODEL COMPARISONS OF 1975 PREDICTED AND ACTUAL ACUTE CARE AND LONG-TERM CARE PATIENT DAYS IN SELECTED AREAS

| Category | Predicted | Actual | Percent Deviation |
|---|---|---|---|
| Madison, Wisconsin | | | |
| Acute Care | 962,298 | 949,703 | + 1.3 |
| Acute Care (excluding Psychiatric) | 929,883 | 926,309 | + .4 |
| Long-Term Care | 2,916,838 | 3,110,425 | + 6.2 |
| New Mexico | | | |
| Acute Care | 1,032,038 | 956,835 | + 7.9 |
| Long-Term Care | 1,014,667 | 1,036,191 | - 2.1 |
| Washington, D.C. | | | |
| Acute Care | 2,702,675 | 2,440,033 | +10.8 |
| Acute Care (excluding Psychiatric) | 2,245,609 | 2,312,900 | - 2.9 |
| Long-Term Care | 2,425,580 | 2,368,733 | + 2.4 |

indicates that the aggregation of the institutional forecasts to the multiple-county level tends to improve the accuracy of the forecasts. For this reason, the model builders concluded that the most appropriate use of the acute care and long-term care submodels would be to aggregate the forecasts to the county or multiple-county level. 7/

Another set of forecast consistency checks was conducted by comparing the predicted number of RNs, LPNs, and nursing aides with the actual numbers at the multiple-county levels in the three test sites for 1975. Table 4.4 shows the results of such comparisons performed for RNs in all settings including ambulatory, community and public health, and other. The predicted values are close to the actual one except for the RNs in the long-term care facilities in the Washington, D.C. area. In fact, there is no difference between the predicted and actual values in the settings other than the inpatient setting.

For the hospitals in the Madison, Wisconsin area where more detailed data were available, a comparison between the predicted and actual patient days for 1975 of each institution was conducted with a statistical method called the "test of difference between two means". As can be seen from Table 4.5, a total of 19 different regression models were applied to the acute care hospitals in the Madison, Wisconsin area. Using the 20 hospital group equations described earlier in Table 4.1 for acute care hospitals, a prediction of patient days was made for each acute care hospital in each group. 8/ The mean predictions for each group were then compared to the actual means for the same group of hospitals. The differences between two means were then examined for significant differences according to the t-test at a 95 percent level of confidence. As can be seen from the table, only two models or groups of hospitals showed significant differences at this level of confidence between the means of the actual and predicted values of patient days, although it should be noted that only models 9 and 15 had a "reasonable" number of degrees of freedom and one of these exhibited a significant difference.

As a final method of checking the forecast consistency of the CSF model, the predicted and actual numbers of patient days were compared for each hospital separately. The difference between the predicted

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7/ The institutional forecasts have to be aggregated to the county level in any event in order to be consistent with the nurse supply forecasts and the forecasts of nursing requirements in the other two employment settings.

8/ No explanation was available as to why only 19 of the 20 acute care models were used. Possibly the 20th model referred to a null set in Madison, Wisconsin.

TABLE 4.4: CSF MODEL COMPARISONS OF 1975 PREDICTED AND ACTUAL REGISTERED NURSE SUPPLIES BY TYPE OF PERSONNEL AND EMPLOYMENT SETTINGS IN SELECTED AREAS

| Category | Predicted | Actual | Percent Deviation |
|---|---|---|---|
| Madison, Wisconsin | | | |
| Acute Care | 1611.1 | 2015.0 | -20.0 |
| Long-Term Care | 391.9 | 475.5 | -17.6 |
| Ambulatory | 205.2 | 205.2 | -- |
| Community and Public Health | 366.5 | 366.5 | -- |
| Other | 93.8 | 93.8 | -- |
| TOTAL | 2668.5 | 3156.0 | -15.4 |
| New Mexico | | | |
| Acute Care | 5791.5 | 5849.0 | - 1.0 |
| Long-Term Care | 320.8 | 391.4 | -18.0 |
| Ambulatory | 828.3 | 828.3 | -- |
| Community and Public Health | 1763.1 | 1763.1 | -- |
| Other | 1259.4 | 1259.4 | -- |
| TOTAL | 9963.1 | 10091.2 | - 1.3 |
| Washington, D.C. | | | |
| Acute Care | 1837.0 | 1775.8 | + 3.4 |
| Long-Term Care | 152.2 | 89.4 | +70.3 |
| Ambulatory | 284.8 | 284.8 | -- |
| Community and Public Health | 607.5 | 607.5 | -- |
| Other | 448.5 | 448.5 | -- |
| TOTAL | 3330.0 | 3206.0 | + 3.9 |

TABLE 4.5: CSF MODEL TESTS OF DIFFERENCES BETWEEN MEANS OF ACTUAL AND PREDICTED PATIENT DAYS FOR GROUPS OF ACUTE CARE HOSPITALS IN 1975

| Model No. | Number of Data Points (hospitals) | No. of Degrees of Freedom | Value of t-test* | Significant at .05 Level |
|---|---|---|---|---|
| 1 | 6 | 10 | -0.28 | No |
| 2 | 6 | 10 | -0.84 | No |
| 3 | 6 | 10 | -0.12 | No |
| 4 | 1 | -- | NA | -- |
| 5 | 0 | -- | NA | -- |
| 6 | 3 | 4 | 3.29 | Yes |
| 7 | 3 | 4 | 0.30 | No |
| 8 | 5 | 8 | 0.99 | No |
| 9 | 12 | 22 | 3.49 | Yes |
| 10 | 1 | -- | NA | -- |
| 11 | 0 | -- | NA | -- |
| 12 | 3 | 4 | 0.26 | No |
| 13 | 2 | 2 | 1.22 | No |
| 14 | 1 | -- | NA | -- |
| 15 | 10 | 18 | -0.15 | No |
| 16 | 1 | -- | NA | -- |
| 17 | 3 | 4 | -0.53 | No |
| 18 | 3 | 4 | 2.09 | No |
| 19 | 5 | 8 | 0.41 | No |

*Negative values indicate that the actual means was higher than the predicted means.

NA - t-test not applicable due to lack of data points.

and actual values varied a great deal ranging from 12 to 572 percent. However, the individual institution models were not expected to give highly accurate results, and these models were designed to be aggregated for the total planning area.

Extension of and Proposed New Validation Tests--CSF Model

The above suggests some additional areas where the validation tests can effectively be extended. One is simply extending the period of forecasts after 1975 as more data become available. This will allow a repeat of the forecast consistency checks for a period of more than one year. The period for which the actual and predicted values are compared can also be extended backward, toward the years before 1974, in order to allow checking the historical tracking ability of the CSF model.

The second area where the validation tests of the CSF model can be extended fruitfully is to apply the methods described above in checking the forecast consistency to all the forecasts possible with the available data. For example, the tests of difference between two means were used for the health service utilization forecasts at the institutional level in the Madison, Wisconsin region. These tests can be applied to the nurse employment forecasts for patient service areas in all test sites.

Finally, the goodness of fit tests conducted for the projections of patient days in acute and long-term care facilities were limited to the Madison, Wisconsin region only. These same tests could be applied to nurse supply projections and in other than inpatient settings and, to the extent data are available, in the other test sites as well.

Validation Tests Conducted--Pugh-Roberts Model

Of all the four models, the Pugh-Roberts model was subjected to the most validation testing. As a part of building and refining the model on a trial and error basis, four types of model validation tests were undertaken by the Pugh-Roberts model builders. The first type consisted of checking the simulation results for their face validity or plausibility. Face validity checks of initial simulations with the model revealed a number of inconsistencies between model relationships, and aspects of model behavior, that appeared unrealistic. This is to be expected in any complex system during the process of development which relies heavily on a priori data or in a System Dynamics model. The necessary modifications were, of course, made. Then the results of simulations conducted following these modifications were further examined for plausibility by a Task

Force.9/ This examination revealed some additional structural inconsistencies and unrealistic behaviors in the model, which were subsequently corrected.

The second type of validation test conducted for the Pugh-Roberts model consisted of forecast consistency checks. This was done by carefully scrutinizing simulation results for the first 4 years of the forecast (1972-76), and comparing them with data available for those years. In addition, these forecasts were compared with similar projections made by the Research Triangle Institute and the Interagency Conference on Nursing Statistics. As a result of these comparisons, some major adjustments or calibrations were made to the model.

As the third type of validation test, the Pugh-Roberts model builders checked the historical tracking ability of the model. This was done by running a series of simulations for the period from 1962 to 1972, under a variety of assumptions. The results of the initial simulation were carefully examined to see how closely the model could duplicate real-world behavior during the period. The results diverged somewhat from the real-world behavior as indicated by the historical data. It was discovered, however, that this was because the assumptions made with respect to the exogenous variables in the simulation runs were not applicable to the conditions actually affecting nursing in these years. A new set of simulations was run after correcting the assumptions about the external factors affecting the supply of hospital and nursing home beds, and the results conformed more closely to actual behaviors observed during the 1962-72 period.

Clearly then, the face validity tests, forecast consistency tests, and the tests of historical tracking ability were undertaken by the Pugh-Roberts modelers as logical steps to refine the model. As the final step of refining the model through the validation tests, policy/assumption impact forecasts were generated by the Pugh-Roberts model builders as a part of a set of sensitivity tests. Sensitivity tests conducted with the Pugh-Roberts model must also be considered as validation tests, because the model's projections involve various assumptions about the possible changes in health care systems most of which are expected to be induced by specific policies.

Seven sets of simulations were conducted as sensitivity tests with the Pugh-Roberts model. Each simulation involved limited changes from the baseline assumptions. The types of changes incorporated into each of the seven sets of simulations were:

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9/ In response to a concern that the model be an accurate representation of nursing and its role in health care, a National Task Force was formed and played an important role in the model development.

(1) a doubling in the size of educational programs and of applicants to those programs

(2) a decline in diploma programs that results in a complete elimination of diploma programs during the first half of the simulation

(3) a more rapid growth in the total population than in the baseline; and a death rate that is 3 percent lower for all age categories than the rates used in the baseline

(4) a large, rapid shift in the demand for nursing personnel in hospitals, especially during the first 5 years of the simulation

(5) a complete elimination of all effects that cause changes to occur in education, other factors affecting supply, such as labor force participation, and demand as a result of supply-demand mismatches

(6) a complete elimination of the effects of supply and demand mismatches (simulation 5) combined with a sharp, rapid increase in hospitals' demand for nurses (simulation 4) that helps to create a significant mismatch

(7) an assumption of no change during the course of the simulation in breadth of nurses responsibilities, fraction of the hospitals that have collective bargaining agreements with nurses, and fraction of the hospitals that pay different wages to RNs at different levels of preparation.

The results of the seven sets of simulation are presented in Table 4.6, where for each simulation the percentage differences between values of variables in 1990 are displayed. The larger percentage changes shown in column 1 relative to other columns indicates a greater sensitivity of various aspects of the model's behavior to the assumptions of doubling the size of educational programs and the number of applicants to those programs. The next largest changes from baseline values are predicted when there is a rapid increase in hospitals' demand for nurses with no market adjusting process due to supply and demand mismatches (simulation assumption 6).

Extension of and Proposed New Validation Tests--Pugh-Roberts Model

Since the validation efforts undertaken by the Pugh-Roberts model builders have been so thorough, no additional types of tests appear to be necessary. It is suggested, however, that those validation tests already conducted can be augmented by extending the period of the forecast consistency checks beyond 1976 as data become available. Also, as more projections from other sources (other models) become available, the Pugh-Roberts model's forecasts should continue to the compared with them.

TABLE 4.6: RESULTS OF SENSITIVITY SIMULATIONS: PERCENTAGE CHANGES FROM BASELINE VALUES

| | Simulation Numbers | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Total RNs | 30 | -3 | 1 | 3 | 3 | 3 | -1 |
| RN demand | -10 | 0 | 3 | 9 | 0 | 20 | -10 |
| RNs employed | -10 | -2 | 2 | 5 | 0 | 6 | -10 |
| Inactive considering employment | 4 | -19 | -10 | -15 | 44 | -16 | 35 |
| Total LPNs | 45 | 1 | 2 | -12 | 10 | 10 | -1 |
| LPN employment | -1 | 0 | 2 | -32 | 10 | -17 | -3 |
| Employment in hospitals | -10 | -1 | 3 | 9 | 0 | 14 | -13 |
| Ambulatory care | -13 | -2 | 0 | -4 | 1 | -10 | -3 |
| Nursing home | -10 | -1 | 0 | -5 | 0 | -15 | -1 |
| Home care | -23 | 0 | 0 | 0 | -9 | -31 | 0 |
| Nursing schools | 33 | -14 | 0 | 1 | 13 | 2 | -7 |
| Public health | -14 | 0 | 3 | -1 | 1 | -8 | -1 |
| Private duty | -11 | -1 | 0 | -1 | 1 | -7 | -1 |
| RNs at the A.D. level | 51 | 7 | 2 | 8 | 8 | 8 | -1 |
| Diploma | 18 | -14 | 1 | 1 | 0 | 0 | -1 |
| Baccalaureate | 31 | 2 | 1 | 3 | 4 | 4 | -9 |
| Advanced | 39 | 0 | 1 | 2 | 1 | 1 | 0 |
| Enrollments in LPN programs | 66 | -2 | 7 | -28 | 39 | 39 | -7 |
| A.D. | 38 | 15 | 4 | 11 | 16 | 16 | -5 |
| Diploma | 83 | -100 | 1 | 4 | 2 | 2 | -2 |
| Baccalaureate | 29 | 9 | 2 | 6 | 8 | 8 | -15 |
| Advanced | 47 | 0 | 1 | 3 | 2 | 2 | 0 |
| Nursing pers./pt. short-term hosp. | 2 | 0 | 0 | 2 | -1 | 6 | -6 |
| long-term | 1 | 0 | 0 | 2 | -1 | 6 | -6 |
| Frac. of pers. who are aides | 0 | 2 | 0 | 19 | 0 | -1 | 13 |
| LPNs | 0 | 0 | 0 | -48 | 0 | -48 | 1 |
| RNs | 0 | -1 | 0 | 8 | 0 | 18 | -7 |

Beyond the above updatings of the forecast consistency checks, the best way to extend the validation efforts undertaken by the Pugh-Roberts model builders is to scrutinize more closely and validate the multipliers. The multipliers specify the magnitude of impacts of changes in various factors on key variables in the Pugh-Roberts model. Table 4.7 shows the role the multipliers play in determining nurse supply. As can be seen from Table 4.7, as the ratio of the current real wages to 1972 wages changes by 25 percent, the nurse labor force changes by 5 percent in the same direction.

The validation of such a multiplier can be conducted in either of two different ways. First, the real-wage multiplier with respect to the nurse labor force can be checked for plausibility and realism by comparing it with similar coefficients estimated by other studies. Where the multipliers examined have not been studied previously by others, or where direct comparisons are not possible because of the different approaches taken, their plausibility can be further examined on theoretical grounds, that is, on the basis of consistency with relevant literature or a priori reasoning.

The second suggested method of validating the multipliers would be to conduct selected empirical studies consisting of correlations between the impacting variables and the impacted variables (such as wage rate and nurse labor force). Multivariate analyses may be conducted for such correlation studies. For example, to the extent data are available or collected on the nurses wages, nurse labor force, and other factors affecting nurse supply for a sufficient number of the SMSAs over several years, multiple regression analyses can be conducted to estimate the partial impacts of wages on the nurse labor force. Then, the estimates thus obtained can be compared with or even replace the multipliers in the Pugh-Roberts model.

Validation Tests Conducted--WICHE Model

In order to test the WICHE model, six States were selected as the project test sites. They are Iowa, Louisiana, New Mexico, New York, Rhode Island, and Washington. In all but Washington, nurse requirements and resource projections were made or are being made according to the process specified by the model. In addition, although they are not members of the six States selected, Colorado and Mississippi have also tested the WICHE model on their own initiatives.

The projections made in these States were scrutinized by the panel of experts who participated in making the projections and the advisory committee of the pilot test States. In addition to such face validity tests, the nurse requirements and resources projections made according to the WICHE process have been compared with the projections made according to other models in New Mexico. As a result of these validation efforts, some refinements of the WICHE model have been made. These mainly involved changing assumptions and altering the requirements calculation software accordingly.

TABLE 4.7: EFFECT OF VARIOUS FACTORS ON THE FRACTION OF LICENSED NURSES AT EACH EDUCATIONAL LEVEL WHO ARE EMPLOYED OR WILLING TO CONSIDER EMPLOYMENT--PUGH-ROBERTS MODEL

| Effect on nurses willing to consider employment of: | Determined by the values of these variables: | These values of the variables: | Correspond to these multipliers that increase or decrease the fraction of those employed or considering employment |
|---|---|---|---|
| 1. Average nurses wages for each educational level | Real wages of personnel at each level (adjusted to factor out inflation)<br><br>1972 wages for personnel at that level | 0.50<br>0.75<br>1.00<br>1.25<br>1.50 | 0.90<br>0.95<br>1.00<br>1.05<br>1.10 |
| 2. Breadth of nurses responsibilities | Dimensionless index in which a value of 1.0 represents the breadth of nurses responsibilities in 1972 | 0.0<br>0.5<br>1.0<br>1.5<br>2.0 | Effect varies (greater impact on higher educational levels, for example):<br><br>LPN — Advanced degree<br>0.98 — 0.90<br>0.99 — 0.95<br>1.00 — 1.00<br>1.01 — 1.04<br>1.02 — 1.08 |
| 3. Effect of changes in overall economy over time | Projected effect over time | 1972<br>1977<br>1982<br>1987<br>1992 | 1.00<br>1.02<br>1.01<br>1.00<br>1.00 |
| 4. Other exogenous factors | Projected effect over time | | No changes due to other factors assumed in most simulations |

Extension of and Proposed New Validation Tests--WICHE Model

The conventional validation tests cannot be applied to the WICHE model. Validity tests, therefore, must be tailored to WICHE's non-traditional modeling approach. One possibility for WICHE is to reconstitute the panels for the six pilot test States, but with different compositions of interests and points of view, so that the sensitivities of the model outputs to the panel compositions can be ascertained. If a great deal of such sensitivity exists, for most of the six States, it should be stipulated that the model be used mainly to produce conditional projections, where the conditions should represent varying sets of assumptions that are responsible for the majority of the sensitivity.

An alternative suggestion for WICHE model validation is to compare the results of the pilot applications among the six States to see if the difference, if any, in the projected numbers of nurses required and available per capita amoung States can be rationalized in terms of two criteria. One is the stipulated health care goals that the panel used in making nurse requirements projections. Another is each State's population composition and socioeconomic conditions.

It was noted above that the projections made by the WICHE model for New Mexico have been compared with those made by other models. Such comparisons can be extended for projections made for other sections by the Vector and CSF models. The Vector State model has made nurse requirements forecasts for each of the 50 States from 1972 to 1985 at the nine employment settings. As more States join the six pilot test States to use the WICHE model to make nurse requirements projections, those projections can be compared with the Vector model's projections for comparability. The CSF model's institution-specific projections can also be aggregated to the multiple-county level and compared with the WICHE model's projection, at the substate level. As mentioned in Chapter 3, the WICHE model can be used to forecast nurse requirements and research at the substate level.

Finally, since the WICHE model is designed not only to provide a process for forecasting but also to educate policymakers, the model can be examined fruitfully to see how well it succeeds in its task of education. As mentioned in Chapter 3, the WICHE model provides a great deal of background materials and data. As another validation technique for the WICHE model, it is suggested that these background materials and data be scrutinized by experts and policymakers to ascertain the model's performance in its task of "descriptive clarification" 10/--the determination of the present and past trends in

10/ Gary D. Brewer, in Politics, Bureaucrats, and the Consultant (New York: Basic Books, 1973), p. 59.

problem areas. For all types of models, it has been recognized that models are instruments for exploring reality as well as portraying it. The validation test suggested for the WICHE model to check its descriptive clarification can be extended to an examination of the model in terms of its usefulness in exploring as well as portraying the reality of the health care and nursing sectors.

# V. MODEL INTERACTION

Chapter 4 described how the validation efforts of the four models may be extended fruitfully and it also suggested new validation approaches for each of the four models. The validation efforts are directed toward refining the four models individually and, thereby, improving their forecasts in terms of the confidence one can place in them. This chapter addresses the issue of how to increase the value and usefulness of the four models by using them in combination, rather than singly. The objective of this chapter is to identify and describe methods of combining the four models that appear to have the highest potential for payoffs. In order to identify such methods, a discussion of various techniques for combining or linking models is presented first. Then, the techniques judged to be most applicable to the four models are suggested for possible implementation.

It is, of course, beyond the scope of this project to actually apply the suggested methods to the four models. Rather, the intent was to examine each model carefully, undertake discussions with the original model builders, ascertain the needs of the Division of Nursing, and design and suggest the most appropriate interactive modes based upon the findings. It will be left to a future effort to actually implement and test the efficacy of these suggestions and designs.

## Methods of Linking Models

In analyzing the existing modes of model interactions, two different types will be defined: vertical model interaction and horizontal model interaction. Vertical interaction can be defined as the process of physically linking the components 1/ of two or more separate models. The investigation of the potential for vertical integration of models requires a disaggregation of each model into its component parts and a comparison of the structural characteristic of each complementarity.

In evaluating the potential for vertical linkage, the major issue to be addressed is that of compatibility. The question of compatibility can be examined by looking at the intermediate and final outputs of each model and comparing them with the initial and intermediate inputs of the other models. In other words, the complementarity of the sectors addressed by each model may provide

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1/ Each of the four models contains several components or submodels. The model structure specifies the role of each component within the models and the interrelationships among the components. Chapter 3 describes the model structure of each of the four models.

some potential for vertical linkage. If one set of variables is treated exogenously by one model component but generated endogenously by another model component, a possibility for linkage may exist. Before a vertical linkage can take place, however, a comparison of the definitions must be made to see if they are compatible. One model may estimate all registered nurses employed in a hospital setting, while another model may include registered nurses in public health nursing as well. It is extremely important to recognize and account for such definitional variations before model linkage is attempted.

On the other hand, horizontal interaction is defined as interactive intermodel usage in either a prescribed sequence or in an iterative fashion, rather than a formal linkage of model components and equations. By way of further explanation, there are three variations of horizontal interaction which can be identified to this point:

- parallel use of models - providing a range of requirements forecasts corresponding to the different assumptions and methodologies of each model
- complementary use of models - mixing the use of the models to take advantage of different costs, turnaround times, and other factors
- feedback use of models - using the outputs of one model as a basis for modifying the results of another or to provide objectives for simulations of another model

The first of these variants is the simplest, and consists of the possibility of using two or more of the models in parallel to generate a range of probable outcomes or a "consensus" forecast. With parallel uses of models, one can ascertain: Are consistent output patterns generated? How close are they? Are variations in the output patterns systematically related to underlying model assumptions or length of the forecast? With the answer to these and other questions, the parallel use of the models can produce useful policy information significantly in excess of that generated by any single model forecast.

The second variant of horizontal model interaction, the complementary use of models, is closely related to the first, but provides a special focus on the sequential use of the models as determined by the ease and cost of implementation. Many forecasts are time consuming to implement. Others generate multiple forecasts in a very short period of time utilizing specially designed computer software packages. At the same time, each model has associated with it some average cost per experiment or forecast, which will vary depending on the nature of the process or the type of algorithm being employed. There may also be some model design characteristics which make one model more suited to short-run, rather than long-run forecasts (such as the nature and difficulty of establishing forecasting conditions, the number of variables being forecasted). Many of these factors are, of course, interrelated, but an examination of them is expected to identify those models that are best suited to short-range planning due to quick-turnaround forecasting capability and reasonable cost per forecast, and those models that are suited to long-range forecasting because of high costs per forecast and substantial time necessary to generate each forecast. Thus, with the proper mix and sequence of model usage, it should be possible to treat the various models as being complementary, so that the forecasts are mutually supportive.

The last variation of horizontal model interaction so far identified, the feedback use of models, involves the possibility of using the output of one or more models to suggest experiments with one or more of the other models. This is not a formal model feedback, but rather a feedback mechanism that is based on the differences observed in the modeling approaches. For example, a requirements model could be used to generate an estimate of the nurse shortage or surplus for that year, but a market equilibrium model could then be employed to simulate the alternative types of policies necessary to bring the estimate of actual nurse employment in line with the nurse requirements forecasts. One can then predetermine the feasibility of instituting alternative policies to reach that goal and, at the same time, ascertain which policy is the most effective in reaching the goal.

## Potential Vertical Interactions

As discussed in Chapters 2 and 3, many differences exist between the four models with respect to their intended uses and the requirements concepts embodied within the models, as well as in geographical coverage, comprehensiveness, basic model structure, computer software requirements, and other factors. Due to these differences, vertical interactions among the four models are not feasible in most cases. There are, however, two possible areas of vertical interactions that are likely to improve the total value of the models to the user. The first is to use the output of the CSF's health service utilization submodel as input for the Vector model's forecasts of nurse requirements. The second is to use the Vector model's intermediate output (that is, the model's forecasts of health services utilization) as input for the Pugh-Roberts model's projections of nurse requirements. The particular nature of each of the suggested vertical interactions will be discussed.

## Vertical Interaction Between the CSF and Vector Models

A careful examination of the four models has shown that there is a sufficient degree of commonality between certain components of the CSF and Vector models to allow vertical interactions between the two models. These key components are the CSF model's health service utilization submodels and the Vector model's demand-for-service module. The CSF submodels produce projections of health services for several specific types of institutions based on input data describing the population and health system characteristics of each institution's patient service area. These characteristics consist of age, family income, mortality rate, number of hospitals, and physician supply by selected specialties. One of the Vector model's modules forecasts the demand for health services for each of the groups in the population module, where the population module consists of population characteristics such as age, sex, family income, and insurance coverage.

As can be seen from the above, the basis of projecting the demand for health services in both models is the population characteristics, and these characteristics are comparable between the two models, although not identical. To link the CSF and Vector models vertically, however, at least one of the measures representing the intermediate outputs of the two models must be made identical. To examine whether some of the intermediate outputs of the two models are classified in the same way, Table 5.1 shows that the CSF model contains 20 submodels for acute care institutions and 8 for long-term care institutions. At the same time, the Vector model's demand-for-service module produces projections of health services demand in six provider settings. All hospitals (excluding Federal) in the CSF model's acute care settings correspond to the Vector model's non-Federal, short-term inpatient units. Thus, the CSF model's forecasts of patient days in acute non-Federal institutions are identical to and, therefore, may replace the Vector model's projections of the demand for inpatient care at non-Federal, short-term hospitals, to become the basis of the Vector model's forecasts of nurse requirements at these institutions.

Since the CSF model's forecasts are at individual institutional levels, these have to be aggregated to the state level, as was done for New Mexico, for validation purposes. However, the Vector model's forecast cannot be disaggregated to the institutional level. This is the reason for suggesting that the intermediate output of the CSF model be the input for the Vector model's forecasts of nurse requirements, but not vice versa.

A prescription can be made so that the linking of the two models in this manner will produce superior forecasts if two assumptions are confirmed. The first assumption is that the CSF model's forecasts of health care utilization aggregated to the state level are more reliable than those produced by the Vector model. The second assumption is that the Vector model's final output is more useful to policymakers than those of the CSF model because the Vector model addresses specific relevant policy issues. It is suggested that before adopting the above method of linking the CSF and Vector models, a comparison be made between nurse requirements projections

TABLE 5.1: CLASSIFICATION OF THE INTERMEDIATE OUTPUTS OF THE VECTOR AND CSF MODELS

VECTOR MODEL

Output of the Demand-for-Services Module

Projections of health service demands in the following provider settings:

1. Non-Federal short-term hospital inpatient units
2. Hospital outpatient and emergency units
3. Physicians' offices
4. Nursing care homes
5. HMO clinics
6. Home health care

CSF MODEL

Acute Care Setting

Size
1. 0-49 beds
2: 50-149 beds
3: 150-299 beds
4: 300+ beds

Control
1: Government/Non-Federal
2: Nongovernment/Not-for-profit
3: For profit
4: Government/Federal

Technology
1: Low technology
2: Medium technology
3: High technology

Teaching Status
1: Teaching
2: Nonteaching

Long-Term Care Setting

Size
1: 3-24 beds
2: 25-49 beds
3: 50-99 beds
4: 100-199 beds
5: 200-299 beds
6: 300+ beds

Control
1: Proprietary
2: Not-for-profit
3: Government

for New Mexico produced by the CSF model, the Vector model, and the vertical interaction of the two. Such comparison will, however, not enable one to determine whether the suggested vertical interaction improves the accuracy of the forecasts of the two models. This is because there is no way to validate nurse requirements forecasts with historical data. If the interaction produces forecasts that are way out of line with the forecasts made by the two models individually, one will be able to analyze the underlying cause behind such a discrepancy. The fact that such analysis can be made indicates that the suggested interaction may not necessarily improve the accuracy of the forecast, but will provide a tool to make a more robust policy analysis. As mentioned before, the Vector model is a macromodel at the state level, whereas the CSF model is a micromodel at the institutional level. The suggested interaction enables the users of the Vector model to look behind the aggregate figures at the individual institutions and, thereby, gain a better knowledge of the nurse and health care sector.

Vertical Interaction Between the Vector and Pugh-Roberts Models

It has been observed that there is also a sufficient degree of similarity between the Vector and Pugh-Roberts models' intermediate outputs to allow vertical interaction between these two models. The point of linkage is the Vector model's demand-for-services module and the Pugh-Roberts model's demand sector. As mentioned above, the Vector model's projection of health services demands are based on the projections of future population cohorts in terms of age, sex, family income, and insurance coverage. The Pugh-Roberts model's projections of the demand for health services demands are based on projections of the Nation's population in terms of its total size and distribution among 10 age categories, and fertility rates and death rates for members of each age category.

As was the case for the CSF and Vector models, the inputs for projections of the demand-for-health services by the Vector and Pugh-Roberts models are also comparable, although not identical. However, as mentioned before, at least one of the measures representing the intermediate outputs of each model must be identical, if the models are to be linked vertically.

Table 5.2 compares the outputs of the demand-for-services module of the Vector model with those of the demand sector of the Pugh-Roberts model. The Vector model produces projections of health service demands in six provider settings, whereas the Pugh-Roberts model generates projections in seven employment settings. Two projections are identical between the two models -- nursing (care) homes and hospital outpatient and emergency units, or outpatient departments. To make the two models' intermediate outputs for acute inpatient care identical, Federal hospitals must be excluded from the Pugh-Roberts model. With this modification, then, the intermediate outputs of the Vector model for demand for services at the above

TABLE 5.2: CLASSIFICATION OF THE INTERMEDIATE OUTPUTS OF THE VECTOR AND PUGH-ROBERTS MODELS

VECTOR MODEL

Output of the Demand-for-Services Module

Projections of health service demands in the following provider settings:

1. Non-Federal short-term hospital inpatient units
2. Hospital outpatient and emergency units
3. Physicians' Offices
4. Nursing care homes
5. HMO clinics
6. Home health care

PUGH-ROBERTS MODEL

Output of the Demand Sector

1. Hospitals
   - short-term
   - long-term
2. Ambulatory care
   - physicians' offices and group practices
   - outpatient departments
   - community health centers and mental health centers
3. Long-term care facilities (nursing homes)
4. Home care agencies
5. Nursing schools
6. Public health settings
   - public health agencies (excluding nurses providing home care)
   - occupational health
   - school health
7. Private duty and other

three provider settings can be used as inputs for making projections of nurse requirements and supplies by the Pugh-Roberts model.

Two versions of the Vector model were developed and are operational: a national model and a state model. The national model was developed first, and then a state model was developed that is similar to the national model in almost all respects. However, the state model supersedes the national model in the sense that it can also produce national forecasts by aggregation, whereas the national model cannot be disaggregated to produce forecasts at the state level. For the vertical interactions with the Pugh-Roberts model, it is suggested that both the Vector's state and national model be attempted. Although projections of the Nation's demand for health service are similar to those made by the Vector national model and the state model by aggregation, using both the Vector's national and state models for linking with the Pugh-Roberts model would provide another set of projections of nurse requirements and supply that could then be compared with each other. Comparison of the forecasts by the Vector state model aggregated to the national level and those by the vertical interaction will also provide an insight into the workings of the nurse and health care sector and, thereby, provide a tool for a more robust policy analysis.

## Potential Horizontal Interactions

### Parallel Use of Models

The simplest horizontal interactions among the four models is the parallel use of the models. The Vector state and WICHE models both generate nurse requirements projections at the state level. The CSF model's institution-specific forecasts can also be aggregated to the state level. By using these three models to forecast state-level nurse requirements, one can generate a range of forecasts for each State. At the national level, the Pugh-Roberts and aggregated Vector state models can be used to generate nurse requirements projections for the entire Nation.

The results of the parallel use of the models can be compared in a number of ways in order to gain a better knowledge of nursing and health care sectors. First, a table could be constructed listing the three models' nurse requirements forecasts for each of the 50 States for a given year. Then, the forecasts of the three models--the Vector, WICHE, and CSF models--could be ranked in each State according to the magnitude of the projected number of nurses required. Such a ranking would enable one to ascertain whether there is a consistent pattern in the relative bias of state projections according to the model that generates the projections.

The second type of comparison would involve an extension of the above comparison over several years. If a consistent pattern among each model's forecasts is found, is such a pattern discernible for multiple-year projections? If such a pattern is observable over several years, is the pattern weaker or stronger as the length of forecast period grows? If there was no discernible pattern among the model projections for 1 year, does a pattern emerge for the projections for the later years?

Another fruitful use of the parallel forecasts comparisons is to systematically analyze the causes of the patterns, if any, that are observed among the model's forecasts for 1 or several years. The cause may be sought in the model structure, the input data, and the assumptions underlying the model development. For example, if one model's forecasts are consistently larger in magnitude than those of another model and are caused by differences between the two models' underlying assumptions, such knowledge would prompt a comparative analysis of the underlying assumptions of the two models. Such analysis will detect any weakness that may exist in the assumptions and, thereby, make adjustment in the model structure and refine the model. Generally speaking, these parallel forecasts will enable model users to better evaluate the relative merits of each model, and enable policymakers to use the four models in combination as a more effective and reliable tool than using them singly.

## Complementary Use of Models

The second type of horizontal interactions appropriate to the four models is their complementary use. It was mentioned in Chapter 3 that the Vector model is programmed to operate in an interactive mode and possesses quick-turnaround forecasting capability and reasonable cost ($12 per simulation). On the other hand, due to its model design, the WICHE model has high start-up costs. The model builders estimate that it will take 6 to 9 months for a State to collect all the necessary background data, convene a panel of experts, and make forecasts based on the panel's judgment. The computer programs of the two models, however, use a common language, namely FORTRAN language, although the WICHE's software is programmed to operate in a batch mode. The above differences and similarities in the model design between the Vector and WICHE models can be used to combine the two models in a complementary way for mutual benefits.

For example, the WICHE model can be used to generate an initial short-range forecast of nurse requirements of a State. Then, utilizing the information obtained form the WICHE model's forecast, the Vector model can be used to make subsequent quick-turnaround projections of nurse requirements of the same State for the later years. The Vector model's projections need not be mere extensions of the WICHE model's forecast into the later years. Instead, the Vector model can incorporate its own assumptions of the future conditions of the health care sector into its long-range forecasts. Thus, by relying on the information gained through the WICHE model's heavy commitment of resources to the initial forecasts and by utilizing the

Vector model's quick-turnaround capability and the reasonable computer costs per forecast, policymakers can use the two models more effectively in combination than singly.

The similarities and differences in the model design of the Vector national and Pugh-Roberts models can also be utilized to use the two models in a complementary way. The two models are quite similar in computer requirements. Both are programmed to operate in an interactive mode, although the Pugh-Roberts model can also be operated in a batch mode. The Vector model's computer programs are coded in FORTRAN language and the Pugh-Roberts DYNAMO III software is also written mainly in FORTRAN language. Moreover, the computer costs per simulation are equally reasonable for both models--$12 per simulation for the Vector model and $20 for the Pugh-Roberts model.

Thus, there is little to be gained by combining the two models in the way suggested for the WICHE and Vector state models. Instead, it is suggested that the Pugh-Roberts model's market equilibrating process be used to forecast the long-range outcomes of the Vector model's projections of alternative policies considered by the model. As mentioned in Chapter 3, the Vector model is designed to evaluate the effects on nurse requirements emanating from proposed NHI schemes, the growth rate of HMOs and the role of nurses. One may use the Vector model to generate a short-run initial projection of nurse requirements under various scenarios specified by the model. Then, on the basis of these projections, the Pugh-Roberts model may be used to forecast nurse requirements and supply in the later years, when the market equilibrating process specified by the model fully adjust to these initial changes in the health care sector. In this way, one may take advantage of different features of the two models for mutual benefits. From the Vector model, one may make use of its formulation and specification of future policy options and their short-run effects. From the Pugh-Roberts model, one may make use of its market equilibrating process to analyze the long-range impacts of the Vector model's alternative policy options where various market forces interact to adjust to the policy actions taken. Using the two models together in such a complementary way would enhance the total value of both models.

## Feedback Use of Models

Horizontal interactions among the four models of the feedback type is suggested as the third potentially beneficial linking method. It has been mentioned that the Vector model generates nurse requirements projections at the state level and national levels as well. However, this model does not produce nurse supply at either level. At the national level, the Pugh-Roberts model's projections of nurse supply could be compared with the Vector model's projections of the Nation's nurse requirements in a given year. Such a comparison would generate a forecast of nurse shortage or surplus relative to requirements at the national level. Given a forecast of nurse shortage or surplus, the Pugh-Roberts model can then be used to simulate the alternative type of policies to increase or decrease the Nation's nurse supply, to eliminate or reduce the projected nurse shortage or nurse surplus as calculated. Note that according to the Pugh-Roberts model, policies designed to change nurses mean wages, their responsibilities, and overall economic conditions, systematically influence nurse supply; and the direction and magnitude of these influences depend on the multipliers specified by the model. Therefore, the feedback interaction of the models as suggested above would enable policymakers to better anticipate nurse shortages or surpluses in the future and to plan better for most effective policies to cope with the anticipated problem.

A similar feedback interaction can be suggested for the WICHE and Vector models at the state level. By matching the Vector model's projection of nurse requirements with the WICHE model's projection of nurse supply for a given state, model users can project a nurse requirements shortage or surplus in the future for that State. Then, the Vector model could be used to simulate the alternative policies which would increase or decrease a state's nurse requirements shortage or surplus. Note that policies changing the coinsurance rate of NHI, the growth of HMOs, and the role of nurses, systematically change the nurse requirements according to the assumptions embodied in the Vector model. Thus, the above feedback interaction of the two models would enable policymakers to better anticipate a nurse requirements shortage or surplus for their State and to formulate appropriate policies to change the nurse requirements to cope with the requirements shortage or surplus problems.

In summary, the potential payoffs from the vertical interactions among the four models are likely to be rather limited due to the substantial differences in the variety of model attributes. Nevertheless, the suggested experiments of vertically linking the CSF model with the Vector state model and, to a lesser extent, those of linking the Vector state model with the Pugh-Roberts model are likely to provide a better insight into the workings of the health care sector and nurse sector. The potential horizontal interactions promise to enhance the total values of the four models. For example, the suggested parallel use of the model would enable one to evaluate the comparative merit of each model and, thereby, enable policymakers to use the four models in combination as a more effective and reliable tool than using them singly. The potentially highest payoffs are likely to accrue from the suggested complementary use of the models. This is because this would enable one to take advantage of the differences and similarities between the four models to economize resources and yet enhance the usefulness of the models to policymakers. Finally, the suggested feedback use of the models is likely to enable the model users to consider more policy options relevant for the likely developments in the health care sector in the future and to analyze their effects and implications in a broader context.



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