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ABSTRACT

Objectives of the project were to identify and describe problem areas and policy issues confronting health manpower planning agencies at all levels, compile an inventory of models and evaluate their usefulness, and to evaluate the potential usefulness of two models (developed under contract to the Bureau of Health Resources Development) designed to project future health manpower requirements. Volume One of the report provides an overview of the health manpower analysis areas discussed in relation to the demand for and supply of health manpower services. The characteristics of 56 models (described in detail in Volume Two) are outlined by way of an overview and a discussion of their applicability to health manpower analysis problems. A detailed description and evaluation of the two large scale models follows (the Preliminary Operational Human Resources Research Center Microsimulation Model and the Simulation of Hospital Utilization and Health Manpower Requirements Model). The lengthy analysis is concluded with a presentation of 14 major conclusions based on the results of the study. Three principal recommendations are outlined. (SA)

AN ANALYSIS OF HEALTH MANPOWER MODELS

Monographs and Data for Health Resources Planning Series

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Volume I

AN ANALYSIS OF HEALTH MANPOWER MODELS

Final Report of Contract No. MI-24313 by Vector Research Inc., Ann Arbor, Michigan

The Division of Manpower Intelligence, contractor for this study, was dissolved as of March 1, 1974 in conjunction with reorganization of the Bureau of Health Resources Development (BHRD).

Inquiries concerning this material should be addressed to the Resource Analysis Staff, Office of the Bureau Director, BHRD, at the National Institutes of Health, 9000 Rockville Pike, Bethesda, Maryland 20014.

Preface

A major program objective of the Division of Manpower Intelligence during the 2½ years of its existence was the analysis of current and future health manpower resources and requirements. In pursuit of this objective, the Division engaged in the development and support of various modelling activities aimed at developing improved techniques and analytical tools. These activities were carried out both by Division staff and by contract studies.

The present report on work performed by Vector Research, Inc. for the Division of Manpower Intelligence under contract number MI-24313, "A Health Manpower Model Evaluation Study," consists of two volumes. This first volume contains a comparative analysis of problem areas in health manpower analysis and the subject matter treated by the models described in Volume II. An indepth evaluation of two models contracted for by the Division of Manpower Intelligence, "The Preliminary HRRC Microsimulation Model" and the "Simulation of Hospital Utilization and Health Manpower Requirements," is included. It is believed that the information contained in these reports should be of value to all persons interested in health manpower analysis.

The material presented in this report was prepared by Seth Bonder, Timothy C. Doyle, and Janice R. Enberg of Vector Research, Inc., with the assistance of W. Peter Cherry, Paul J. Feldstein, and William W. White. The authors wish to express their appreciation for the cooperation of the Human Resources Research Center staff and the Research Triangle Institute staff in the preparation of the report.

SUMMARY

This summary provides an overview of the results of the health manpower model evaluation study conducted for the Bureau of Health Resource Development (BHRD) by Vector Research, Incorporated. These results are presented in a two volume report which includes a detailed de -ription of 56 health manpower models, an evaluation of these models in terms of their usefulness to health manpower analysis problems, and an in-depth analysis of two large-scale models developed under BHRD contracts.

The description of the 56 models proviu.. in the second volume of the report contains information on the purpose, scope and subject, and model assumptions, as well as identifying model structure, inputs and outputs, computer characteristics, and modeling techniques employed. The majority of the models were found to have been developed using some form of regression analysis. The remaining models are a mixture of optimization models (e.g., linear programming) or descriptive models (e.g., queueing, Monte Carlo or deterministic stimulation models, etc.). Classification of the models by subject areas revals that over one-half of the models cover topics concerned with health care delivery organizations. Slightly less than half of the models fall in the health manpower resource and consumer service behavior areas. Of the models which deal directly with health manpower, the overwhelming majority are primarily concerned with two health disciplines-- physicians and

nurses. Other subject areas treated by the movels are incidence of illness, health professions education, educational choice, and population dynamics.

Each member of the array of models is briefly described in volume I of this report. This description provides an overview of these models, presenting the attributes commonly shared by the members of model populations and identifying dissimilarities where significant. The models described are then evaluated in terms of their usefulness to current and potential health manpower analysis problems. The analysis issues which provide a backdrop for this model utility assessment are presented within the framework of the general problems concerned with the demand for and supply of health manpower services. Major analysis areas concerned with health manpower demand include: (1) the characterization of health service utilization in terms of the cultural/demographic composition of the health consumer population, (2) the analysis of health service demand in terms of economic factors, and (3) the assessment of the effects of health care delivery constraints on the utilization of services. Similarly, the health manpower supply analysis areas are: (1) the analysis of factors influencing additions to the stock of health manpower, (2) the examinations of the specialty and geographic distribution of health personnel, and (3) the analysis of labor force participation and utilization of health manpower.

The study evaluated the usefulness of the models with this analysis framework in terms of four criteria -- applicability, generality, validity, and operational feasibility. The operational feasibility of a model varies from user to user as a function of the user's computational capabilities and time constraints and the model's operational requirements. Model validity is considered in terms of the realism and consistency of basic assumptions and structural relationships, mathematical soundness, and empirical verification. A tabulation is presented which outlines the testing history (if any) of each model in the inventory.

Model generality is the ability of a model to be used effectively in user problems which are similar, but not necessarily identical to those underlying development of the model. For example, a model suitable only to describe the operations of Johns Hopkins Hospital is a nongeneral (i.e., specific) model. A table is provided which indicates the degree of generality of each of the models examined.

In the evaluation of applicability, emphasis is placed on the relevance of model inputs and outputs to the six major areas of health manpower analysis described above. Important policy actions (user-controlled inputs) and performance measures (outputs) are associated with each analysis area to determine model applicability. The following areas are found to have received the greatest amount of modeling activity: economic factors influencing demand, cultural/demographic factors influencing demand, and factors affecting labor force participation and efficient utilization of health manpower. Of the 56 models examined, eight describe health processes which are not directly relevant to the above analysis areas.

The two large-scale models evaluated in this study are the *Preliminary Operational HRRC Microsimulation model* developed by the Human Resources Research Center at the University of Southern California and the *Simulation of Hospital Utilization and Health Manpower Requirements* developed by the Research Triangle Institute. The models are evaluated in terms of their conceptual and empirical structures, the results of model validation tests and the resources required to operate the models. The examination of the conceptual and empirical structure of the HRRC model indicates that it does not treat many of the parameters used in policy analysis and omits a number of factors which influence the behavior of simulated processes. Furthermore, a general disparity in the level of detail and sophistication offered by the various subcomponents of the structure is observed. Since only limited model validation experiments were performed on this model, VRI echoes the HRRC recommendation that additional experiments are necessary. The operational requirements of the HRRC model are minimal with the exception of the user time required to transfer the programs to his computer facility and to become familiar with model attributes.

The conceptual structure of the RTI model contains three inherent assumptions which may reduce the accuracy of model preductions. These assumptions are: (1) the supplies of hospital resources and personnel are limitless, (2) the current conditions and observed trends in the provision and consumption of hospital services and manpower remain stable over time, and (3) the ratio of hospital services utilized to manpower requirements is some trended constant over time. Within this somewhat constrained environment, the RTI model can provide an alternate mechanism for predicting future requirements for short-term, general hospital personnel. The predictive capabilities of the three component models of the RTI simulation were tested against historical data in a fairly extensive series of verification tests. The results of these tests indicate that two of the component models -- the population history and hospital episode models -- predict outputs which compare favorably with historical data, particularly when the outputs are aggregated. The validity test performed on the third component model -- the manpower requirements model -- was difficult to assess due to lack of comparable historical data.

The report concludes with a delineation of summary conclusions and principle recommendations of the study. The final and most important recommendation of the study is that major health manpower planning agencies should attempt to employ health manpower models as operational tools. These models should be exercised on a continual basis by health planning analysts. Continual use will generate an inventory of information that can be used to address decision problems in a responsive manner. This hands-on experience will provide insights into the deficiencies of existing models and indicate where future model development efforts should be devoted. Allocation of modeling support without such experience will result in modeling efforts that are unresponsive to user needs.

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1.0 INTRODUCTION

This report describes the work performed under contract #N01-MI-24313, *A Health Manpower Model Evaluation Study*, by Vector Research, Incorporated (VRI) for the Bureau of Health Resources Development (BHRD), Health Resource Administration. The objective of the project was to evaluate the potential usefulness of health manpower models, in general, and specifically to assess the applicability of two selected models in the health manpower analysis and planning environment. This objective was accomplished through the performance of four interrelated tasks which are briefly described in section 1.1 of this introductory chapter. The task description is followed by a general outline of the contents of this report in section 1.2.

1.1 Study Tasks

The first task of the study was to identify and describe the spectrum of problem areas and policy issues confronting local, state, and national health manpower planning agencies. This task was accomplished by: a review of existing documentation describing goals and health manpower issues at the national level; an examination of the documentation describing health manpower problems confronting the State of Michigan; and a series of interviews with personnel in the Division of Manpower Intelligence, BHRD, as well as several individuals at the University of Michigan conducting research on State health manpower problems paralleling this first task.

The second study task was to compile an inventory of models directly or peripherally related to health manpower supply and requirements or problems. To accomplish this task VRI performed a comprehensive search, retrieval and review of written material describing existing health manpower models; developed a set of model inventory descriptors to characterize the models identified; and constructed an inventory of health manpower models in terms of these descriptors.

In the third task, the spectrum of analysis areas compiled in task 1 was used as a backdrop against which the usefulness of the models identified in task 2 were assessed. That is, the utility of these models was evaluated in terms of the number and type of health manpower issues treated by these models and the degree of detail or insight that health manpower models contribute to the analysis areas identified.

The fourth and final task of this study was specifically designed to evaluate the potential usefulness of two models developed under contract to BHRD. These models were developed to project future health manpower requirements -- one, to forecast short-term hospital manpower requirements, and the other to provide an econometric model of health manpower system behavior. The evaluation of both models was conducted in three phases. In the first phase members of the VRI staff independently reviewed available documentation on each model and delineated model capabilities and shortcomings. In the second phase, on-site meetings were held with model developers to substantiate VRI's understanding of the models and the results of the first phase evaluation. Topics included in these discussions were: rationale and philosophy underlying the development of each model; structure of the models and their subcomponents; application and limitations of these models; and anticipated modifications and/or enrichment of each model. In the third and final phase information obtained at these meetings was integrated into the comprehensive model evaluation presented in this final report.

1.2 Outline of the Report

The material presented in this report is divided into two volumes. Volume I documents the result of the identification of health manpower analysis areas, the assessment of the usefulness of models in addressing these areas, and the evaluation of the two selected health manpower models. Volume II, the *Health Manpower Model Inventory*, contains a detailed description of 56 health manpower models and a structure for classifying these health manpower models. The specific contents of the first of this two-volume report are discussed in the following paragraphs. A similar description of the contents of volume II is provided in the first chapter of that volume.

Volume I of this report is organized into five chapters -- this introductory chapter followed by three chapters describing the results of the work performed on the above tasks and a chapter describing summary conclusions and recommendations. The second chapter presents an overview of the health manpower analysis areas identified in the first task of the project. The discussion of analysis areas is organized into two parts -- the demand for and supply of health manpower services. Areas for analysis of demand identified in chapter 2.0 include -- the cultural-demographic characterizations of consumer utilization of health care, the influence of economic factors on consumer demands, and the health service delivery system which constrains and modulates this demand. The problem areas confronting the supply of health manpower services are outlined in terms of the geographic and specialty maldistribution of health manpower, the poor representation of minorities and women in medicine, and the ineffective or inefficient utilization of health manpower services, in addition to the more general problem of shortages of certain types of manpower.

The third chapter, entitled Health Manpower Modeling, summarizes the attributes of models described in volume II, *Health Manpower Model Inventory* of this report. Models which treat similar subject material (i.e., manipulate similar parameters) are collectively discussed to facilitate reader understanding of the overall framework of modeling activity which constitutes the spectrum of health manpower models, as well as to simplify the subsequent similarity matching of model attributes and health manpower analysis requirements. Following this overview of the models in the inventory, the applicability of these models to health manpower analysis problems is discussed. A comparison between model input/output variables and analysis factors is used to isolate the collection of models potentially applicable to each analysis area. This comparison is followed by a discussion of the model concentration in each analysis area as well as a description of analysis areas requiring further analytical activity.

In chapter 4.0 the results of VRI's evaluation of the two large-scale models, developed under BHRD contract, are described. The two models examined are the *Preliminary Operational HRRC Microsimulation Model* developed by the Human Resources Research Center at the University of Southern California and the *Simulation of Hospital Utilization and Health Manpower Requirements* developed by the Research Triangle Institute. To facilitate discussion of the model evaluations, a brief description of the structure and components of each model is provided. The description of each model is followed by the results of VRI's evaluation. These results are divided into three model assessment areas:

(1) the conceptual foundation and analytic structure of the model and the statistical estimation techniques employed in model development,

(2) the results of model verification tests or experiments, and

(3) the resources required to operate the model and use its results.

The description of the results of the model evaluation is concluded with a brief discussion of the requirements for applying the models to actual analysis problems.

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2.0 TAXONOMY OF HEALTH MANPOWER [illegible]

This chapter presents a classification [illegible] current and potential health manpower analysis [illegible] confronting regional, state, and national [illegible] agencies. The descriptive material provided [illegible] used in chapter 3 as a backdrop against which [illegible] manpower models identified in this study [illegible] applicability of health manpower models [illegible] the number and type of health manpower issues [illegible] degree of detail or insight that the models [illegible] analysis areas, and the relevance of model [illegible] governmental actions intended to alleviate [illegible]

The chapter is organized into three [illegible] tory section describing the need for more [illegible] health manpower development problems, a [illegible] factors and analysis problems associated with [illegible] power services, and a third section which [illegible] issues confronting the supply of these [illegible]

2.1 Requirement for More [illegible]

There is an increasing awareness [illegible] increases in the numbers of health manpower [illegible] determine the status of the nation's [illegible] lation growth, greater public [illegible] care, rising incomes, expansion of services offered, and increasing health insurance coverage have all contributed to the rising demand for health services. To satisfy this demand, new health manpower programs must focus on the factors which influence the demand for services and evaluate the services provided by various manpower categories rather than simply concentrate on the number of health personnel. This service assessment should include analysis of such elements as the quality of health care, relative cost of services, perception of need, manpower productivity, labor force participation, alternative health practice settings, alternative mixes of manpower delivery teams, and specialty and geographic distribution of health manpower. The assessment should also consider the analysis of factors affecting the total supply of health manpower services.

Many previous health manpower analysis activities have been exclusively tied to some predetermined manpower-to-population ratio (i.e., physicians, dentists, or nurses per 100,000 population) to determine the adequacies of the supplies of health manpower services. The traditional health manpower planning technique has been to measure the supply of health manpower in terms of these ratios, estimate projected or existing health manpower shortages, and enact legislation with the principle objective of alleviating these shortages. Although the ratio techniques provide an easily understood numerical assessment of health manpower supply and demand, their utility (as a sensitive, reliable performance measure of health services provided) is suspect. The accuracy of previous projections of manpower-to-population ratios has been degraded by often inaccurate population forecasts and unreliable predictions of future manpower supplies. This unreliability is evidenced by the considerable variance among the estimates of manpower ratios developed in various studies.[1]

Furthermore, the achievement of a particular ratio will not necessarily guarantee that the health service requirements of the population will be met. That is, the ratios do not reflect changes in the magnitude and type of services required within a given population, nor are they sensitive to alterations in the efficiency of health care service delivery -- two principle factors which may significantly influence the utilization of health manpower services. Therefore, as long as the collective demands for health care continue to change and the modes of health care delivery remain in a continual state of flux, health manpower ratios will provide only limited insight into the actual health manpower situation. As a consequence, programs tied to specific ratio objectives may have only a restricted influence on the escalatory cost of medical care and may not guarantee that individuals who need health services will necessarily receive them.

[1]See Hansen, W. Lee, "An Appraisal of Physician Manpower Projections", *Inquiry*, March 1970.

Recognition of the inherent limitations in these inventory-taking methods as a manpower evaluation tool has resulted in an increased focus on identifying and measuring health manpower factors which more accurately reflect the status of the nation's health manpower system. Health manpower models are one of the tools available to health planners and government policy-makers to investigate the effects of various programs and policies on the supply of and demand for health manpower services. However, for these models to be useful they must: first, manipulate parameters bearing on the user's analysis problems; second, provide an accurate representation of the real world; and, third, perform their analytical function within the time and resource constraints of the user. The remainder of this chapter is concerned with the first item (identifying analysis areas of interest to users). Since the focus of the present study is to evaluate the utility of models to health planners in general, rather than to a single individual or organization, the analysis problems which might typically confront health planning agencies need to be identified.

Clearly, this discussion of analysis areas can neither be exhaustive nor extremely specific because of the breadth of subject material currently or potentially of interest to health manpower planners. Rather, the material presented here should be viewed as a compilation of general health manpower problem areas confronting national or local health planning agencies. In the presentation that follows, specific health manpower problems will be discussed within the framework of two general health manpower analysis areas -- the demand for and the supply of health manpower services.

2.2 Characteristics of the Demand for Health Manpower Services

Two types of health care demands placed on manpower services are those which are placed directly on private practitioners and their employees and those which are placed on health care institutions (e.g., hospitals, nursing homes, psychiatric care facilities, etc.) which in turn establish requirements for health personnel. Both types of demand are usually preceded by the health consumer decision to seek some form of health service. Thus, the analysis of the demand for health manpower services requires an understanding of the factors which influence the consumer's health, his behavior, and his consumption of health manpower services. Factors which influence the consumer's behavior include an individual's cultural beliefs, attitudes toward health care, psychological condition, and perception of illness, as well as the relative utility, cost and quality of health care which he perceives. Since data describing these parameters are difficult if not impossible to obtain, most analyses attempt to describe variations in health service utilization in terms of socioeconomic, demographic, or other differentiable attributes of the population, as well as changes in epidemiological conditions, price, and other health system parameters. These patterns of health service utilization are then used to describe the influence of consumer discretionary behavior on the demand for health services.

For the results of these analyses of health consumer demands to be useful in health manpower planning, they must be translated into requirements for manpower services. The way in which these requirements are met will depend not only on the magnitude and type of services desired, but also on the staffing patterns and manpower resource levels as determined by the operational and functional limitations of health care delivery organizations. Variations in type of services offered and the size of the health service facilities utilized, as well as differences in the allocation and mix of personnel, will have a compound effect on health manpower requirements. These health care delivery factors act as constraints which affect the requirement for manpower at a given level of utilization. They also shape and mold the type of care sought by influencing the prices, accessibility, and availability of services offered. Thus, in order to simplify our discussion of these highly interrelated analysis factors, the description of these areas for analysis is organized into three categories -- cultural-demographic factors, economic factors, and health care delivery constraints.

2.2.1 Cultural and Demographic Factors

The type and magnitude of health care services demanded are often stratified for analysts in terms of parameters such as age, sex, marital status, family size, education, and residence (urban vs. rural). For example, the incidence of illness, morbidity patterns, disease recovery rates, and mortality rates all vary with age. Females in different age groups require different quantities of obstetrical service, and men require none. Marital status and family size reflect the availability of home recuperative care, and hence can be used to characterize total amounts of service demanded. Differences in cultural beliefs and social attitudes toward utilization of health care might be distinguished by an individual's education and/or location of residence.

Data describing the above (and other) cultural/demographic population attributes and health services consumption are used as a basis for determining health service utilization behavior. Predictions of the relative numbers of persons in each population category coupled with descriptions of the health service utilization behavior provide a mechanism for estimating future service consumption, and hence requirements. These estimates are, however, often constrained by limitations inherent in the available data. Relationships between different types of utilization and the desired set of demographic factors are difficult, if not impossible, to ascertain since the cross-sectional and/or longitudinal utilization data required is often unavailable, incomplete, or inconsistent. However, these data constraints can be overcome under certain circumstances, either through statistical manipulation of existing data or extensive data gathering and/or identification activities.

Although the analysis of cultural-demographic factors may increase understanding of health consumer behavior patterns, it offers a few areas where health agencies can intervene and improve health service utilization. One such policy action which could affect utilization is the education of the consumer, particularly in the area of health or health-related subject material. Health education, for example, could change cultural attitudes and increase public awareness of alternative forms of treatment and service delivery. Greater understanding of disease symptoms and treatment of self-limiting illness could result in earlier detection and hence treatment of serious illnesses and a reduction in the utilization of health services for minor ailments. An educated consumer could possibly differentiate levels of service quality being offered and select the type of service most cost/beneficial to him. Furthermore, a part of this educational activity could be devoted to dissemination of information on the availability of free preventive treatments such as chest -rays, pap smears, and vaccinations as well as to inform the public of impending epidemics (e.g., flu or syphilis) or health hazards (e.g., environmental pollution, severe weather, or dangerous working conditions). Although there are other cultural-demographic factors which could be influenced by governmental intervention such as marital status, family size and residence -- educational and information dissemination programs appear to be the only actions contemplated in the near future.

In addition to the aforementioned limitations, analysis of the influence of cultural-demographic factors on health service utilization will not reveal the effects of economic factors on the demand for services, nor does it reflect the constraints placed on the consumer by the health service system. The analysis of the effect of these latter factors on health service demands is the topic of the next two subsections.

2.2.2 Economic Factors

Two economic factors which affect the demand for health services are the price of services (i.e., the cost of health care to the consumer) and the income or ability of the consumer to pay for services offered. The cost of medical care to the consumer consists of not only the fees charged and/or prices demanded by physicians and health institutions, but also other intangible costs such as loss of leisure time, difficulties in obtaining health care, and other inconveniences which confront the health consumer. Since most of the nonmonetary costs are the result of restrictions placed on the consumer by the health delivery system, discussion of these costs will be left to the subsequent subsection. Here we shall concentrate on direct and indirect (e.g., loss of income) monetary costs of health care service, and the effects of these costs on the utilization of health services.

Prices of health care affect not only an individual's decision to seek health services, but also the amount and type of service he uses. For example, the price of health services may influence whether or not a person decides to have elective surgery to improve a chronic condition, to remain in a hospital for a longer recuperative period, or to seek the services of a medical specialist or a general practitioner. The outcome of such decisions may also be influenced by the consumer's ability to pay, a combination of his income and coinsurance.

Analysis of the effects of these factors on the utilization of services is necessary to assess the impact of economic programs aimed at decreasing the cost of health care or reducing health economic barriers confronting low income groups. The effects of programs designed to decrease the cost of care to selected groups (e.g., Medicare and Medicaid) and proposed programs aimed at ameliorating the total cost of care (e.g., the National Health Insurance Standards Act and the Family Health Insurance Plan) on the overall demands for health services need to be examined. Significant reductions in cost of health care to the consumer could increase the quantity of care demanded which may, in turn, escalate the price of care in the short run. Within these programs, alternative reimbursement systems (e.g., prospective vs. retrospective payment) should be examined with respect to their possible moderation of escalating health care costs.

The relationship between income and the consumption of health services should be examined to determine the effects of this factor on the overall utilization of health services. Different income groups may consume differing quantitites and types of health service. Persons with higher incomes may select more comprehensive forms of care (e.g., yearly physicals and elective surgery), have longer lengths of stay in health institutions, utilize more specialized services, and pay higher prices for similar services. Furthermore, the consumer's ability to pay for care could influence a physician's selection of treatment modality and partially account for the amount and type of health services utilized.

A third factor which must be specifically taken into account in analyzing the economics of health care utilization is health insurance. Health insurance not only distorts the impact of cost and income factors on utilization, but also influences the quantity and type of medical care demanded. Insurance protects the individual consumer from unexpected expenses by distributing the cost of medical care across the insured population. By lessening the cost of health care, patterns of consumption are altered. Individuals confronted with "bargain" care are more likely to increase their demand for care, particularly those types of care which offer the greatest insurance coverage. For example, hospital care may be sought instead of ambulatory care because of specific insurance provisions. Similarly, there may be increased demands for specialists vs. general practitioners since their services are more completely insured. Health insurance programs sponsored by the federal government (e.g., Medicaid and Medicare) and by other third party contributions (e.g., company insurance programs) can be viewed as effectively increasing an individual's income and selectively changing his ability to pay for health care services.

The interrelationships between the above factors -- health service utilization and alternative economic policies and programs of governmental planning agencies -- need to be identified to develop, implement, and assess these alternative courses of action. The impact of tax incentives directed toward increasing individual and employer expenditures for health insurance, federal and state welfare programs aimed at decreasing the medical costs or increasing the income of the indigent (e.g., Medicaid), and government-supported health care clinics which provide low cost or free services (e.g., neighborhood health clinics) additionally should be addressed in this analysis.

2.2.3 Health Care Delivery Constraints

In addition to the economics and cultural-demographic factors which influence and characterize an individual's decision to seek health services, external health care delivery constraints may limit and mold the choice of alternatives available to the health consumer. The accessibility of different services may not only influence the type of care sought, but also contribute to the decision to seek care. The disutility associated with consumption of services which require encumbering appointment procedures, long travel or waiting times, or other similar inconveniences may significantly influence a consumer's decision process. Similarly, the relative accessibility of alternative health delivery forms may affect the type of care utilized.

Alternative modes of health care delivery such as prepaid vs. fee for service care, group vs. solo practice, and preventive vs. episodic medical care, affect the manner in which these services are utilized and hence influence the manpower service requirements for patient care. For example, group practices may place greater dependence on auxiliary personnel to provide continuity of care for chronic illnesses than would a solo practitioner; or preventive medical services may require fewer inpatient services (i.e., shorter lengths of stay, fewer admissions, or both) and more outpatient visits than its episodic counterparts; or prepaid patients may demand more services than fee-for-service patients.

Inherent in the health care delivery system are a complex set of procedures which further constrain the action space of the health service consumer. Foremost among these is the restriction that all but the most simple of medical care services requires some interaction with a physician. As a consequence, the physician acts, in part, as a buyer of health services for the consumer. This patient-physician relationship results in the physician rather than the consumer placing demands for many kinds of health services. Physicians not only select the method and location of treatment, but also as a consequence of these decisions, determine the overall magnitude and type of health service required for each illness episode. Factors which influence the physician's decision process include: training and specialized orientation (e.g., a surgeon may treat specific health problems in a different manner than an internist or a general practitioner); special institutional agreements and arrangements (e.g., hospital appointments, clinical testing and laboratory arrangements, etc.); patients' interests (i.e., cost and quality of alternative treatment modalities); and the physician's personal benefits (e.g., income, leisure time, utility, etc.). The physician's decision space is also constrained by the limits of preferred medical practice and professional or organizational sanctions which preclude certain actions such as prolonging a patient's hospital stay or admitting patients to a hospital unnecessarily. Other procedural constraints which are outside the spectrum of physician control are those principally imposed by facility and personnel limitations (e.g., number of beds, type of laboratory facilities, size of hospital staff, etc.).

In addition, the decrease in the relative number of physicians offering what is currently referred to as primary health care (i.e., general or family practice) may result in increased difficulty in obtaining this type of care and subsequently cause inappropriate utilization of medical specialists for self-limiting or non-specific illnesses. The increasing utilization of specialists for initial treatment requires greater consumer medical knowledge (i.e., health education) to select the correct medical discipline and is subject to greater misuse of health manpower talent and a resulting increase in total demand for manpower services.

Thus, one of the major health care delivery constraints which shapes the demand for medical services is the availability or supply of health manpower resources -- the topic of the next section.

2.3 Characteristics of the Supply of Health Manpower

Increasing the number of health professionals still continues to be a primary health service objective to meet increased demands. Programs to stimulate increases in health education enrollments as well as a push toward a three-year medical school curriculum are activities directed toward achieving this objective. The federal government has subsidized construction of new schools and expansion or renovation of existing facilities, encouraged enrollment increases through capitation grants to health profession schools, and supported implementation of curriculum-shortening programs in several health profession schools. Since the first major legislation directed toward increasing the supply of health personnel (Health Professions Educational Assistance Act of 1963), there have been increases in the number of schools, the total enrollment in health education institutions, and the number of health professions graduates; however, the degree to which federal intervention has influenced output increases has been difficult to ascertain.

Although manpower-to-population ratios will probably continue to be the major supply performance measure, what are the parameters which influence this ratio, and more importantly, how can manpower planning agencies influence these factors to modulate the supplies of health personnel? For example, the primary sources of physician supply are schools of medicine and osteopathy and immigration of foreign medical graduates. What are the principal factors which influence these numbers, and what are the impacts of federal or state programs on these supplies? Construction loans or medical school expansion subsidies may increase the capability of schools to produce medical graduates; however, will this capability be utilized? Furthermore, is it the size or quality of educational facilities which primarily determines the number of graduates or are other, possibly less expensive programs, equally as effective in increasing the supply? Programs directed toward increasing class size (such as capitation grants to schools) or those which focus on shortening the educational curriculum (such as subsidies to three-year medical schools) may have a greater impact on physician supply in a shorter period of time and at less cost.

In addition to the assessment of federal and state programs providing monetary incentive to increase supply, the impact of alternative regulatory policies and programs which influence the numbers of health manpower also needs to be examined. Federal policies regarding immigration of health personnel, as well as state licensure and accreditation of both foreign and domestic graduates, could influence the supply of professional and allied health personnel. Alternative immigration policies would modulate the supply of health manpower entering the US, and individual state licensure and accreditation requirements might influence the number of US citizens obtaining foreign medical education. Furthermore, state regulatory policies could be one of the main determinants in an individual's occupational selection process, particularly in certain allied health disciplines. Other ramifications of these requirements could be the relative geographic distributions of numbers of manpower in specific health disciplines as well as the utilization of health-trained personnel currently not participating in the labor force. These two areas of analysis, i.e., distribution and utilization, are the subject of the next two sections.

2.3.1 Health Manpower Distributional Issues

There are essentially three types of distributional questions confronting the nation's health manpower system. First, the maldistribution of physicians among the medical specialties and the scarcity of selected types of manpower has become a major concern. Second, the problems associated with the disparity in the number of health personnel among the several states or similar geographic or socioeconomic boundaries remain unsolved. Finally, there is a maldistribution and poor representation of minorities and women in certain health professions (minority enrollment in medical schools has made large gains in recent years, but is still quite disproportionate to the population percentages).

The first two of the above problem areas are principally concerned with improving the accessibility of primary health care and providing services to those living in areas of inadequate health services. The basic problems of insufficient medical services for lower income groups in city slums and poor rural areas have not been solved. In ten years the percent of active physicians in general practice has decreased from 42.7% in 1960 to 22.9% in 1969. Unequal distributions between specialties has had the effect of causing service shortages even when the total number of health personnel is considered adequate. To alleviate regional manpower shortages, loan forgiveness programs and scholarships are available for those who promise to practice in medically underserved areas. Special project grants for recruitment and training of students likely to practice in shortage areas and specialized programs such as the National Health Service Corps have been established to improve the geographic distribution of health manpower. With respect to specialty distribution, special grants were allocated under the Act of 1971 to support family medicine training to increase the number of primary care practitioners. Finally, programs to improve minority representation in the health disciplines, such as scholarships, loans, and loan forgiveness programs for the financially or educationally disadvantaged have been developed.

Issues for analysis in the geographical location of manpower include the success of current programs in attracting graduates to medically underserved areas, the potential of alternate incentive programs (e.g., tax exemptions, moving subsidies, etc.), and the accessibility of health professionals relocated into these underserved areas. The impact of differences in state licensure and accreditation on the maldistribution of health personnel needs to be evaluated as well as their influence on the migration and location of foreign medical graduates. Alternative programs to standardize these requirements or approach greater uniformity in state regulatory policies may be necessary to reduce the effect of diverse state laws on choice of work location.

State and regional health planning agencies are principally concerned with the numbers of health personnel within sections of their respective geographic borders. These agencies require data describing the current stock of manpower as well as an understanding of the factors which influence these numbers. This requisite information can, in turn, be utilized to assess the impact of alternative programs to increase the supply of health manpower within a particular geographic area. For example, data describing the relative numbers of medical graduates choosing residencies within a region, and subsequently producing medical services in that region, might influence a state to increase support of residency programs. The selection of a particular residency program over another would then depend on the results of an analysis of the factors which influence a medical graduate's decision to select the location of his resident training, e.g., salary, working environment, professional reputation of institution, etc.

In the area of specialty distribution, suggestions have been made that graduated capitation rates to schools and scholarships be linked with relative specialty shortages, and that financial incentives be developed for hospitals so that size and composition of residency programs become related to specialty requirements. Shifts in the requirements for particular specialties should also be investigated (e.g., effect of a decreasing birth rate on the demand for obstetric services). There are a variety of factors which contribute to a physician's choice of specialty such as expected earnings, working environment, perceived job prestige, as well as the accessibility, length and cost of specialty training, and socioeconomic and demographic characteristics of medical graduates. Federal and state programs directed toward improving specialty distribution or increasing the accessibility of primary health care should concentrate on those factors which appear to have the greatest impact on this distribution. In addition, the effectiveness of minority subsidies in meeting the objectives of equal opportunity in the health professions and equalizing health care among different population groups is another issue deserving attention. This analysis problem also includes the questions of to what extent minority graduates will devote themselves to serving minority populations and whether this group would provide a partial remedy to the primary care problem.

2.3.2 Efficient Utilization of Health Manpower and Labor Force Participation

More recent legislation (i.e., the Health Manpower Act of 1971) and the associated program activity has witnessed a shift in policy from exclusive concentration on the numbers of health professionals to an increased attention toward improving the utilization of highly trained health personnel as well as increasing manpower productivity. To this end, programs in interdisciplinary team training, project grants to train for new roles, types or levels of personnel, and capitation grants for training physician assistants and dental therapists are recent indicators of a shift in emphasis from numbers of health personnel to the supply of services. Other contributions directed toward improving manpower utilization and productivity can be expected to come from evaluations of alternative practice settings (i.e., solo versus group practices and fee-for-service versus prepaid or health maintenance organizations); from implementation of modern management strategies concerned with optimal allocation, scheduling and interdisciplinary mixes of health personnel; and from the application of technological innovations which increase manpower productivity.

Although the legislation stresses increasing the supply of allied health workers as a vehicle for improving utilization of physician and dentists' time, and subsidies are provided for physician and dentist extender (physician assistants, nurse practitioners, dental therapists) training programs, the questions concerned with appropriate task delegation and state licensure and credentialing requirements are still unresolved. Other issues created by this use of extender personnel services are: the willingness and ability of physicians and dentists to utilize these personnel; the incentives and disincentives which govern utilization of support personnel; the cost effectiveness of task redistribution to the consumer (i.e., monetary cost, accessibility and quality of care); the allocation of physician and dentist time produced as a result of task delegation; and the appropriateness of alternative mixes of manpower, technology, and practice settings to satisfy various service demands. In addition, questions concerning the utility of various management tools directed at improving the productivity or utilization of health manpower, as well as major factors governing an individual's participation in the health labor force, require further investigation.

Of particular interest to health manpower analysts are the factors which influence the labor force participation rate of nurses. Nurses constitute the largest category of health professionals; however, only about one half of the individuals trained in the nurse disciplines participate in the nurse labor force. Minor increases in the nurse labor force participation rate could, therefore, result in a substantial increase in the utilization of nurse manpower resources. Programs directed toward stimulating an increase in this rate (e.g., nurse refresher training courses) need to be evaluated in terms of their effectiveness and new approaches to this problem identified. With regard to the latter, the relative importance of factors which influence nurse participation (e.g., marital status, location of residence, family income, level of training, etc.) should be identified in order to expose new alternative courses of action. The effectiveness of these alternatives on increasing the utilization of existing nurse labor forces should then be compared to policies directed toward increasing the supply of nurse graduates.

The analysis areas summarized in this chapter represent an overview of the key issues in health manpower planning. They will be used in chapter 3.0 as a backdrop for assessing the utility of the models identified in the study.

3.0 HEALTH MANPOWER MODELS

In this chapter we shall concentrate on the integration of the models identified in this study into a health manpower modeling framework and describe the manner in which these models address the analysis areas presented in chapter 2.0. In order to accomplish this purpose, the chapter is organized into three sections. The first section provides an overview of the models, describing individual models in terms of their locations within a health manpower model classification structure. The second section discusses the evaluation of these models in terms of four criteria describing their usefulness to the health manpower analysis problems. The final section summarizes the analysis and presents some overview conclusions.

3.1 Overview of Health Manpower Models

Before discussing the applicability of health manpower models to the analysis areas described in chapter 2.0, the spectrum of models to be subjected to this evaluation must be delineated to acquaint the reader with the models examined in this study. Because each member of this array of models is described in the second volume of this report, these detailed descriptions are not reproduced here. Rather, this section focuses on an overview of these models, presenting the common attributes of the model population and identifying dissimilarities where they are significant.

In all, the study examined 56 models covering a diverse collection of health manpower topics such as the prediction of coronary recovery states and the geographic migration of dentists, and varying in complexity from a single regression model to a large-scale Monte Carlo simulation model or a multi-dimensional linear programming model. The diversity of subject matter treated by these models is further reflected by the differences in the scope or perspective of individual models. For example, where one model might describe the utilization of hospital manpower services as a function of health consumer attributes, another would investigate both the supply and demand for health manpower services as a function of price. In addition to variations in subject matter, complexity, and perspective, the amount of available documentation detailing the structure and contents of each model also fluctuated greatly from one model to the next.

Thus, the general incongruity of the models examined combined with an absence of any hierarchical ordering of the subject material treated in these analytic descriptions hinders most attempts to concisely describe this spectrum of health manpower models. One method of presenting the models identified in this study would be to discuss them in terms of the health manpower disciplines they address. Another technique would be to characterize the models with respect to the magnitude of the health manpower systems treated (i.e., single hospital, medical school, community health system, state health manpower processes, or national manpower issues). Still a third way would be to describe individual models within an overall conceptual framework of the processes which govern the supply of and demand for health manpower. The third technique is chosen in this report for two reasons. First, the description of models within this conceptual structure should provide greater insight into the overall depth and scope of the health manpower modeling spectrum as well as facilitate understanding of the interrelationship among modeling efforts. Second, such a conceptual framework of models is more amenable to the evaluation of model usefulness in terms of the analysis areas presented in chapter 2.0.

The conceptual model structure chosen for this discussion is a condensed, slightly revised version of the general model classification structure presented in the Health Manpower Inventory. As can be seen in figure 1, the conceptual model structure consists of six interconnected health manpower process blocks which describe health manpower supply and demand and three suspended circles representing the three economic markets which govern the interaction of these processes. Although the processes and markets depicted in this structure encompass most of the attributes of the models examined in this study, the reader is cautioned that this structure does not necessarily define the boundaries of health manpower modeling activities nor does each model necessarily fall within one and only one component of the structure. For example, additional modeling areas which might be considered as peripheral to this framework are models of health research processes or models characterizing the growth of the population (see volume II of this report), both of which could significantly affect health manpower supplies and demands. Furthermore, many of the models, particularly those concerned with the economic markets, manipulate parameters relevant to the processes classified in different blocks of this structure. To facilitate this discussion, however, most models will be associated with only those blocks reflecting their major components.

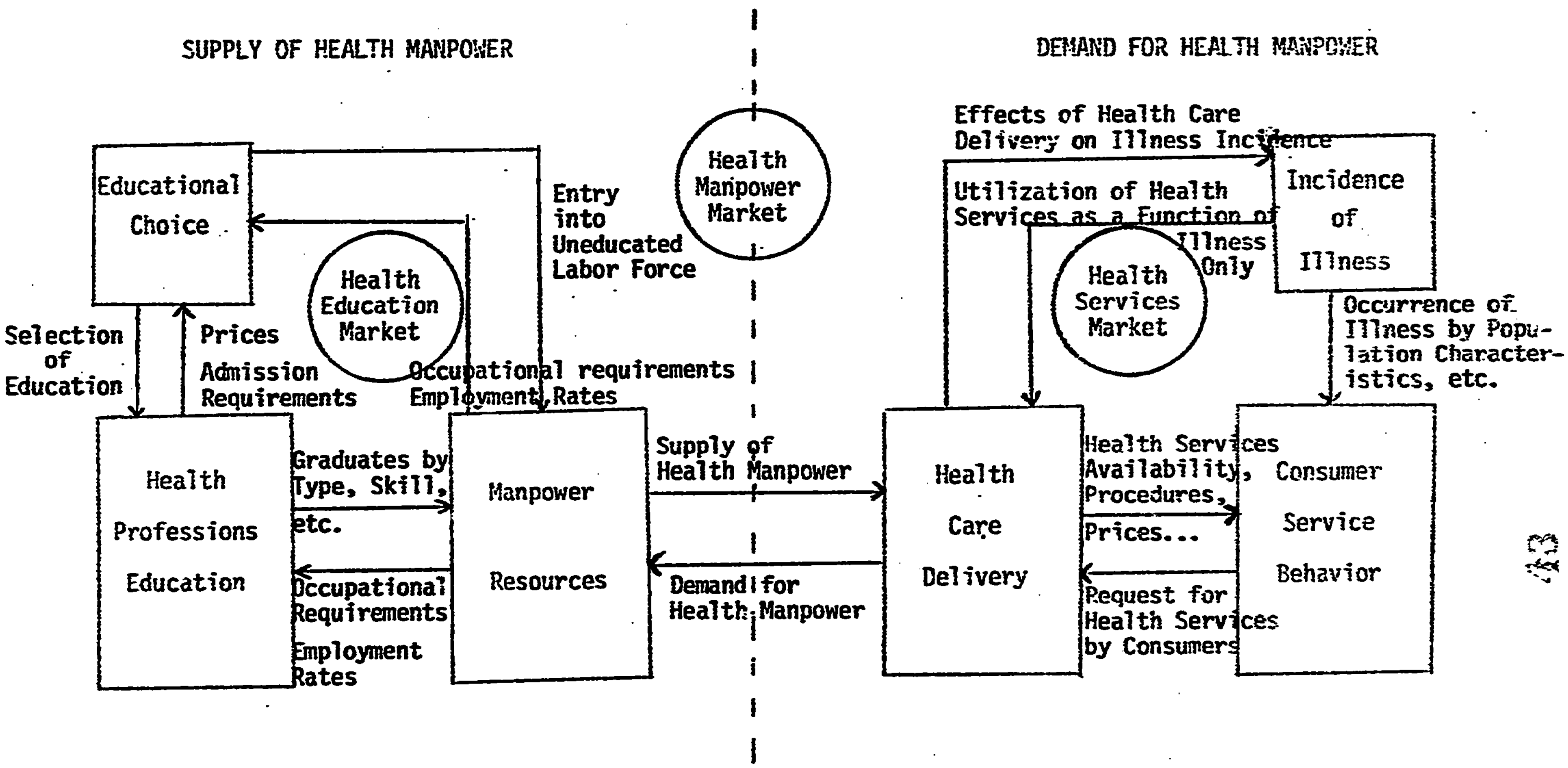


FIGURE 1: CONCEPTUAL MODEL STRUCTURE

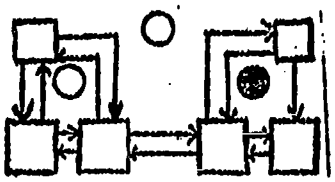
The left half of figure 1 is essentially concerned with the supply or development of health manpower resources and the right half with the utilization of or demand for these resources. Processes in the blocks which treat the supply of health manpower (i.e., educational choice, health professions education, and manpower resources models) are governed by factors in the health professions education market. This market essentially describes the behavior of prospective students, graduates from health education institutions, and persons selecting health disciplines not requiring formal education, as a function of the price, entry prerequisites, and other factors governing amount and type of training facilities utilized. On the demand side of this structure, the utilization of manpower services in the health services market is a function of the price of these services (across the various forms of health service delivery), changes in illness incidence, and health consumer behavior. The overall demand for and supply of health manpower is brought together in the health manpower market (depicted by the circle in the center of figure 1) as a function of prices, wages, and other economic variables.

Although a few of the models examined in this study attempt to describe the interactions of the processes within each of the aforementioned three markets, the vast majority of models either concentrate on the factors which influence the supply of services or attempt to describe the conditions influencing the demand for these services. That is, the models treat subject material related to each of the three market circles and/or the process blocks surrounding or adjacent to these circles. In order to facilitate the description of the models identified in this study, each of the following discussions is organized into three subsections. Each subsection concentrates on the models which attempt to characterize a particular market and its associated process blocks. The health services market models and the related process models are presented first, i.e., models of health manpower demand, followed by the models describing manpower supply, and concluding with the models concerned with the interaction between health manpower supply and demand.

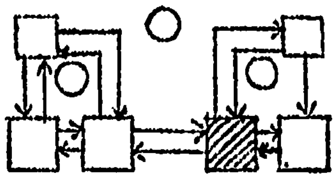
3.1.1 Models of the Demand for Health Manpower

Of the 56 models examined in this study, all but 17 concentrate on the demand for health manpower and the services they perform. These demand models manipulate, forecast, or otherwise describe such processes as: health services market behavior, health care delivery, health consumer behavior, and incidence of illness, which govern the demand for health manpower services. In the following paragraphs the models which fall into each of these four process categories are briefly described.

Health Service Market Models



Within the collection of models treated in this study, 39 are demand models. Seven of these are regression analysis models of economic behavior in the health services market. Martin Feldstein [1967, 1970, 1971] has developed three of these market models -- an aggregate model of the supply and demand for hospital inpatient care, an econometric model of the allocation of health care resources under Medicare, and a model of the health service market determination of physician prices. Another econometric model which concentrates on the expenditures for physicians services is the model developed by Fuchs and Kramer [1972]. It describes variations in the type of physician services utilized as a function of such variables as service costs, physician availability, patient income, etc. A more recent model which also focuses on the supply and demand for physician services (as well as certain non-physician manpower services) is the Human Resources Research Center [1972] model discussed in detail in chapter 4.0 of this report. The remaining two health service market models are the aggregated models of the medical and dental care sectors by Paul Feldstein and Kelman [1972] and Paul Feldstein [1972]. These two generalized models describe market interactions in each of the three markets shown in figure 1 (health services, health manpower, and health education) in both the dental and medical sectors. As such, these two models attempt to describe the overall status of the health manpower system rather than concentrating on a single region of the modeling spectrum.



Health Care Delivery Models

Approximately one-half of the 39 models concerned with factors influencing the demand for health manpower fall in the category of health care delivery models. In all, 19 models of health care delivery were examined in the study. Within this group, 13 models are developed using data describing the health care delivery functions of a single hospital or specific community, with the remaining six models being developed using information from nation-wide surveys or hypothetical data. This differentiation between models which utilize hospital or community specific data and models concerned with a more global perspective of health services delivery defines the primary application of the model's results. That is, models which are developed within the framework of an individual hospital or community are primarily intended for use with hospital or community health services planning problems rather than with health service delivery analysis problems at the state or national level.

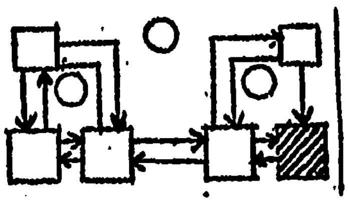
The 13 models concerned with individual hospital or community problems examined in this study can be subdivided into two subject groupings -- models of scheduling or allocation of nurse manpower (six models) and models which describe hospital processes, predict future utilization of hospital beds, describe demand for community maternal care facilities, etc. (seven models). Three of the six nurse management models were developed at Johns Hopkins University to improve the utilization of nursing personnel. Connor [1960] developed an inpatient classification scheme relating the degree of illness to direct patient care requirements which in turn is used to specify the relationship between hospital patient case load and total nursing workload. Singer [1961] used Connor's classification scheme to develop a Markov process model which predicts the number of patients in each of these categories at some future time. Wolfe [1969] also used this scheme to develop a linear programming model to optimize the allocation and mix of nursing personnel to meet current or future demands. The remaining three nurse management models by Thomas [1964, 1968], Jelinek [1964, 1967], and Laberge-Nadeau and Feuvrier [1972] also relate the number and type of nursing resources required to the number of patients in various health conditions. Thomas specifically focuses on the requirement for nurses in relation to the number of patients in 14 Markovian coronary recovery states; the Laberge-Nadeau-Fevrier simulation model describes the amount of time consumed in performance of specific tasks with variations in the number and class of patients and the number and type of nursing personnel on a hospital staff. The description of the work behavior of the nursing unit is also the principal subject treated in Jelinek's model. This model characterizes the behavior of a nursing unit in terms of regressive equations which relate the number of nursing hours (per patient day) that are devoted to various activities to size of available nursing staff, number of patients in each class, type of nursing staff, number of patients in each class, type of nursing unit, etc.

The remaining seven models are concerned with the analysis of a single hospital or community (i.e., health care delivery organization, planning and utilization models) and use a combination of analytic techniques to describe these processes. For example, Moss [1970] developed a queueing model to simulate utilization of personnel services, medical facilities equipment, and consumable supplies by sampling from analytical probability distributions of arrival and service times. Similar Monte

Carlo simulation techniques are employed by Uyeno [1971] where samples of empirical data rather than analytic probability distribution provide statistics concerning patient waiting time, personnel utilization, facility utilization, etc., under alternative patient care requirements, team compositions, and facilities. The empirical simulation developed by Hearn and Bishop [1970] describes the activities and events concerned with the care of hospital patients with changes in hospital procedures. Simulation techniques are combined with regression analysis in Kennedy's model [1968a, b, c, d] of maternal and child care in a community. In this model, regression analysis (which is used to estimate the relationship between the number of mother's visits, birth weight of infants, etc., and selected demographic data) is combined with simulated maternal and child care characteristics to schedule maternal health care visits, allocate resources, and estimate utilization. The model developed by the Research Triangle Institute [1972], which is described in detail in chapter 4.0 of this report, employs a similar combination of simulation and regression analysis techniques to forecast health manpower requirements as a function of hospital utilization. Prediction of health care resource utilization is also the main topic of the regression analysis model developed by Abranovic [1969]. Abranovic's model focuses on the future resource requirements in a single category of hospital services -- ancillary services -- in terms of the projected inpatient census and the characteristics of the ancillary department. The final single hospital planning model identified in this study is a linear programming model developed by Lazarus [1971]. This model derives optimal solutions (number of patients by hospital service category) for each of three objective functions (social welfare, income, and admissions) subject to constraints on bed allocations, operating room capacity, staff size, etc., to develop a plan for an 805-bed hospital.

Of the 19 models within the health care delivery category, we have discussed all but the six models concerned with the more generalized descriptions of these delivery processes. Only one of these six models, the model by Reinhardt [1970, 1972], is based on empirical information. The purpose of this regression model is to measure the influence of medical aides, physician fees, types of practice, and other inputs on the physician's production of services. The other five models in this collection of generalized health care delivery models are primarily theoretical structures which optimize personnel utilization, community benefits, or hospital outputs under hypothetical conditions. Four of these models are linear programming formulations developed by Baligh and Laughhunn [1969], Shuman [1969], Shuman, Young, and Naddor [1969, 1970] and Abernathy and Hershey [1972]. The Baligh-Laughhunn model develops an economic measure related to the treatment of hospital patients by patient class and minimizes its value subject to a resource, a patient, a budgetary, and two policy constraints. In the two models by Shuman and his colleagues, three basic linear programming structures are formulated to investigate potential cost savings through various personnel substitutions, the maximization of the overall level of quality of health services provided, and the minimization of the total cost of these services to the community under alternative mixes of health manpower. The Abernathy-Hershy model employs Monte Carlo simulation techniques to explore two hypothetical nurse staffing alternatives (fixed staffing and controlled variable staffing) and uses a linear programming structure to specify the optimum staff allocation policy to minimize costs. Finally, Zemach [1970] formulates a linear difference equation structure to examine the utilization of health services in a region and the allocation of resources necessary to provide these services.

One model which could be included in the health care delivery category but which has not been discussed previously is the Conversational Modeling Language (CML) model by Fetter and Miles [undated]. The CML modeling strategy is applied to health manpower modeling. Since the model is more a description of the modeling language than of the processes of the health care system, it is not evaluated in terms of the health manpower analysis problem in chapter 2.0.

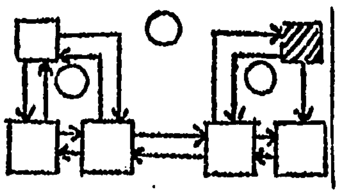


Health Consumer Behavior Models

In addition to the model developed at the Research Triangle Institute (RTI), there are nine other models (not previously discussed) which can be classified as health consumer behavior models. These models essentially describe consumer utilization of various health resources with respect to changes in specific attributes of the consumer population. For example, the RTI model simulates admission rates, surgery status, length of stay, etc., as functions of such consumer characteristics as age, sex, income, residence, etc. Two other models in this category which relate admissions, length of stay, and patient days to similar demographic characteristics are the models developed by Rosenthal [1964] and Baer [1971]. Rosenthal's model consists of three linear equations relating patient days, admissions, and average length of stay to age, marital status, sex, education, etc. Regression analysis is also employed in Baer's single equation model describing the relationship of patient characteristics and hospital service utilization to length of stay.

Two of the ten health consumer behavior models identified in this study concentrate on estimating the demand for medical care as a function of consumer and health service factors which influence demand. Dars' [1971] model consists of two separate structures -- one concerned with estimates of linear relationships between health insurance variables (benefits, coverage, and expenditures) and consumer income, medical care prices, time, etc., and the other with the demand for medical care (expenditures, expenditures per ill-health day, and health status) as a function of consumer household variables. Edwards' [1972a, b] model, which is currently under development, simulates 23 measures of medical care requirements in terms of the health characteristics of standard metropolitan statistical areas. The consumer health characteristics of specific geographical regions are also used by Hopkins [1967], Beenhakker [1963], and Fitzmaurice [1972] to describe regional requirements for hospital beds. Hopkins' model concentrated on the hospital bed needs in 58 California counties, estimating the linear relationship among hospital patient days per county and such variables as net effective buying income, number of live births, and number of deaths. Similarly, the models by Beenhakker and Fitzmaurice provide a more complex linear representation of the number of patient days consumed in Maryland and Indiana counties, respectively, as a function of county health service and county population characteristics.

The remaining two models in this category are those developed by Andersen [1968] and Navarro, et al. [1969, 1970a, b]. Andersen's model consists of a delineation of important social, economic, and demographic factors influencing the utilization of health services by family units. These factors are determined using correlation analysis and analysis of variance. The Markov model developed by Navarro, et al., predicts proportions of the population in different health service states, thus providing estimates of the utilization of health services during a period of time.



Illness Incidence Models

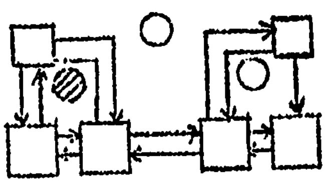
The smallest group of models on the demand side of the model structure shown in figure 1 are models concerned with illness incidence. These models could be included within the consumer service behavior category since these models must, of necessity, rely on health services utilization data to determine incidence. These models are segregated from consumer behavior models in that their outputs are intended to reflect the health status of a population rather than the utilization of health services. Four models were identified in this study which treat occurrence of illness (i.e., mortality and mobidity rates) from this perspective. Three of these models employ regression analysis to describe the relationships between the medical care environment, population attributes, etc., and the health status (mortality rates) of the population.

Auster, Leveson, and Sarachek [1969] and Anderson [1972] developed models which relate such variables as income, education, medical care expenditures, and other socioeconomic/health parameters to age-adjusted and diagnosis-specific death rates. Larmore's [1967] model concentrates on an econometric production function for health, estimating the relationships between population characteristics and mortality rates, disability days, number of physician visits, etc. The fourth model in this category is a birth/death Markov model developed by Ortiz and Parker [1971] describing mortality rates by disease and age to determine life expectancy.

3.1.2 Health Manpower Supply Models

Of the 56 models examined, 15 manipulate data concerned with the supply of health manpower. The following paragraphs provide a brief description of these models as they appear to be classed within the structure presented in figure 1.

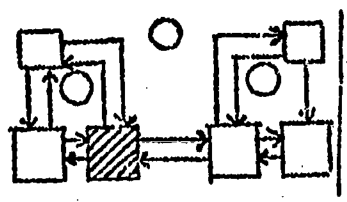
Health Education Market Models



Models which fall into this category are those which describe the interaction of economic forces influencing the production and occupational distribution of health profession education graduates. Two models which are categorized in this area are those developed by Feldstein and Kelman [1972], mentioned previously under health service market models, and Deane [1971].

The first of these two models is a large-scale multiple market model of the medical care system which treats both demand for and supply of five medical services. Within the supply sector of the model, existing stocks of manpower are adjusted due to graduations from health education programs, immigration, and labor force participation rates. Similarly, Deane's model also concentrates on more than one of the economic markets (i.e., educational resource market and labor market) using regression equations to predict changes in the number of nurse graduates, participation rates, vacancy rates, wages, etc.

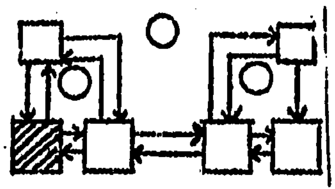
Health Manpower Resource Models



The greatest number of models within the category of health manpower supply are those classed as health manpower resource models. The ten models which fall in this collection include six models concerned with describing the geographic and specialty distributions of physicians and four models describing the labor force behavior of nurses and allied health personnel. The models of geographic distribution describe the number of physicians in a specific region (i.e., state or census tract) as a function of the socioeconomic and health characteristics within these boundaries. The models by Benham, Maurizi, and Reder [1968], Hawkins [1969], and Scheffler [1971] examine the distribution of physicians across states. Each of these three models employs regression analysis to relate the number of physicians (or physicians per capita) to differences in income, education, population density, number of hospital beds, etc., across states. In addition to variation in the number and type of variables chosen, these three models differ in that Hawkin's model also examines the distribution of physicians within a specific state and both the Hawkins and Scheffler models investigate geographic distributions with regard to several medical specialties. The models developed by Elesh, Schollaert, and Lazarz [1972a, b] investigate the distribution of physicians across census tracts in two urban areas, describing the relationship between physician types (specialists or general practitioner), office location, and the economic and demographic character of the census tract.

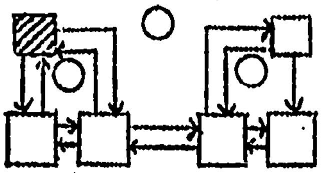
Physician geographic distribution is treated from a different perspective in the models by Held [1973] and Sloan and Yett [1969a, b, 1971a, b]. These models describe the migration patterns of physicians from state of training to state of practice location as a function of place of birth, location of residencies, mean physician income, state medical exam failure rate, hospital bed population, etc. In addition to the migration behavior of physicians, the Sloan and Yett model also treats the physician choice-of-specialty process. This model describes the number of residents in a particular specialty as a function of economic and job satisfaction parameters.

Three of the four models concerned with health manpower labor force behavior concentrate on the participation of nurses in the labor pool (i.e., number of nursing hours or weeks worked). The model by Benham [1970] is essentially a model of the nurse labor market which has as an output nurse labor force participation. The Bognanno [1969] and Sloan and Blair [1973] models estimate the supply of nursing hours with respect to changes in such parameters as race, age, location of residence (geographic region), etc. The fourth model concerned with labor force behavior is a two-equation model by Shaw [1967] relating length of service and absenteeism in the allied health professions to salary, age, number of dependents, and length of previous employment.



Health Professions Education Models

The only model in the inventory which is principally concerned with describing the health professions education environment is the model of medical school production activities developed by Latham [1971]. This linear programming model maximizes the production of medical education outputs (i.e., market prices times output quantity) subject to constraints on medical school activities and inputs (numbers of students). The primary purpose of this model is to estimate the cost of each educational activity (e.g., research, medical education, patient services, etc.) and specify the optimal mix of these activities.

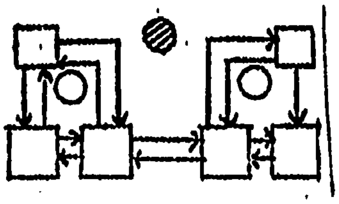


Educational Choice Models

The two regression analysis models in this category are those developed by Altman [1971] and Sloan and Yett [1969a,b; 1971a,b]. Altman's model is used to estimate future admission rates to nurse training programs as a function of the growth of various types of nurse education programs and the wage differential between nurses and public school teachers. Since this model concentrates on factors whi[illegible] influence educational choice as well as variables characterizing changes in the educational institutions, it could also be classed as a health professions educational model. The Sloan-Yett model might also be classified under both categories; however, the model's primary focus is on factors influencing decision processes of college graduates rather than limitations in available medical school spaces. That is, the number of applicants planning to enter a medical college is a function of the number of college graduates, tuition, fees, PhD stipends, physician income, etc.

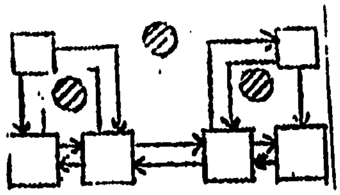
3.1.3 Models of the Interaction Between Health Manpower Supply and Demand

Models concerned with the factors influencing the supply of or demand for health manpower generally fall within one of two classes. That is, they either focus on the specific market interaction between health care delivery processes and the health manpower resource processes, or they attempt to characterize the interrelationships of the three markets and associated processes shown in figure 1. Models which are of the first type correspond to those which fall within the health manpower market and model category depicted as the center circle in figure 1. The second type of models is essentially multi-market models -- models which treat two or three of the markets shown in figure 1.



Health Manpower Market Models

Of the four health manpower market models in the inventory, one model describes the supply of and demand for manpower in 20 health disciplines, two are concerned with the market for nurse labor, and the fourth characterizes hospital demand for residents. Maki [1967] developed a quadratic programming model to estimate the demand, supply, excess demand, and employment for 20 health occupations. The model minimizes the difference between demand and employment subject to constraints on the percent change in number of workers, the total available resources, and non-negative employment. The model by Deane [1971] concentrates on the labor market behavior of ten occupations, all within a single disciplinary field -- nursing. Deane's regression analysis model contains a block of 126 simultaneous equations to describe the effects of changes in the factors influencing nurse labor supply and demand on nurse wages, employment, desired employment, vacancies, and retirements. Another model characterizing the behavior of the nurse labor market is that developed by Hixson [1969]. This model describes the nurse employment turnover rate, the number of RNs, LPNs, and nursing aides as a function of patient population in various hospital services, distribution and mix of nursing personnel across these services, nurse wages and hospital discretionary policies. The fourth model concerned with the interaction between health services and manpower supply is Sloan's single equation model which relates a hospital's demand for residents to stipends, medical school affiliation, patient census, and outpatient visits.



Multi-Market Models

Only three of the models examined in this study explicitly treat the behavior in two or three of the markets depicted in figure 1 -- Paul Feldstein's two models of the dental sector and medical care system and the Human Resource Center (HRRC) [1972] model. Feldstein's model [Feldstein and Kelman, 1972] of the medical care system describes the demand for and supply of five types of medical services as well as the demand for and supply of health manpower in each of these services. The Feldstein [1972] dental care model examines each of the three markets (dental services, dental manpower, and dental education) presented in figure 1. Each of these market structures contains two equations specifying the relationship between the demand for and supply of services, manpower, and training facilities as a function of dental population, prices, wages, and training facilities. The model developed by HRRC is a preliminary operational version of a comprehensive conceptual structure of the health care system. The operational model, which is described in detail in chapter 4.0 of this report, characterizes the demand for and supply of physician visits and the demand for physician and non-physician manpower.

3.2 Usefulness of Health Manpower Models

This section presents an analysis of the usefulness of the models described in the previous section with respect to each of the analysis areas described in chapter 2.0. Since the emphasis of this study is on the major components of the health manpower analysis environment rather than the specific analytic requirements of a particular user or organization, the assessment of model usefulness presented here does not provide a utility ranking of the models examined. Nor is it intended to be used to reject or confirm the usefulness of a particular model in a specific analytic role. Such model scaling and acceptance criteria ultimately must be determined by the potential user, who will be aware of the importance, scope, and analysis perspective of each problem encountered and cognizant of the analysis constraints which encompass this problem. The purpose of this section is to provide potential model users with general criteria to assess model usefulness and then to apply these criteria; i.e., the assessment of the usefulness of the models within the framework of the aforementioned health manpower analysis environment. This section continues with a description of four criteria for the evaluation of model utility and concludes with assessments of the usefulness of the models in the inventory within the framework of these criteria.

Health manpower models serve two general types of functions. First, they simulate the individual or composite processes which collectively define the health manpower system. Second, they are used to predict the effects of changes in model parameters or causal relationships on the status of this sytem. The descriptive function is performed to expose or systematically delineate the interrelationships between health system components, processes and other factors influencing the status of the health manpower system. The information gained as a result of model development and use may help to verify and enrich intuition, quantify relationships, identify current health manpower problems, and expose the factors contributing to these problems. Model predictions are extensions of this descriptive capability into the future. A prediction or estimate of future conditions or relationships is obtained by projecting current trends into the future or by predicting the timing of anticipated events. This capability of models to look forward in time. with varying degrees of uncertainty, permits the user to estimate the effects of governmental interventions and other occurrences on specific components of the health manpower system.

The particular usefulness of a model which performs the descriptive and/or the predictive function depends upon:

(1) the relevance of the model subject matter to the user's problem,

(2) the adaptability of the model to the user's special modeling requirements,

(3) the ability of the model to reflect accurately and reliably actual conditions, and

(4) the capability of the user to employ the model within the time and resource constraints of his particular analysis problem.

These four interrelated multidimensional criteria for model usefulness might be appropriately termed the model applicability, model generality, model validity, and operational feasibility. A model is applicable to a particular problem if it describes the performance of the health manpower system under the specific conditions of interest to the user. That is, a model's applicability will depend upon the particular sector of the system treated by the model as well as the specific relationships within this sector that the model describes. Model generality is concerned with the ability of a model to address a broad spectrum of analysis questions without significant modification of the model's structure. The validity of the model depends upon the degree to which the model is internally consistent and experimentally accurate. An internally consistent model is free of contradictory assumptions, incompatible theories and erroneous mathematics. The experimental accuracy of the model depends on the relative ability of the model to represent (simulate) conditions as they exist in the real world. The comparison of user time and resource constraints with the model's operational requirements (i.e., computational, user interface, input data, etc.) determines the operational feasibility of the model -- the ability of the user to employ the model for his needs.

3.2.1 Model Applicability

In an evaluation of model applicability, specific emphasis is placed on the relevance of model outputs and inputs to the analysis decisions. For a model to be applicable to a particular problem, model outputs should describe or predict the status of the system in terms of the specific system measures of interest to the user. Similarly, the model inputs should reflect the factors external to the system which the user may either monitor to gain understanding of system status, use to estimate future system status, or attempt to control in order to alter the system processes and future conditions. Since these factors which influence the status of the system are in part dependent upon various policies and actions of public agencies, models applicable to the problems in this area (i.e., the primary focus of the analysis areas presented in this report) should have inputs associated with these policy actions.

Thus, an assessment of model applicability consists of a comparison between the system performance measures of interest to the user and the model output variables and a similarity matching between the policy actions and the model input variables. The comparison of a model's predictions (the outputs) with the performance measures of interest within a particular analysis area indicates rather directly its applicability. Obviously, the outputs of one model may suit one set of analysis problems, but not others. A model able to predict all the desired performance measures would be clearly more applicable to a specific problem than one which predicted none of these measures. However, the applicability of a particular model to an analysis problem may not be measured simply in terms of the number of performance measures which it predicts. In addition to the number of performance measures predicted, the user's perception of the relative importance of each measure, as well as the input variables which the model uses to predict the value of each measure, play an important role in the assessment of model applicability. Similarly, the assessment of model applicability in terms of the degree of correspondence between input variables and policy actions requires an understanding of user interest.

Since the users of the models are not identified in this study, and since each analysis area presented covers a wide spectrum of interest, the assessment of model applicability will of necessity be somewhat general in nature. That is, a dimension-by-dimension comparison of model inputs and outputs with alternative policy actions and measures of each analysis problem is not provided. Rather, the material here will concentrate on the collective applicability of selected groupings of these models to each analysis area.

The six major analysis areas presented in chapter 2.0. are subdivided into two groups -- those concerned with the demand for health manpower services (roman numeral I) and those concerned with the supply (roman numeral II) of these services. An outline of these analysis areas (alphabetic headings) and numbered topics within them follows:

I. Characterization of the demand for health manpower services
   A. Cultural-demographic factors
      1. Characterization of demand in terms of age, sex, marital status, etc.
      2. Analysis of policy actions which alter these characteristics (i.e., consumer health education) and influence demand.
   B. Economic factors
      1. Description of the effects of the price of care on the utilization of services.
      2. Analysis of the influence of consumer income on the type and amount of health care demanded.

3. Evaluation of the relationship between alternative forms of health insurance and health service demands.
4. Assessment of alternative health care reimbursement systems and other economic incentive programs with respect to their influence on health care costs and the demand for services.

C. Health care delivery constraints

1. Analysis of availability or other factors governing the use of health services of differing levels of accessibility and the demand for manpower.
2. Characterization of the impact of various modalities of health care delivery, such as preventive versus episodic or group versus solo practice, on the utilization of health services.
3. Description of the effects of health care delivery procedures on the consumption of health services (e.g., analysis of the factors which influence physician recommendations regarding the type and amount of health services to be utilized by their patients).

II. Characterization of the supply of health manpower services

A. Additions to the stock of health manpower

1. Identification of factors which influence the number of medical school graduates or graduates of other health professions' education programs.
2. Assessment of the impact of government financial programs aimed at increasing the number of health graduates,

e,g., health educational institution construction loans or expansion subsidies, capitation grants to schools, and curriculum shortening programs.

3. Evaluation of federal and state regulatory policies (e.g., FMG immigration policies, state licensure and accreditation requirements, etc.) which influence the supply of health personnel.

B. Specialty and geographic distribution of health manpower and entry mix

1. Analysis of factors influencing the distribution of physicians among the medical specialties.
2. Analysis of factors affecting the geographic distribution of health manpower (particularly physicians and nurses).
3. Analysis of the factors governing the poor representation of minorities and women in the health professions.
4. Assessment of alternative programs and policy actions (e.g., National Health Service Corps, special education grants, state licensure and accreditation provisions, etc.) on the distributional issues and programs aimed at ameliorating entry mix problems.

C. Labor force participation and utilization of health manpower

1. Analysis of the utilization of allied health personnel as substitute providers of routine medical and dental services, including consideration of such factors as physician or dentist acceptance, delegation of tasks, quality of auxiliary services, etc.

2. Analysis of other techniques designed to improve the supply of services and the utilization and productivity of health manpower (e.g., implementation of optimal management strategies, use of alternative practice settings, and application of technological innovations to improve health care delivery).
3. Analysis of factors which influence the labor force participation of health manpower with particular emphasis on those factors which influence nurse labor force behavior.

The applicability of the specified models to each of the six analysis areas places specific emphasis on the correspondence between the model input variables and policy actions and model output variables and the system performance measures associated with each analysis area.

Tables 1 and 2 on the subsequent pages provide a representative list of system performance measures and policy actions associated with each of the six major health manpower analysis areas. The first of these two tables focuses on the three principal analysis areas concerned with the characterization of the demand for health manpower services, and the second table concentrates on the analysis areas associated with the supply of these services. The collection of performance measures and policy actions detailed in these tables, while sufficiently general to cover most of the significant measures and actions associated with each analysis area, is not intended to provide an exhaustive listing of these analysis components. The set of measures and actions presented is, however, Analysis of Cultural-Demographic Factors Characterizing Demand

Policy Actions

Consumer health education

Performance Measures

Utilization of health services by type of service

Utilization of services by selected groups

Demands for health manpower

Expenditures for health care

Analysis of the Effects of Economic Factors Influencing Demand

Policy Actions

Medicare and Medicaid

National Health Insurance

Alternate modes of health care reimbursement

Performance Measures

Utilization of health services by type of service

Utilization of services by selected groups

Expenditures for health insurance

Expenditures for health care

Price of health services

Analysis of the Effects of Health Care Delivery Constraints on Utilization of Health Manpower Services

Policy Actions

Federal support to ambulatory and other health care clinics

HMO incentives

Facility construction programs (Hill-Burton)

Performance Measures

Geographic distribution (accessibility) of health services

Utilization of health services by type of service

Utilization of services by selected groups

TABLE 1: POLICY ACTIONS AND PERFORMANCE MEASURES ASSOCIATED WITH THE DEMAND FOR HEALTH MANPOWER SERVICES

Additions to the Stock of Health Manpower

Policy Actions

- Scholarship loans for disadvantaged
- National Health Service Corps
- Scholarships linked with specialty shortage
- Loan forgiveness linked with location of practice
- State licensure and accreditation policies
- Federal immigration policies
- Facility expansion and construction programs
- Capitation grants to increase enrollment
- Support of curriculum shortening programs

Performance Measures

- Number and type of students entering various health professional training programs
- Educational costs
- Number of foreign medical graduates
- Number of graduates who pass licensure and accreditation exams
- Number of health profession educational institutions
- Enrollment in health profession educational programs
- Number of graduates in each health discipline

TABLE 2: POLICY ACTIONS AND PERFORMANCE MEASURES ASSOCIATED WITH THE SUPPLY OF HEALTH MANPOWER SERVICES

Analysis of the Specialty and Geographic Distributions of Health Manpower and Entry Mix

Policy Actions

- Scholarships linked with specialty shortage
- Loan forgiveness linked with location of practice
- National Health Service Corps
- State licensure and accreditation policies
- Tax incentives and moving subsidies to improve geographic distribution
- Capitation grants to improve specialty distribution
- Grants to support family medicine training
- Scholarship loans for disadvantaged

Performance Measures

- Number of graduates who pass licensure and accreditation exams
- Number of women and minorities in each occupation and specialty
- Specialty distribution of physicians
- Geographic distribution of health manpower

Analysis of the Labor Force Participation and Efficient Utilization of Health Manpower

Policy Actions

- Programs in interdisciplinary team training
- Capitation grants to stimulate dental therapy and physician assistant programs
- Refresher courses to stimulate labor force participation

Performance Measures

- Labor force participation rates of health manpower disciplines
- Quality of services
- Efficient utilization of health personnel
- Productivity of health personnel

TABLE 2 - Continued

representative of the analysis elements requiring attention, as described in chapter 2.0. Thus, the policy actions and system performance measures can be compared to model input and output variables, respectively, to assess model applicability. To facilitate this comparison, policy actions and performance measures are distributed across the health manpower model conceptual structure, as shown in figures 2 and 3. Listing these analysis components in this manner helps to isolate those models in the inventory potentially applicable to the general dimensions of each analysis problem. Although nearly all of the above models might be applicable either directly or indirectly to each of these analysis areas, specific groups of models clearly appear to be more relevant to a particular area than the remaining models.

Integrating the information presented in the above tables and figures with the description of model input and output variables provided in volume II of this report, the models can be classified in terms of the analysis areas which they treat. Tables 3 and 4 provide a list of the models associated with each of the analysis areas characterizing the demand for and supply of health services, respectively. As can be seen from the lists in these figures, the greatest number of models appear to be applicable to the analysis of economic factors influencing demand (20 models). Analysis areas afforded comparable levels of modeling activity include the characterization of demand for services in terms of the cultural-demographic composition of the consumer population (18 models) and the analysis of labor force participation and efficient utilization of health manpower (18 models). In the remaining three analysis areas, 12 models are concerned with the analysis of health

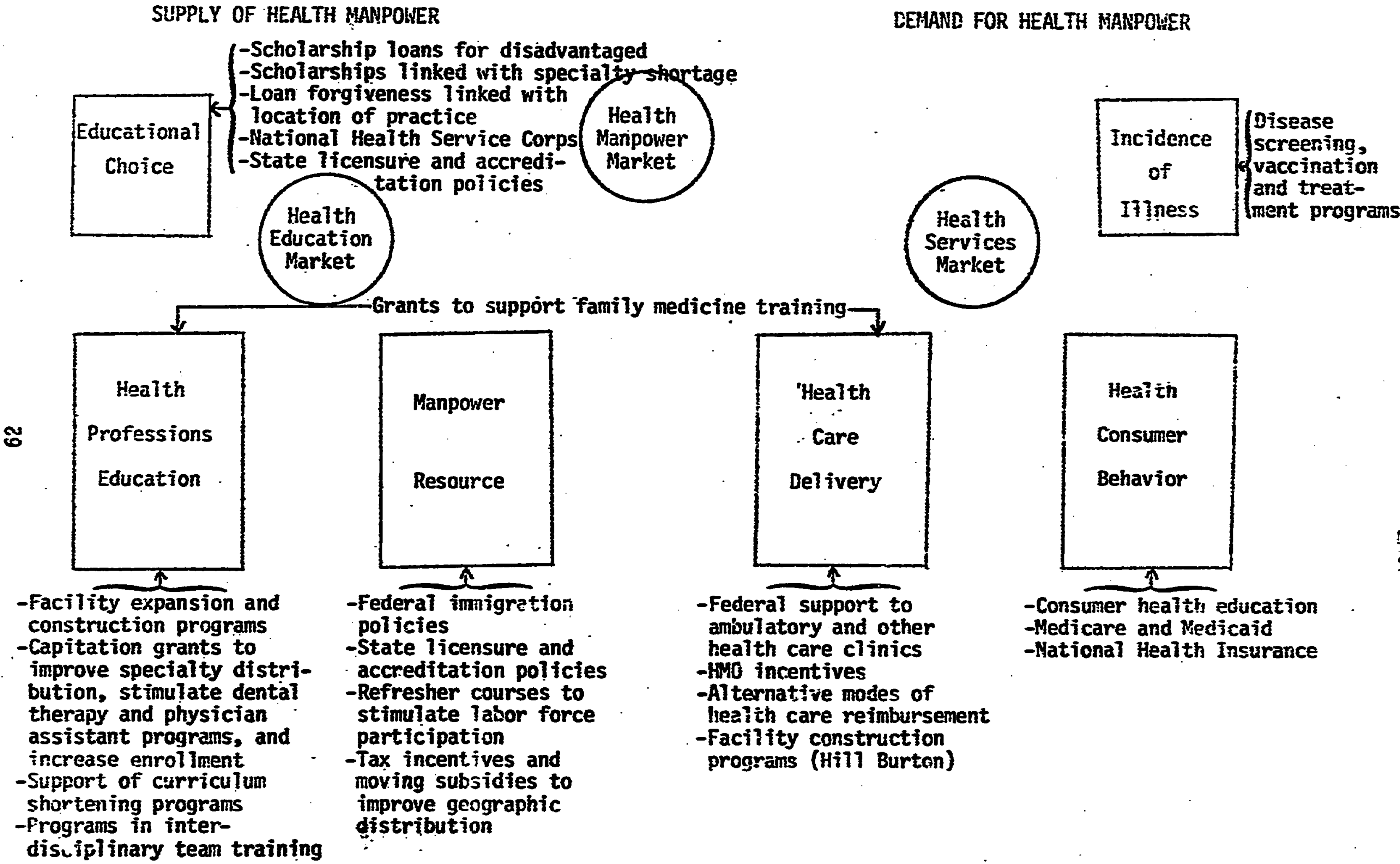


FIGURE 2: ALLOCATION OF POLICY ACTIONS ACROSS CONCEPTUAL MODEL STRUCTURE

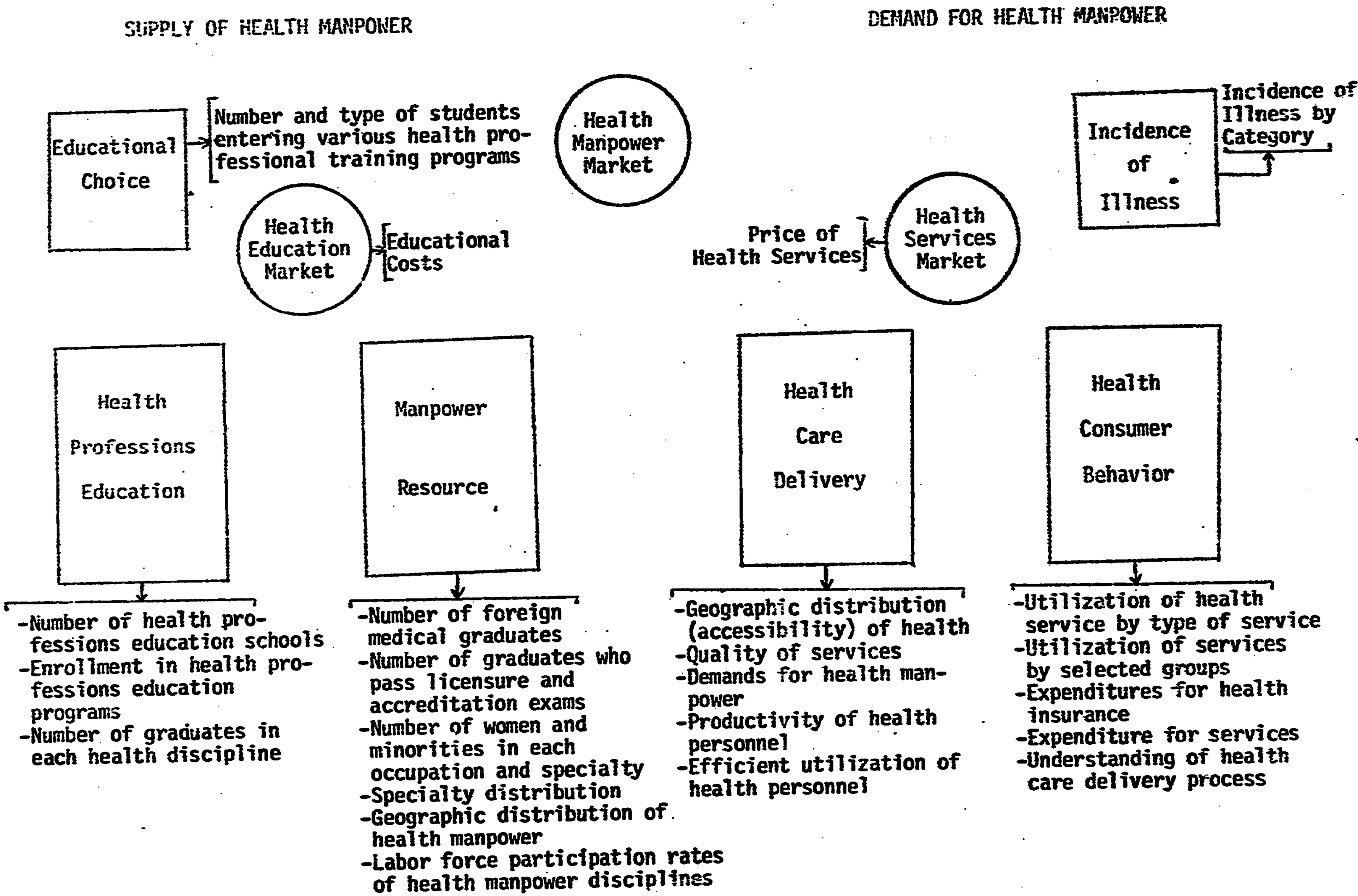


FIGURE 3: ALLOCATION OF PERFORMANCE MEASURES ACROSS CONCEPTUAL MODEL STRUCTURE

<u>Analysis of Cultural/Demographic Factors Characterizing Demand</u>

A2 -- Abranovic (1969) -- Hospital Ancillary Services Planning Model
A4 -- Andersen (1968) -- Behavioral Model of Families' Use of Health Services
B1 -- Baer (1971) -- Patient Characteristics, Hospital Services, and Length of Stay
B3 -- Beenhakker (1963) -- Prediction of Future Hospital Bed Needs
D1 -- Dars (1971) -- Demand for Health and Medical Care: An Econometric Model
E1 -- Edwards (1972a, b) -- Model Predicting Population Demands for Medical Services
F1 -- M. Feldstein (1967) -- An Aggregate Planning Model of the Health Care Sector
F4 -- P. Feldstein (1972) -- Econometric Model for Forecasting and Policy Evaluation in the Dental Sector
F5 -- P. Feldstein and Kelman (1972) -- An Econometric Model of the Medical Care Sector
F7 -- Fitzmaurice (1972) -- Demand for Hospital Services
H5 -- Hopkins (1967) -- Linear Regression Model -- Estimating Hospital Bed Needs in California
L2 -- Larmore (1967) -- An Econometric Production Function Model for Health
N1 -- Navarro et al (1969, 1970a, b, (undated)) -- A Markov Model of Medical Care Utilization
R2 -- Research Triangle Institute (1970a, b, 1969, 1972a, b, c, d, e, f, g) -- Health Manpower Requirements Simulation Model
R3 -- Rosenthal (1964) -- Demand for General Hospital Facilities
T1 -- Thomas (1964, 1968) -- Demand for Nursing Resources
Y1 -- Yett - HRRC (1973) -- Micro-Simulation Model of Health Manpower
Z1 -- Zemach (1970) -- Community Health Service Utilization and Resource Allocation Model

<u>Analysis of Effects of Economic Factors Influencing Demand</u>

A2 -- Abranovic (1969) -- Hospital Ancillary Services Planning Model
A4 -- Andersen (1968) -- Behavioral Model of Families' Use of Health Services
B3 -- Beenhakker (1963) -- Prediction of Future Hospital Bed Needs
D1 -- Dars (1971) -- Demand for Health and Medical Care: An Economic Model
D2 -- Deane (1971) -- Econometric Model for Market for Nurses
E1 -- Edwards (1972a, b) -- Model Predicting Population Demands for Medical Services
F2 -- M. Feldstein (1970) -- The Rising Price of Physician Services

TABLE 3: MODELS CONCERNED WITH CHARACTERIZING THE DEMAND FOR HEALTH MANPOWER SERVICES

F3 -- M. Feldstein (1971) -- An Econometric Model of the Medicare System
F4 -- P. Feldstein (1972) -- Econometric Model for Forecasting and Policy Evaluation in the Dental Sector
F5 -- P. Feldstein and Kelman (1972) -- An Econometric Model of Medical Care Sector
F7 -- Fitzmaurice (1972) -- Demand for Hospital Services
F8 -- Fuchs and Kramer (1972) -- Expenditures for Physician's Services
H5 -- Hopkins (1967) -- Linear Regression Model - Estimating Hospital Bed Needs in California
R2 -- Research Triangle Institute (1970a, b, 1969, 1972a, b, c, d, e, f, g) -- Health Manpower Requirements Simulation Model
R3 -- Rosenthal (1964) -- Demand for General Hospital Facilities
S3 -- Shuman (1969) -- Mathematical Models for Health Manpower Planning
S4 -- Shuman et al (1969, 1970) -- Optimum Health Manpower Mix Model
S7 -- Sloan (1970) -- Hospital Demand for Residents
Y1 -- Yett - HRRC (1973) -- Micro-Simulation Model of Health Manpower
Z1 -- Zemach (1970) -- Community Health Service Utilization and Resource Allocation Model

Analysis of the Effects of Health Care Delivery Constraints in Utilization of Health Manpower Services

A2 -- Abranovic (1969) -- Hospital Ancillary Services Planning Model
A4 -- Andersen (1968) -- Behavioral Model of Families' Use of Health Services
B3 -- Beenhakker (1963) -- Prediction of Future Hospital Bed Needs
D2 -- Deane (1971) -- Econometric Model of Market for Nurses
E1 -- Edwards (1972a, b) -- Model Predicting Population Demands for Medical Services
F1 -- M. Feldstein (1967) -- An Aggregate Planning Model of the Health Care Sector
F3 -- M. Feldstein (1971) -- An Econometric Model of the Medicare System
F7 -- Fitzmaurice (1972) -- Demand for Hospital Services
F8 -- Fuchs and Kramer (1972) -- Expenditures for Physician's Services
K1 -- Kennedy (1968a, b, c, d) -- Maternal and Child Care Simulation Model
Y1 -- Yett - HRRC (1973) -- Micro-Simulation Model of Health Manpower
Z1 -- Zemach (1970) -- Community Health Service Utilization and Resource Allocation Model

TABLE 3 - Continued

Additions to the Stock of Health Manpower

A3 -- Altman (1971) -- Present and Future Supply of Registered Nurses
D2 -- Deane (1971) -- Econometric Model of Market for Nurses
F4 -- P. Feldstein (1972) -- Econometric Model for Forecasting and Policy Evaluation in the Dental Sector
F5 -- P. Feldstein and Kelman (1972) -- An Econometric Model of Medical Care Sector
L3 -- Latham (1971) -- Cost of Medical Education Model
M1 -- Maki (1967) -- Forecasting Model of Manpower Requirements in the Health Occupations
S6 -- Sloan and Yett (1969a, b; 1971a, b) -- Model of Physician Educational Behavior Patterns

Analysis of Specialty and Geographic Distributions of Health Manpower and Entry Mix

B4 -- Benham (1970, 1971) -- A Three-Equation Model for the Registered Nurse Labor Market
B5 -- Benham et. al. (1968) -- Migration, Location and Renumeration of Physicians and Dentists
E2 -- Elesh et. al. (1972a, b) -- Distribution of Physicians in an Urban Area
H1 -- Hawkins (1969) -- Physician Distributions
H3 -- Held (1973) -- Migration of the 1955-1965 Graduates of American Medical Schools
S1 -- Scheffler (1971) -- Geographic Distribution of Physicians and Specialists
S6 -- Sloan and Yett (1969a, b; 1971a, b) -- Three Models on Physician Educational and Occupational Behavior Patterns

Analysis of Labor Force Participation and Efficient Utilization of Health Manpower

A1 -- Abernathy et. al. (1972a, b) -- Nurse Allocation Planning and Scheduling Model
B4 -- Benham (1970, 1971) -- A Three-Equation Model for the Registered Nurse Labor Force
B6 -- Bognanno (1969) -- Hours of Labor Offered by the Registered Nurse
C1 -- Connor (1960) -- A Hospital Inpatient Classification System
H4 -- Hixson (1969) -- Demand and Supply of Professional Hospital Nurses' Services
J1 -- Jelinek (1964, 1967) -- Allocation of Nursing Time to Patient Care Model
K1 -- Kennedy (1968a, b, c, d) -- Maternal and Child Care Simulation Model
L1 -- Laberge- Nadeau and Feuvrier (1972) -- Model of Patient Care Demands for Nurse Manpower
M2 -- Moss (1970) -- A Simulated Health Service Queue
R1 -- Reinhardt (1970, 1972) -- A Production Function for Physician Services

TABLE 4: MODELS CONCERNED WITH CHARACTERIZATION OF THE SUPPLY OF HEALTH MANPOWER SERVICES.

S3 -- Shuman (1969) -- Mathematical Models for Health Manpower Planning
S4 -- Shuman et. al. (1969, 1970) -- Optimum Health Manpower Mix Model
S5 -- Singer (1961) -- Model of the Variation of Patient Categories Within a Hospital
S8 -- Sloan and Blair (1973) -- Short-Run Supply Responses of Professional Nurses
T1 -- Thomas (1964, 1968) -- Demand for Nursing Resources
U1 -- Uyeno (1971) -- Design of Primary Health Care Teams
W1 -- Wolfe (1964) -- Multiple Assignment Model for Staffing Nursing Units
Y1 -- Yett - HRRC (1972) -- Micro-Simulation Model of Health Manpower

TABLE 4 - Continued

care delivery constraints on utilization of health manpower services, seven models with the analysis of health manpower supply, and seven models with the analysis of specialty and geographic distribution of health manpower.

Models Which Characterize
The Demand for Health Manpower Services

The models characterizing the demand for health manpower services relate health service utilization and/or health manpower requirements to consumer population attributes, economic factors and health service constraints. That is, one group of models concentrates on the utilization of services while the other group focuses on the manpower requirements necessary to satisfy these service demands. The models concerned with the utilization of services provide output measures of factors such as physician or outpatient visits, hospital admissions, hospital patient days, and hospital lengths of stay. The output measures found in the models predicting health manpower requirements reflect the number of personnel or personnel hours required (demanded) for the various health manpower disciplines. Models in the first category can be used to describe the factors which influence the utilization of various types of services or to predict future magnitudes and types of service utilized. Models falling in the second category are more applicable to health manpower analysis problems, i.e., estimating the current or future requirements for specific numbers of health manpower. Clearly, service demand models and manpower demand models need not be mutually exclusive. A single model could predict service utilization and then translate these service demands into manpower requirements.

Tables 5, 6, and 7 provide an abbreviated listing[1] of some of the interactions between the major input and output variables of the models concerned with the analysis of the *utilization of health services*. Table 8 displays these interactions for models treating the *demand for health manpower*. In tables 5 - 8 the interaction between the model input and output variables is presented in a matrix format. The major input and output variables are identified by row and column headings, respectively, and the models which describe each interaction are shown as entries in the intersection of the appropriate row and column. The model identification codes shown in these matrices correspond to the prefix codes provided in the model listing in table 3.

Examination of the input and output variables shown in table 5 reveals that the models within the first analysis area -- cultural-demographic factors characterizing demand -- cover a wide array of relationships between population attributes and health service utilization. Many of the traditional population characteristics plus three health attributes (health condition, attitudes toward medicine, and knowledge of disease) are related to four general measures of service utilization. A similar examination of the model variables delineated in table 8 shows that three of the models in table 5 (E1, R2, and Y1) also provide estimates of the demand for health manpower.

[1] The lists of variables displayed in these and subsequent tables and figures are a representative collection of the types of variables treated by these models rather than an exact and comprehensive delineation of the variables for each model. Readers interested in a complete listing of the variables manipulated by each model are referred to volume II of this report.

Input variables \ Output variables	Health care expenditures (D1 only): Number of patient days	Number of outpatient visits	Number of hospital admissions	Length of stay
Age	F7 R2 F5 E1 R3 A4 H5 D1	E1 L2 F5 Y1 A4 D1	E1 R3 F1 Y1 R2 B3	R2 R3 Y1
Sex	F1 R3 H5 R2 F5 A4	F5 Y1 L2 A4	R3 Y1 R2	R3 Y1 R2
Race	F7 R2 R3 H5 A4	L2 Y1 A4	R3 Y1 F3 R2	R3 Y1 R2
Family size	E1 R3 F5 A4 D1	E1 F5 A4 D1	E1 F3	R3 B1
Urbanization	E1 R3 F5	E1 F5	E1 R3 F1	R3 F1
Marital status	F5 R3	F5	F1 R3	R3 F1
Education level	F7 A5 R3 A4 D1	A4 D1	R3	R3
Population size	F7 R2 N1 F4	N1	R2 B3	R2
Health condition	A4 N1	A4 N1		
Employment status	H5 A4	A4 L2	B3	
Geographic location	D1	L2 D1		
Attitudes toward medicine	A4	A4		
Knowledge of disease	A4	A4		

TABLE 5: MODEL INPUTS AND OUTPUTS CHARACTERIZING HEALTH SERVICE UTILIZATION IN TERMS OF POPULATION CULTURAL-DEMOGRAPHIC ATTRIBUTES*

*Models listed in this table are contained in table 3 under Analysis of Cultural/Demographic Factors Characterizing Demand.

Output variables / Input variables	Health care expenditures (D1 only)		Number of hospital admissions	Length of stay
	Number of hospital patient days	Number of outpatient visits		
Price of health care	F7 D1 F5 A4 R3	D1 A4 E1 F4 F8 Y1 F5	Y1 F3 R3	R3 Y1
Income or wages	R2 E1 D1 F7 R3 A4 H5 F5	Y1 F4 E1 D1 F8 A4 F2	R3 B3 E1 R2 Y1	R3 Y1 R2
Public expenditures for health care	F5 E1 A4	E1 F5 F2 A4	F3 E1	E1
Health insurance coverage	R3 A4 R2 F2 D1 F5	D1 A4 F5 Y1 F8	R2 R3 Y1	R2 Y1 R3
Enrollment in Medicare	F7			
Price of health insurance	D1	D1		

TABLE 6: MODEL INPUTS AND OUTPUTS CHARACTERIZING HEALTH SERVICES UTILIZATION IN TERMS OF ECONOMIC FACTORS*

*Models listed in this table are contained in table 3 under Analysis of Effects of Economic Factors Influencing Demand.

Output variables / Input variables	Number of patients or patient days	Number of outpatient visits	Hospital admissions	Length of stay
Number of physicians	A4 F7 B3 E1	E1 F8	A4 E1 F3	E1 F1
Number of hospital beds	A4 E1 F7	E1 F8	A4 F3 E1 F1	E1 F1
Presence of hospital outpatient facilities or services	F7			
Personnel and office resources	K1			

TABLE 7: MODEL INPUTS AND OUTPUTS CHARACTERIZING THE UTILIZATION OF SERVICES IN TERMS OF HEALTH CARE DELIVERY CONSTRAINTS*

*Models listed in this table are contained in table 3 under Analysis of the Effects of Health Care Delivery Constraints in Utilization of Health Manpower Services.

These models determine the utilization of health services (e.g., hospital bed days) in terms of the cultural-demographic composition of the population and then derive the demand for health manpower from the amount of services utilized. Prediction of the relative number of persons in each population category (coupled with these analytic descriptions) provides a mechanism for estimating future utilization of health services and the derived demand for manpower.

One policy action identified within the analysis area concerned with cultural-demographic effects on demand (see table 1) -- consumer health education -- receives very limited treatment by the models examined. In fact, the only model in the inventory which might provide insight into the effects of such education on the utilization of services is Andersen's (A4) model. Two of the input variables of this model shown in table 5 -- attitudes toward medicine and knowledge of disease -- could be used to reflect the results of health education on consumer behavior, but only if one can first state the effects of education on consumer attitudes and knowledge.

Model input and output variables associated with the second analysis area (characterizing the influence of economic factors on the demand) for health manpower services are shown in tables 6 and 8. This analysis area contains four analysis topics (see outline on page 54). Three are concerned with the description of the effects of price, income, and insurance on the demand for health services, and the fourth concentrates on the impact of alternative federal and state financial programs on this demand. The interrelationships between these economic factors and the utilization of health services are presented in table 6. Of the 14 models listed in this table, only two include all four economic factors as inputs to the model equations. Six models examine the effects of three of these factors on health service utilization, three models include two economic factors, and three models include only price or income. Treatment of each of these factors by the models is briefly discussed below.

The set of models which describes the effects of wages or the price of care on utilization of services examines such relationships as the effects of price on total medical expenditures (D1), the effects of room charges on patient days per capita (R3), and the effects of physician fees on doctor's office visits (Y1). Similarly, models used to analyze the influence of consumer incomes on the type and amount of health care demanded describe the interaction between the proportion of families in various income groups and the number of outpatient visits, inpatient visits, and lengths of hospital stay (E1), as well as between effective buying income and the number of hospital patients per month in the communicable disease category (B3).

The set of models which describe the relationship between alternative forms of health insurance and health service demands include the nine models which have inputs corresponding to the last three rows in table 6 (i.e., health insurance coverage, enrollment in Medicare, and price of health insurance). The way in which these models characterize the relationships between health service utilization and the amount and type of insurance is reflected in the specific type of input variables they employ. The characterization of the gross impact of health insurance on demand is examined by models which consider only the presence or absence of various forms of insurance coverage (e.g., Medicare, Medicaid, hospital insurance, insured outpatient care). Other models consider the relative amounts of coinsurance coverage maintained (i.e., coinsurance rate) for a specific type of care (e.g., hospitalization insurance). However, none of the models examined, with the possible exception of the Yett-HRRC model (Y1), permits an analysis of the simultaneous effects of different amounts of various forms of insurance on health service utilization. This latter type of analysis would be particularly applicable to problems concerned with the impact of alternative provisions in a National Health Insurance program.

The fourth topic within the analysis of economic effects on demand -- the effects of alternative reimbursement systems and other financial programs on health care cost and utilization -- is not treated directly by any of the models examined. The only input variables which might be associated with this topic are those concerned with special government insurance programs (e.g., Medicare) or other public expenditures for health care. That is, an investigation of the effects of alternative federal or state reimbursement systems on the demand for health services would first require an understanding of the impact of current public expenditures on these demands, irrespective of the particular mode of payment utilized.

In addition to using economic factors to predict utilization of health service, some of the models use the economic factors to estimate demands for health manpower. Table 8 shows the grouping of seven models (six of which were not represented in table 6) which relate economic factors to the demands for health manpower directly (i.e., the row containing wages, prices, etc.). Unlike the previous analysis area (the effects of cultural-demographic factors on demand), these seven models estimate demands for manpower directly as a function of economic factors such as salary and hiring costs, stipends, and service charges, and some measure of service utilization *which is assumed to be available as input.* Three of the models in table 8 estimating demand for manpower as a function of health service utilization only (E1, R2, and Y1) also estimate utilization as a function of economic factors (as shown in table 6). Accordingly, they may be used to study the effects of the economic characteristics of the population on the demand for manpower in a two-step estimation process.

The third and final health manpower analysis area concerned with characterizing the demand for health services is the assessment of the impact of health care delivery constraints on the utilization of services and manpower (see outline on page 55). As discussed in chapter 2.0, the three main analysis topics within this area are:

(1) analysis of availability or other factors governing the use of health services of differing levels of accessibility and the demand for manpower,

(2) characterization of the impact of various modalities of health care delivery on the utilization of services and manpower, and

(3) description of the effects of specific procedures within these service modalities on the consumption of services.

As can be seen from tables 7 and 8 only the first of the above topics is specifically addressed by the models. That is, the model input variables concentrate on factors, such as numbers of personnel (primarily physicians) and health care facilities, which influence the availability of health care resources to the consumer and hence shape his methods of utilization. As such, these models describe the more aggregate effects of availability on utilization, ignoring the more detailed effects such as those caused by the substitutability among service types. Furthermore, the impact of service accessibility factors such as the disutility of appointment procedures, waiting time, and travel distances is largely untreated by the models in the inventory. As in the analysis of economic effects on demand, factors constraining health service availability are used to estimate manpower demands directly, as well as to estimate utilization measures which may be translated into demand for manpower.

Models Which Characterize the Supply of Health Manpower Services

As outlined on page 55, the environment of health manpower supply can be viewed in terms of three major areas of analysis -- additions to the stock of health manpower, specialty and geographic distribution of health manpower, and efficient utilization of health manpower resources. From this outline we see that each analysis *area* is further divided into more specific analysis *topics*. Table 2, also presented earlier, provides a statement of the policy actions and performance measures typically associated with each analysis area. Finally, table 4 presents a listing of those models in the inventory which are applicable to each analysis area. Combining information from these three sources -- the outline, table 2, and table 4 -- the following discussion examines the applicability of the models to each of the analysis topics.

The three analysis topics within the analysis of additions to the stock of health manpower services are:

(1) identification of factors which influence the number of graduates of health professions educational institutions,

(2) assessment of the impact of government financial programs aimed at increasing the supply of health graduates, and

(3) evaluation of the influence of federal and state regulatory policies on these supplies.

An examination of the list of input and output variables provided in table 9 reveals that most models in this area focus primarily on the first of the above topics. That is, the models primarily describe the supplies of health manpower disciplines in terms of educational process factors.[1] Factors such as expected income in health professions (e.g., nurses) versus other occupational substitutes (e.g., public school teachers) or the number of high school graduates are used to estimate changes in supply (A3 and F5), but these factors are only indirectly affected by governmental actions. Variables listed in table 9 which are also associated with, but not directly related to, financial programs include the number of spaces in educational institutions (associated with government construction programs) and tuition and fees (associated with government loan and scholarship programs). The only input variables directly related to financial programs are federal construction subsidies and number of scholarships. None of the models examined treat the third analysis topic listed above, i.e., regulatory policies. Thus, only a

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[1] Several of the interactions described by these models are identities or definitions rather than causal relationships between variables. For example, the number of medical school graduates may be defined as the total number of students admitted three years ago minus the number of dropouts since that time (F5) or the maximum number of graduates limited by the number of spaces in educational institutions (A3).

Output variables / Input variables	Number of medical school admissions and/or graduates	Number of dental school admissions and/or graduates	Number of nursing school admissions and/or graduates	Health personnel	Number of medical school applicants	Net immigration of foreign trained nurses and physicians
Occupational wage or income measures	M1	M1 F4	M1 F5 A3	M1	S6	F5
Number of students or spaces in educational institutions	L3 F5 D2	F4	A3			
Federal construction subsidies	F5	F4				
Number of scholarships	F5		F5			
Number of high school or college graduates	F5		F5			
Tuition and fees					S6	
Number of school dropouts	F5 D2	F4				

TABLE 9: INPUT AND OUTPUT VARIABLES OF MODELS CONCERNED WITH ADDITIONS TO THE STOCK OF HEALTH MANPOWER

limited number of factors are used to predict number of health education applicants, admissions, and graduates. Specific analyses of the effectiveness of alternative programs to increase the number of graduates (e.g., capitation grants, construction loans, and curriculum shortening) would require greater and more detailed representation of these programs and their specific provisions in the models than is currently provided.

Models which are applicable to the second major analysis area concerned with health manpower supply treat one or more of the following analysis topics:

(1) analysis of factors influencing the distribution of physicians among the medical specialties,

(2) analysis of factors affecting the geographic distribution of health manpower,

(3) analysis of the factors governing poor representation of minorities and women in the health professions, and

(4) assessment of alternative programs and policy actions on the above distributional issues and entry mix problems.

As can be seen in table 10, only one of the seven models in this analysis area manipulates variables which describe physician choice of specialty (S6). Several of the input variables in this model could reflect policy actions identified in table 2. Number of residencies offered could be influenced by capitation grants to teaching hospitals for increasing the number of residencies in selected specialties or by specific grants to institutions establishing new programs such as family medicine training. Similarly, scholarships linked with specialty shortages would effectively increase stipends to residents in this specialty.

Output variables / Input variables	Number of physicians in a specific region	State physician retention	Number of nurses in a state	Number of residents in each speciality
Physician's Age		S6		
Population characteristics (age, education levels urbanization, medical insurance coverage, etc.)	H1 H3 B5* E2 S1	H3 S6		
Occupational wages or income measures	S1 H3 H1 B5	S6 H3	B4	S6
Number of medical schools (graduates) in a geographic region	H1 B5 S1 H3	H3		
Number of physicians (specialists, FMGs, house staff, ect.)	H3 H1	H3		
Regional variables (degree days, price of land, population migration)	H3	S6 H3		
Previous contact with state		S6		
Number of nursing graduates in state			B4	
Number of hospital beds or admissions	S1 H3 H1	S6 H3		
Failure rate of state licensing exam	B5*	S6		
Stipends and number of residencies offered				S6
Number of hours worked by physicians		S6		
Physician dissatisfaction				S6

*also has output variable -- number of dentists in state

TABLE 10: INPUT AND OUTPUT VARIABLES OF MODELS CONCERNED WITH GEOGRAPHIC DISTRIBUTION OF HEALTH MANPOWER AND DISTRIBUTION OF PHYSICIANS AMONG THE MEDICAL SPECIALTIES

Each of the seven models in this analysis area can be used to evaluate the effects of various factors on the geographic distribution of manpower. Six models focus on the geographic distribution of physicians, one also describing the distribution of dentists, and another concentrating on nurse distribution. These models estimate the number of all physicians, specialists, general practitioners, dentists, and/or registered nurses by region. The factors included in the equations which may explain the selection of occupational location in a particular region are listed in table 10. The geographic regions treated in these models are states, census tracts and regions within a state. The input variables in this list which could be relevant to the analysis of state or federal policy actions include: (1) number of nursing or medical graduates in a state, (2) the number of hospital beds in a state, and (3) the number of residencies and size of stipends offered. The first two of the variables reflect the impact of programs designed to increase medical school capacity (including construction of new schools) or the effects of programs for stimulating increases in the number of hospital beds on the geographic distribution of physicians. The third variable could reflect the actions of the more direct programs which promote residencies in medically depressed regions.

The third topic in this analysis area -- equal representation of minorities in the health professions -- is not directly treated by any of the models in the inventory. However, if one assumes that the minorities and women select health professions with the same consideration as people in general, then the models presented in table 9 might provide some insight into this problem. That is, the relationship between tuition, fees, and number of medical school applicants (S6) could be used to make inferences on the effects of scholarship or loan programs on improving entry mix. Clearly, such extrapolations would be tenuous in nature, especially for minorities, since the economic composition of the minority population (and hence the behavior toward educational costs) is quite different from that of the overall population.

The third and final analysis area is the analysis of efficient utilization of health manpower resources. As noted previously eighteen of the models examined are applicable to the three analysis topics classified under this area. These topics are:

(1) analysis of expanded roles for allied health manpower,

(2) analysis of other techniques to improve health manpower productivity and utilization, and

(3) analysis of factors which influence the labor force participation rate of health manpower.

The models applicable to these analysis topics fall into two general categories, models which examine the first two of the above topics and those which examine the third. The first category, then, is composed of models of health care delivery processes (see section 3.1.1) which describe optimal scheduling, allocation, and utilization of personnel in the delivery of health services. The second category of models examines factors which influence the number of hours offered and the labor force participation rates of health personnel, i.e., the third analysis topic.

Many of the models of health care delivery processes are mathematical programming models whose outputs are the values of the process variables which maximize or minimize the selected objective function. Coefficients of the constraint and objective functions are inputs to these models. The large number of inputs and outputs are not particularly amenable to presentation in the tabular form used previously. Therefore, general measures of some of these quantities are provided in table 11, along with the input and output variables from the nonprogramming models which are also applicable to this area.

The models concerned with the allocation and scheduling of nurses' services (A1, C1, J1, L1, S5, T1, and W1) define optimal or efficient management systems to improve the use of these resources. Other models in this group (H4, K1, M2, S3, and S4) provide descriptions of health care delivery processes under existing or optimal conditions to provide insight into the relationships between the provision and consumption of health services. The nurse allocation and hospital process models are applicable to problems in individual hospitals and, although they describe efficient methods of utilization, they are generally inappropriate for analysis of more aggregated problems at the state or national level. However, these models could be indirectly applicable to the analysis of alternative techniques designed to improve manpower utilization in that each model can be considered a description of different health care delivery procedures and techniques which have differing levels of manpower productivity and utilization.

Six of the 18 models concerned with the utilization of manpower resources are applicable to the first analysis topic listed above -- the analysis of expanded roles for allied health manpower. In two of these models (Y1 and R1) the number of total physician visits supplied is a function of the number of nurses, technicians, and secretaries employed.

Output variables / Input variables and co-efficients	Labor force participation rate of nurses	Number of hours worked by nurses	Total physician visits supplied	Amount of time spent by nurses in various activities	Number and type of staff required under different situations	Staffing costs and other measures of utilization
Age	Y1	B6 S8				
Race		S8				
Living arrangement		B6				
Number of young children	B4	B6 S8				
Community size		B6				
Foreign born		S8				
Geographic region of residence		S8				
Occupational wage or income measures	B4 Y1	B6 S8				
Number of hours worked			Y1 R1	C1 J1		W1
Number and type of personnel employed			Y1 R1		A1 S4 S3	A1 U1 H4
Personnel costs -- salary, firing, etc.					A1 S4 S3	A1 W1 K1
Tasks and task performance times					L1	W1 M2
Patient classification categories and related care requirements		S5		C1 J1	T1	U1

TABLE 11: INPUT AND OUTPUT VARIABLES OF MODELS WHICH ADDRESS LABOR FORCE PARTICIPATION AND EFFICIENT UTILIZATION OF HEALTH MANPOWER

Two models, (S3) and (S4), provide theoretical structures for examining the optimal mix of health manpower to minimize cost to a community or maximize the quality of health services received. The fifth model (U1) investigates the effects of increasing the numbers of allied health manpower on patient service and waiting times in a health care clinic. The final model in this group (M2) simulates a health service queue to measure efficiency in terms of skill level requirements and usage, cost, etc. None of these models contains input variables which reflect the importance of government policy actions on the availability or number of allied health personnel in expanded roles.

Models which address the third analysis topic are easily recognizable in terms of their output variables (i.e., labor force participation and nursing hours worked) as shown in table 11. These models relate a nurse's personal and familial attributes to her decision to join the labor force and propensity to work. These models are similar to others in this analysis area in that they do not reflect any governmental policy actions or inputs.

3.2.2 Model Generality

Model generality is the ability of a model to address a broad spectrum of user problems which are similar (but not necessarily identical) to those considered in the development of the model. Some models are developed to study the problems of particular users with no attempt to render them applicable to other problem environments. These models are called *specific* because they treat the processes of particular organizations or geographic areas. The Latham [1971] model, for example, seeks the optimal output mix for the University of Iowa Medical College subject to its unique institutional structure and resource constraints. Thus, the Latham model is tailored specifically to the University of Iowa and is not readily applicable to any other medical school. This is not to say, of course, that Latham's basic approach could not be applied successfully to other schools, but simply that the model, itself, is not directly transferable. On the other hand, some models are expressly designed to serve any number of users as long as they possess a commonality of analysis interest. The Abernathy [1972] model, for example, is generally applicable to any acute-care hospital for assistance in nurse allocation and scheduling problems.

In practice, generality is a matter of degree. Few models, if any, can be transferred from one user to another without minor modifications in model logic and substantial data-base replacements. The coefficients of regression equations frequently require re-estimation because the original data base is no longer current or is not completely applicable to the new user. Re-estimation may, in turn, cause certain independent variables to be dropped from the equations because their coefficients are no longer significantly different from zero. At the other end of the spectrum, few models are irrevocably specific because few systems are completely unique. One institution may profitably adapt a model designed expressly for another institution if it has the ingenuity as well as the resources to do so.

The 56 models cataloged in volume II are classified in table 12 as either general (G) or specific (S). These classifications are not

Model	Class	Model	Class	Model	Class
A1	G(HD)	F3	G	N1	G(SD)
A2	S(E)	F4	G		
A3	G	F5	G	O1	G(SD)
A4	G(SD)	F6	G(HD)		
A5	S(E)	F7	S(E)	R1	G
A6	G	F8	G	R2	G
				R3	G
B1	S(E)	H1	G		
B2	G(ND)	H2	S	S1	G
B3	S(E)	H3	G	S2	S(E)
B4	G	H4	G(SD)	S3	G(HD)
B5	G	H5	S(E)	S4	G(HD)
B6	G(SD)			S5	S(E)
		J1	S	S6	G
C1	G(SD)			S7	G
		K1	S(E)	S8	G
D1	G				
D2	G	L1	S	T1	S(E)
		L2	G		
E1	G	L3	S	U1	S(E)
E2	G(SD)	L4	G(SD)		
				W1	S
F1	G	M1	G		
F2	G	M2	G(SD)	Y1	G
				Z1	G(HD)

TABLE 12: GENERALITY OF MODELS IN THE INVENTORY

sacrosanct. Rather, they reflect judgments intended to illuminate this utility dimension of each model. It is reasonable to expect, however, that specific (S) models in table 12 could require more effort than general (G) models to apply to new situations. Many of the models deemed general (G) were developed and tested with specific data (SD), i.e., data specific to a particular organization or geographical area; or with hypothetical data (HD); or in some cases, with no data at all (ND). Though such models are generally applicable, they must be provided with appropriate data bases before they can be used effectively. In many instances, even the general models developed with generally applicable data will require new data bases (because the old ones are no longer current). Some of the models judged specific (S) to a particular system are believed to be "reasonably" amenable to generalization or extrapolation (E) to other similar systems. Such extrapolations, of course, will require model modifications as well as data-base acquisitions. These latter efforts are discussed further under the topic of operational feasibility.

3.2.3 Model Validity

Given that a model is applicable to a particular analysis problem and that it is adaptable to the specific problem environment (i.e., sufficiently general), the third question which must be posed in a model utility assessment is -- is it valid? The question of model validity is adequately resolved only through a careful analysis of model assumptions, a rigorous checking of mathematical logic, and a comprehensive examination of model predictions and their correspondence with analogous outputs in the real world. In addition, a model must be *currently* valid to offer significant utility to potential users. That is, trends and events may have transpired which invalidate the model's assumptions, its logical relationships, its data base, and hence any prior comparisons with real-world behavior.

The first step in the evaluation of validity is to test the model's basic assumptions and structural relationships in the light of current realities. Are they consistent? Are they realistic? Do they tend to oversimplify? These questions should be asked with cognizance that a useful model need only abstract those aspects of the real system which are particularly relevant to the problems at hand. If the basic assumptions and/or structural relationships are found irrational, there is no need to proceed further since it is highly unlikely that the model will effectively simulate real system behavior.

If a model's basic assumptions and structural relationships are deemed sound, one might next want to examine the completeness and correctness of the model's mathematical structure. Inherent in this analysis should be an evaluation of the various assumptions implicit in the particular mathematical techniques selected. These assumptions (e.g., linear, statistical independence, etc.) are an integral part of any mathematical formulation and define a hypothetical environment which hopefully behaves in a manner similar to the behavior of the processes described. Statistical tests of the correspondence between mathematical assumptions of component parts of the model and actual behavior of the associated subprocesses of the overall system provide some measure of the validity of the hypothesized description. For example, if the model uses an exponential probability distribution to generate times to recovery, was this selection based on a successful goodness-of-fit comparison with empirical data? If a linear regression equation is used to predict demand for health services, based on given population and environmental characteristics, were the estimated coefficients of this equation tested for statistical significance?

The ultimate test of a model's validity is the outcome of carefully designed experimental runs (which are normally executed on a computer but which may simply be performed via hand computation in some cases). These exercises view the model as a "black box" which operates on selected, historical, real-world inputs and produces simulated outputs which are compared to the actual historical outputs of the overall system. The closer simulated outputs are to their historical counterparts, the more successful is the test. A good test result provides experimental evidence to support an inference that the model is logically sound and error free. However, since all facets of a model rarely come into play for any one set of input values, we cannot state that the model is valid in general. The procedure is to test as many historical input/output combinations (scenarios) as practicable to increase the probability that the model is fully exercised. The results of these tests are used to provide a reasonable measure of the correspondence between the model descriptions and actual system behavior.

A valid model of processes and interrelationships which are relatively time invariant may be useful for problems in many successive time periods. However, it is unreasonable to expect the dynamic social environment which governs the health system (and hence health manpower supply and demand) to maintain such static relationships. Population size and composition change over time as do the rates of disease incidence, the modalities of medical treatment, and the behavior of the health consumer. Furthermore, public intervention into this system, such as the introduction of Medicare and Medicaid, can greatly alter the environment in which health care services are delivered. Thus, there are few if any models of health systems which remain even approximately valid over a long period of time.

As can be seen from the above discussion, the analysis of model validity consists of four interrelated analysis dimensions. First, the model's basic assumptions and structural relationships should be examined for consistency and realism. Second, the collection of assumptions implicit in the mathematical techniques utilized should be evaluated and tested empirically. Third, the model outputs should be empirically verified against historical data. Fourth, the historical period chosen to test the model empirically should be sufficiently current for one to be reasonably confident of the model predictions.

Clearly, a detailed evaluation of assumptions, structural relationships, and mathematical formulations contained in the models described previously, as well as comprehensive investigation of the results of verification tests performed on these models, is beyond the scope of this study. Instead, this investigation has concentrated on compiling a detailed summary of model assumptions, hypotheses, and constraints underlying the conceptual structure of each model, the major analytic relationships and mathematical composition of these models, the data sources utilized in model construction, and the model verification study performed. This information is provided in volume II of this report.

An examination of the explicit assumptions (i.e., those noted by the model developer) listed in the inventory reveals that the models are based on a large variety of assumptions (over 200) which are generally model-specific and have varying degrees of plausibility. That is, several of the assumptions must be considered nearly statements of facts or definitions, such as -- mean family income can change over time (R2), women younger than ten or older than 50 are assumed infertile (O1), and there exists some form of total resource constraint (M1). The majority of explicit assumptions are statements about health system conditions or health system parameters which would be recognized by most individuals in the health field as intuitively reasonable under certain conditions. For example, the assumption that the stock of nurses is fixed during the time period under observation (H4) is reasonable for certain time periods. Similarly, the assumption that two part-time employees are equivalent to one full-time employee is plausible under the condition that employee productivity is constant across employees and independent of working period length (20 hours versus 40 hours per week). Another example of this type of assumption -- patients who have longer lengths of stay have more hospital services performed in their behalf (B1) -- is reasonable only if the patients are identical in terms of the rate at which they consume hospital services.

Only a very few of the explicit model assumptions examined fall into a third category which might be termed as questionable. The assumptions in this category are plausible only in highly constrained environments. An example is the assumption that an individual's health is a function of this year's medical services only; i.e., it does not depend on service received in previous years (A6). If this assumption is true, one of the major tools used by physicians to diagnose patient condition -- the medical history -- is of no value. Although the assumptions which fall in this latter category are less generally acceptable than those in the other two categories, they only differ from the others in the number and type of conditions which must exist for them to be plausible.

An examination of the analytical structures of the models reveals that most employ regression analysis to describe the health system both cross-sectionally and over time while the remaining models use (in descending order of prevalence) mathematical programming, Monte Carlo simulation, and analytic Markovian formulations. Associated with each analysis technique is a series of implicit assumptions. Regression analysis models assume that there exists some deterministic, predictive (not necessarily causal) relationship between the collection of input variables associated with each model and the output variable. With one exception, all of the models examined assume that the form of this relationship is either linear or linear in logarithms. The one exception (B6) assumes a quadratic relationship between a nurse's age and the number of hours which she works. Mathematical programming models assume that the health process described pursues a single objective (e.g., to minimize costs, to minimize excess demand for health manpower, to maximize quality of services, etc.). This objective function is taken as a linear combination of decision variables by all developers of the models in the inventory except Maki (M1) who assumes a quadratic objective function. In all the programming models, the constraining relationships are assumed to be linear. Monte Carlo simulation models assume that the processes being described are stochastic in nature. The underlying probability distributions which describe this stochastic behavior are assumed to be known. Finally, the analytic Markovian formulations in the inventory also assume that the process under observation is stochastic and, additionally, that the probability of making a transition to each state of the process is dependent only on the state presently occupied.

As noted above, explicit and implicit assumptions range from axiomatic statements about the process being modeled to statements which simplify the model's view of the process to the point of destroying any meaningful analogy. A rating of an assumption's validity within this range must be based on the particular analysis requirements of the prospective user. Each user normally considers a somewhat unique process environment and has special problem-solving requirements. The validity of any assumption is really user dependent. That is, it must be evaluated in terms of its comparative costs (decreased model reality) and benefits (increased model tractability) as related to the analysis requirements of the particular user. Thus, an exhaustive evaluation of the validity of every assumption listed with the models cataloged in volume II would not be meaningful beyond the context of user-specified information. Consequently, such an evaluation of explicit and implicit assumptions is left to each potential user, the person most aware of the intricate aspects of his particular problem. To facilitate this analysis, volume II describes the explicit structural assumptions and mathematical formulations for each model.

The third and fourth dimensions of model validity assessment -- empirical verification of the overall model and the currency of this test -- are summarized in table 13. This table provides information on each model in the health manpower model inventory, indicating whether its outputs were tested for validity against historical data. If validation studies were performed (i.e., comparison of model predictions to historical data), the years from which data was obtained for estimation of the model parameters and the dates of the historical comparison are indicated. Component model test results -- in terms of significance levels for coefficients, estimates of percent of error, and estimates of variance -- are also shown if this information was provided in the available model documentation. Frequently, the evaluations of test results were subjective in nature (e.g., describing whether or not model estimates compare favorably with historical data) involving lengthy descriptions of the correspondence between model predictions and available data. These descriptions are not repeated here. Individuals interested in the results of these tests are referred to the list of model references provided at the end of this report.

3.2.4 Operational Feasibility

Clearly, no model is completely self-contained nor self-executing. To exercise a model a user must perform many "supportive" tasks. Namely, he has to maintain a current data base, select and specify options, supply input values in the proper format, execute the model (either by hand computations or on a computer of sufficient capacity and speed),

A1 - Abernathy, et al - not tested
A2 - Abranovic - tested with January 1968-July 1968 data, developed with July 1967-January 1968 data
A3 - Altman - not tested
A4 - Andersen - not tested
A5 - Anderson - not tested
A6 - Auster - not tested
B1 - Baer - not tested
B2 - Baligh and Laughhunn - not tested
B3 - Beenhakker - not tested
B4 - Benham - not tested
B5 - Benham et al - not tested
B6 - Bognanno - not tested
C1 - Connor - developed with 1958-1959 data. Results of analysis of variance and t-tests accepted as significant
D1 - Davis - not tested
D2 - Deane - estimated with 1966 data, tested with 1947-1966 data. Largest mean percent of error was 3.6 percent; largest mean squared percentage error was 27.66%. Forecasts to 1970 compared "favorably" with actual data available.
E1 - Edwards - hospital admissions estimated with 1957-1966 data, tested with 1967-69 data; average error of 4%. Patient days estimated with 5 year time span of data base, 1960-65, 61-66, 62-67, 63-68, 64-69, tested with 1970 data, average errors 2.9% - 4.4%. Inputs for production function for hospital care -- all statistically significant at 1% level.
E2 - Elesh, et al - Detroit model explained 45-50% of variance, Chicago model explained 35-40% of variance.
F1 - Feldstein - not tested
F2 - Feldstein - not tested
F3 - Feldstein - not tested
F4 - Feldstein - not tested
F5 - Feldstein - estimated with 1960 and 1965 data, tested using 1960 data to predict 1965 values.
F6 - Fetter - not tested
F7 - Fitzmaurice - not tested
F8 - Fuchs and Kramer - not tested
H1 - Hawkins - not tested
H2 - Hearn and Bishop - simulation of 100 days compared to frequency distributions observed in the real situation; no significant difference between simulated and observed mean values or frequency distributions. Output and input profiles agreed within 14 days in 81% of patients.
H3 - Held - not tested
H4 - Hixson - results of confidence levels of coefficients appear to confirm underlying hypothesis
H5 - Hopkins - estimated with 1960 data, tested with 1965 data; over-estimated bed use by 30%

TABLE 13: EMPIRICAL VERIFICATION STUDIES PERFORMED ON THE MODELS

J1 - Jelinek - not tested
K1 - Kennedy - estimated with July 1965-December 1966 data, tested with 1969 data
L1 - Laberge-Nadeau and Feuvrier - tested by comparison of simulation results to actual hospital operations - dates unknown
L2 - Larmore - not tested
L3 - Latham - not tested
L4 - Lazarus - not tested
M1 - Maki - estimated with 1950 data, tested with 1960 data - naive model forecast with error of 2.3%, quadratic model forecast error was .02%
M2 - Moss - "results have been tested using empirical data from local health service units and have been found to provide good replication of the health activity".
N1 - Navarro et al - not tested
O1 - Ortiz and Parker - not tested
R1 - Reinhardt - not tested
R2 - RTI - estimated with 1960-1972 data, tested with 1960-1970 data (see chapter 4.0 of this report)
R3 - Rosenthal - not tested
S1 - Scheffler - not tested
S2 - Shaw - not tested
S3 - Shuman - not tested
S4 - Shuman - not tested
S5 - Singer - estimated with June 9-September 20, 1958 data, tested with September and October, 1959 data
S6 - Sloan and Yett - Model 1 estimated with 1948-1965 data, tested with 1948-1965 data, also estimated with 1936-42 and 1942-61 data; tested with 1936-61 data. "A" applicant model--estimated and tested with 1950-65 data
S7 - Sloan - all coefficients are significant at the 1% level
S8 - Sloan and Blair - not tested
T1 - Thomas - not tested
U1 - Uyeno - "actual and simulated waiting times in a pediatrician's office were compared; very good correspondence was found between the model and this data".
W1 - Wolfe - all but 6 of 124 hypotheses tested were accepted at the .05 significance level.
Y1 - Yett-HRRC - estimated with 1967, 1969, and 1970 data, tested with 1960-1970 data. (See chapter 4.0 of the report)
Z1 - Zemach - not tested

TABLE 13: EMPIRICAL VERIFICATION STUDIES PERFORMED ON THE MODELS.

(Continued)

and interpret model outputs. In addition, he may initially have to modify the model's coding to achieve compatibility with his computing system and, subsequently, he may wish to improve or enrich the model's logic relative to his particular analysis requirements. These matters of user responsibility and capability relate to the criterion of model utility termed *operational feasibility.*

The operational feasibility of a model varies from user to user. For a particular user, it is determined by comparing the model's operational requirements to the user's computational capabilities and time constraints. The operational requirements of each model in the inventory, as provided in the available documentation, are outlined in volume II of this report.[1] Each prospective user must make his own feasibility determination in the light of his particular analysis capabilities.

A guide to measuring a model's operational feasibility is to consider the reason for the model's creation. Many models are developed in conjunction with one-time studies to assist in the identification of historical trends and relationships. They are used in the analyses to test and, in some cases, to suggest hypotheses. Since these models are not intended for repeated future use, they normally require updated data bases and re-estimation of parameters as well as restructuring (and recoding) to render them more computationally efficient. Models that are developed expressly to serve repeatedly as tools (for analysis,

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[1] The characteristics of model operational requirements provided in volume II are relatively limited due to the lack of requisite information in available model documentation.

forecasting, or planning) are less likely to require major overhauls, but even these can rarely be transferred from year to year or from user to user without some modification and updating.

3.3 *Summary*

Table 14 summarizes the characteristics of each model in the inventory (volume II) in terms of its empirical validity, its generality, and its applicability. Model codes are designated in tables 3 and 4 of section 3.2.1. Information given in the columns headed "Tested/Untested" and "General/Specific" is taken directly from tables 12 and 13. In these columns a "T" indicates the corresponding model has been tested in some manner by the developer(s), a "U" indicates the model has not been tested, a "G" indicates the model is generally applicable (within the bounds of the subject matter treated), and an "S" indicates the model is applicable only within a very specific environment (e.g., Johns Hopkins Hospital or the State of California).

A letter "X" is shown in a model's row directly under each analysis topic to indicate the model's potential applicability to that topic. This applicability information is summarized from tables 3-11. Analysis topics are indicated along the top of the table in a coded format which corresponds to the outline provided in section 3.2.1.

Of the 56 models examined only eight models treat subject matter not related to any of the analysis topics. Three of these models (A5, A6, O1) relate socioeconomic and health characteristics to death rates

MODEL CODE	TESTED/UNTESTED	GENERAL/SPECIFIC	IA1	IA2	IB1	IB2	IB3	IB4	IC1	IC2	IC3	IIA1	IIA2	IIA3	IIB1	IIB2	IIB3	IIB4	IIC1	IIC2	IIC3
A1	U	G																		X	
A2	T	S	X		X				X												
A3	U	G										X									
A4	U	G	X	X	X	X	X	X	X												
A5	U	S																			
A6	U	G																			
B1	U	S	X																		
B2	U	G																			
B3	U	S	X			X			X												
B4	U	G														X					X
B5	U	G														X					
B6	U	G																			X
C1	T	G																		X	
D1	U	G	X		X	X	X														
D2	T	G			X				X			X									
E1	T	G	X		X	X		X	X												
E2	U	G														X					
F1	U	G	X						X												
F2	U	G				X	X	X													
F3	U	G			X			X	X												
F4	U	G	X		X	X						X	X								
F5	T	G	X		X	X	X	X				X	X								
F6	U	G																			
F7	U	S	X		X	X	X		X												
F8	U	G			X	X	X		X												
H1	U	G														X					
H2	T	S																			
H3	U	G														X					

ANALYSIS TOPIC

TABLE 14: USEFULNESS OF MODELS IN HEALTH MANPOWER ANALYSIS AREAS

ANALYSIS TOPIC

MODEL CODE	TESTED/UNTESTED	GENERAL/SPECIFIC	IA1	IA2	IB1	IB2	IB3	IB4	IC1	IC2	IC3	IIA1	IIA2	IIA3	IIB1	IIB2	IIB3	IIB4	IIC1	IIC2	IIC3
H4	T	G																		X	
H5	T	S	X			X															
J1	U	S																		X	
K1	T	S							X											X	
L1	T	S																		X	
L2	U	G	X																		
L3	U	S										X									
L4	U	G																			
M1	T	G										X									
M2	T	G																	X	X	
N1	U	G	X																		
O1	U	G																			
R1	U	G																	X	X	
R2	T	G	X			X	X														
R3	U	G	X		X	X	X														
S1	U	G														X					
S2	U	S																			
S3	U	G			X	X													X	X	
S4	U	G			X	X													X	X	
S5	T	S																		X	
S6	T	G										X			X	X					
S7	T	G				X															
S8	U	G																			X
T1	U	S																		X	
U1	T	S																	X	X	
W1	T	S																		X	
Y1	T	G	X		X	X	X		X										X	X	X
Z1	U	G	X		X				X												

TABLE 14: CONTINUED

or describe mortality rates to determine life expectancy. While these models are related to the health care system (they may provide input to population models or models describing health consumer behavior), they are not directly relevant to the specific analysis areas presented in chapter 2.0. Another model (B2) is intended for use in short-range hospital planning to determine the optimum mix of patients, given resource limits. Similar to this model are the illustrative application of a modeling language to health manpower modeling (F6) and the hospital planning model (L4) which determines the optimal allocation of beds among the various departments of a hospital. While these three models consider manpower resources fixed, they could conceivably be used to investigate the effects of different amounts of fixed resources on optimal outputs, thus leading to identification of better resource mixes. The remaining two models in this group include a model of the activities and events concerned with the care of hospital patients which might be used to describe the effects of changes in hospital operations on manpower utilization (H2) and a model which forecasts absenteeism and length of service of hospital auxiliary personnel (S2).

An examination of the relative concentration of models under each analysis topic reveals that the number of models concerned with characterizing the demand for health manpower (classed under roman numeral I) is much greater than the number concerned with analysis of health manpower supply (classed under roman numeral I). This imbalance of model emphasis supports the observation made in section 3.1 -- that the majority of models treat processes which influence the demands for health manpower. This maldistribution of effort is further compounded by the fact that most of the models which treat factors governing manpower utilization (analysis topics IIC1 and IIC2) describe health service delivery and could easily be considered demand models.

There are at least two reasons which could contribute to this apparent maldistribution of health manpower modeling efforts. First, model builders may have concentrated on areas where data is more accessible, the processes better defined, and the results more directly applicable to decision-making activities. Health care delivery organizations are more amenable to process descriptions in terms of measurable input and output parameters (e.g., number and type of services provided, time required to provide services, manpower required, etc.) than the less structured processes which govern labor force participation, educational choice, selection of work location, migration and immigration of health personnel, and health professions education. Second, there may be a greater requirement for understanding the processes that govern the demand for health care and health manpower services. The increases in the supply of physicians, nurses, and allied health personnel far exceeded the rate of population growth during the past decade.[1] The price of medical care is escalating at unprecedented rates, indicating that much of the imbalance in supply and demand is attributable to increasing demands, i.e., an implication of a more urgent need for an

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[1] DMI Interim Report, *The Supply of Health Professionals*, Report No. 73-44 BHME/DMI/MRR [undated].

understanding of the processes influencing demand. However, this imbalance is also attributable to the maldistribution of manpower across the health disciplines and across geographic regions. Thus, models of supply as well as demand are required.

Further modeling activity is particularly needed to describe the impact of various policy actions on supply and demand. For example, few models can be used to examine the impact of proposed federal and state programs which tend to influence demand (e.g., programs designed to reduce health care costs or increase the accessibility of health services) as well as those which attempt to modulate the supplies of health manpower services to meet rising demand. More importantly, very few models contain components which reflect the impact of current programs on health manpower processes. The programs which are treated are those influencing demand (i.e., Hill-Burton, Medicare, and Medicaid). Since more approaches are employed by federal and state agencies to influence manpower supplies than demand,[1] it would seem reasonable to expect models which treat supply to be more applicable to current government analysis problems. That is, decisions concerning the discontinuance or modification of these programs could be assisted by the analysis provided by models which predict the status of the health system as a function of program parameters. In any case, it is clear that for health manpower models to become more useful as analytic tools for health manpower planners, they must incorporate more of the decision alternatives and policy actions contemplated by these program developers.

[1]See the lists of policy actions in section 3.2.1.

4.0 THE HRRC AND RTI HEALTH MANPOWER MODELS

This chapter describes and evaluates the health manpower models developed by the Human Resources Research Center (HRRC) and the Research Triangle Institute (RTI). The chapter is organized into five sections. The first and third sections describe the development history and the structure of the HRRC and RTI models, respectively, in terms of major subcomponents, interactions, and feedback, and the general form of the model equations. Each of these descriptions is, in turn, followed by VRI's evaluation of the models in sections 4.2 and 4.4. The last section discusses the applicability of the models to various analysis problems.

The evaluation presented in this chapter parallels the model usefulness criteria presented in the previous chapter with the exception that the evaluation presented here is in much greater depth, and the order in which these utility criteria are discussed is reorganized. That is, the model's validity is discussed first followed by an evaluation of the model's operational characteristics and then the applicability of the model. The assessment of model validity concentrates on the conceptual structure of the model, analytic specification, and empirical estimation and verification techniques used in model development. The conceptual structure of the model is examined in terms of its realism (i.e., the degree to which the model includes or describes health manpower processes as they appear to occur in the real world) and its physical reasonableness (i.e., the reasonableness and consistency of model assumptions and constraints). The presence or absence of model factors, variables and relationships which reflect how well the model describes health manpower processes are also delineated. Parameters and sectors of the model which are treated as exogenous rather than endogenous are discussed in terms of the relative utility of the model in describing health manpower processes.

The assessment of model validity also includes an evaluation of the analytic relationships and empirical estimation techniques employed in model development and the methods used to verify model results. In this evaluation, the theoretical structure and internal logic of the model is examined for consistency and accuracy. Hypotheses and constraints underlying the model specifications are examined for their consistency and reasonableness. An evaluation of the empirical estimation techniques such as the degree of confidence in the estimated relationships or the use of inappropriate or inaccurate data is also discussed.

Finally, the validity evaluation is concluded with the degree to which the model's predictions have been favorably tested against outputs of the actual process. This examination includes identification of the types of verification tests employed by the model developers (e.g., tests of model performance against *a priori* assumptions or comparisions of model output with actual data) and an analysis of the internal consistency and experimental validity of these tests.

Using the documentation and other information obtained from the model developers, the resources required to operate the model (i.e., operational feasibility) are then delineated. In this discussion, the computer hardware and software requirements, data processing time required, requisite input data and technical skills needed to use or exercise the simulation are described. The remainder of the evaluation concentrates on the application of these model to analysis problems.

4.1 Preliminary Operational HRRC Microsimulation Model

This section describes the general structure and specific components of the HRRC preliminary operational model. Since this model was developed within the framework of a more comprehensive study to develop a conceptual microanalytic health manpower model, this description will first concentrate on the evolution of the conceptualized model structure to the operational model. This brief history of model development is presented here to provide the reader with sufficient background and perspective to understand the role of the operational model within the overall conceptualization scheme. Individuals interested in further details concerning the conceptualizational versions of this model are referred to *Proceedings and Report of Conference on a Health Manpower Simulation Model*, Volume I, December 1970. Following this development history, the major subcomponents of the operational model are briefly discussed with specific emphasis on the interactions among these components. The final subsection describes the attributes of each of the model components, including the general form of the model equations. Since this discussion is not intended to be a comprehensive report of the model's development and structure, persons wishing more information are referred to Yett, et al, *The Preliminary Operational HRRC Microsimulation Model*, Human Resources Research Center, University of Southern California, Los Angeles.

4.1.1 Development Background

The basic goal of the HRRC project from which the current operational model evolved was to obtain a more useful methodology than was currently available for projecting the demand for and supply of health manpower and for health manpower policy analysis. To accomplish this aim, the HRRC group proposed a conceptual structure of a large-scale model to investigate the behavior of individuals and responses of institutions to events affecting the health care system, with specific emphasis on analyzing and forecasting the demand for and supply of health manpower. This conceptualization, referred to as Mark I, served as the basis for a second conceptual structure called the Mark II and for Mark IIA, the preliminary operational model.

Mark I consists of three modules corresponding to the three major markets -- health services, health manpower, and health professions education. Within these modules are five populations, three of individuals (potential consumers of health services, health manpower, and potential students) and two of institutions (health service institutions and health education institutions). Due to practical and theoretical constraints, Mark I was not developed but was used as a foundation for the development of a second, less complex model structure -- the Mark II. The Mark II was intended to be the best conceptual representation of a model which could be made operational within 2-3 years using available simulation techniques and existing data. A simplified version of the Mark II, the Mark IIA was developed to provide a preliminary operational version of the Mark II. Three major simplifications made in Mark IIA are: (1) diagnosis (health condition) is excluded from the determination of health service utilization rates, (2) the expected values of random variables are used in place of using the full frequency distributions with random drawings from these distributions (Monte Carlo techniques), and (3) the entire health education sector of the Mark IIA is treated exogenously (determined outside the model).

4.1.2 General Structure of Mark IIA

The Mark IIA model is a deterministic model which employs regression analysis in the estimation of equation coefficients and elasticities. It consists of five separate, interacting submodels, two of which generate populations and three of which determine demand for and supply of health services. The two population submodels -- one for consumers and one for physicians -- generate populations of individuals who demand health services and supply physician services, respectively. Demand for and supply of various health care and manpower services is determined in the physician services, hospital services, and nonphysician manpower models.

Interactions Among Submodels

Each of the five submodels generates input for and/or receives output from the other submodels. The two population submodels differ from the other submodels in that they produce input to other submodels but receive no feedback information. Figure 4 shows the linkages and feedback loops among the submodels. The two population submodels generate the numbers and attributes of consumers (by age, sex and income) and physicians (by age, type of practice, specialty and domestic-foreign trained). The outputs of these models are fed into the hospital services and physician services submodels, where the demand for and supply of physician services is determined. The hospital and physician services submodels are linked through the supply of outpatient visits and in-hospital physician visits. That is, the physician services submodel estimates the number of outpatient visits by hospital-based physicians.

which is used by the hospital services submodel as the demand for these services. Similarly, the hospital services submodel estimates the number of inpatient days provided, which it feeds into the physician services submodel where it is used to estimate the supply of physician visits to hospitals.

In the nonphysician manpower model, the demand for aides generated by the physician services and hospital services sectors is combined with the supply of aides (determined exogenously) to determine wages for each occupation. These wages are then fed back to the physician services and hospital services submodels to estimate the demand for aides in the subsequent simulation period.

4.1.3 Description of the Submodels Within the Structure

This section describes each of the five submodels in terms of inputs, outputs, exogenous and endogenous variables and general model equations.

Population of Consumers

The population of consumers submodel generates a population of individuals to 1980 who demand medical services. For each year, the population data are stored in 344 age/sex/race cells, determined by 86 age cohorts and 4 sex/race cohorts. Birth rates, death rates, and net immigration are determined exogenously, subject to the following assumptions: (1) birth rates level off in 1970 and remain stable 1970-1980; (2) the white/non-white ratio of birth rates remains constant through 1980; (3) mortality rates are stable 1968-1980; and 4) the level of net immigration will remain the same 1972-1980.

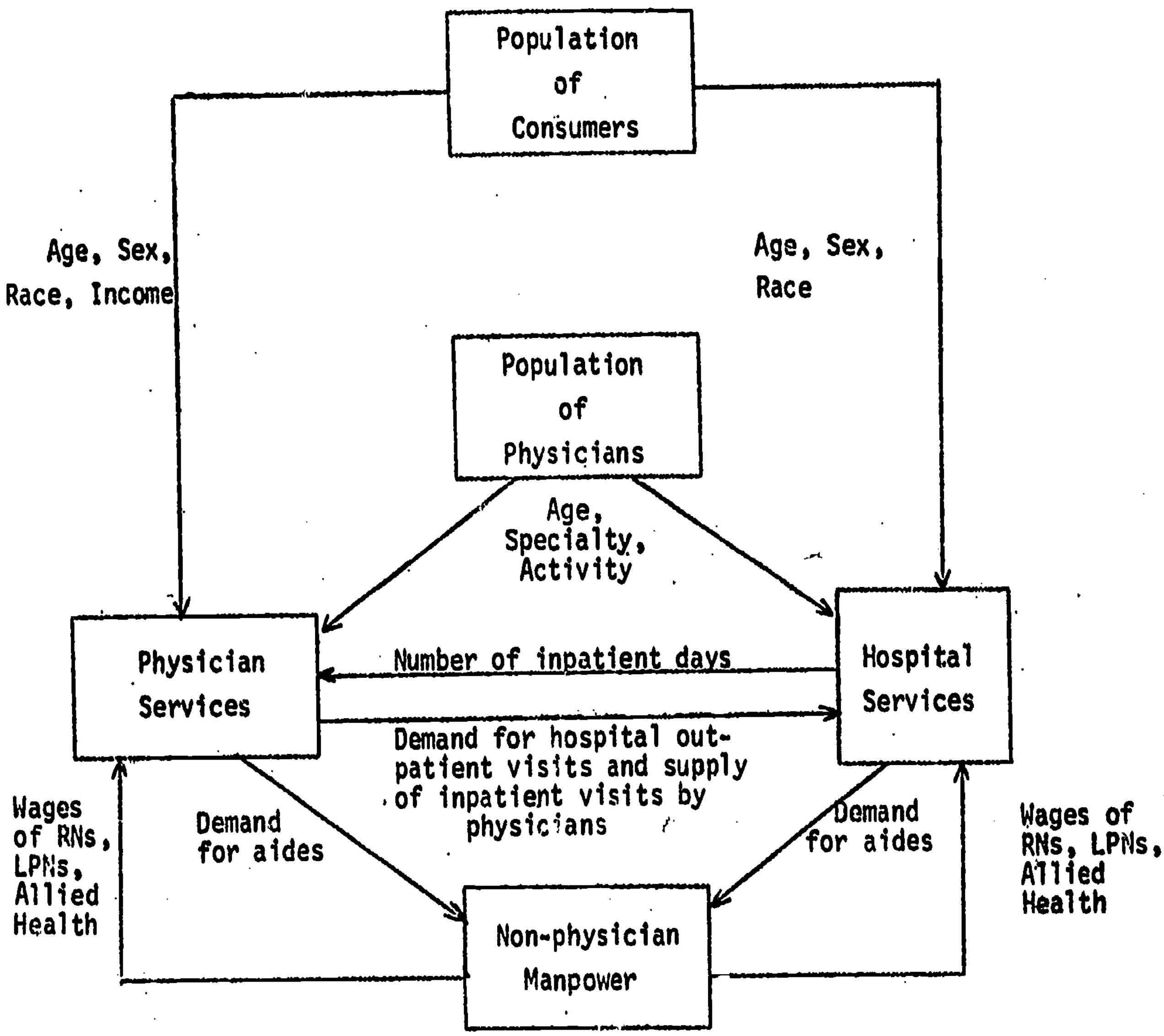

FIGURE 4: SCHEMATIC OF INTERACTIONS OF THE SUBMODELS OF THE MARK IIA

Female and male birth rates are determined as a function of the race and age of mother. The number of births each year is then obtained by multiplying these birth rates by the number of females in each age/race cohort. Deaths are determined by the product of the number of individuals in each age cohort and the specific mortality rate for that cohort. Total immigration for a given year is apportioned among the population cells according to the relative cell size. The population for each year (in each age/sex/race cohort) is determined by subtracting the number of deaths that year from the previous year's population and adding that year's number of births and immigrants. The income distribution for this population as of 1969 is determined using HIS family income data to partition the number of individuals in each age/sex/race cohort into three family income classes. This distribution is adjusted each year using comparable data on family income by race obtained from the Current Population Survey.

Population of Physicians Submodel

The population of physicians submodel generates and forecasts yearly domestic and foregin trained populations of physicians. These populations are characterized by the physician's age, type of practice (activity) and specialty. The joint distribution of 1970 US trained physicians by age, activity, and specialty is summed over activity to get the age/specialty distribution. The intermediate series of three unpublished estimates by DMI was used to project US graduates. Each year survivors are advanced to the next age level, using mortality rates specific to physicians. Physicians in each age/specialty cell are then distributed across activities according to percentages observed in 1967 AMA distributions. Inactive physicians for each age group are distributed across specialties in proportion to the number of active physicians within each specialty/age group.

The net increment to the stock of foreign medical graduates (FMG) is projected and distributed across specialties and activities according to percentages obtained from the distribution of the existing stock of FMGs in 1970. The net flow of FMGs is determined exogenously. The stocks of foreign and US trained physicians are then added by specialty and activity to obtain the total population of physicians.

Physician Services Submodel

The physician services submodel separately estimates the demand for the supply of physician visits. The submodel also estimates physician demand for nonphysician manpower and brings together supply of and demand for visits in the market to determine the price of physician visits.

The demand for outpatient physician services in year t, stratified by age (i), sex (j), race (k), income (ℓ) and site (m) is determined using equation 1 below. Eleven sites (m) are used in the model -- seven specialties (plus one "other" category) in office-based activity, two hospital-based activities, and one "other" activity category. The equation is

$$R_{ijk\ell m}(t) = r_{ijk\ell m} \left[\frac{P_m(t)\ C_i(t)}{P_m\ C_i}\right]^{\beta_m} \qquad [1]$$

where

$R(t)$ = number of visits demanded per person in year t,

r = number of visits demanded per person in base year,

$P(t)$ = price in year t,

$C(t)$ = coinsurance rate in year t,

p = price in base year,

c = coinsurance rate in base year,

β = price elasticity of visits demanded, and

t = year simulated.

The rates of utilization in the base year (r) are the observed mean number of visits per person by age/sex/race/income/site in 1969 (obtained from HIS data). The rates of utilization by site (specialty and practice location) are adjusted to agree with those reported by physicians. That is, to reconcile differences in the utilization of different specialties as reported by patients with that reported by the specialists, themselves, doctor visit rates (r) are adjusted to match the reported supply of these visits in the base year. Base-year price per visit by site (p_m) is obtained from 1967 HIS data. The simulation base year is set to be 1969.

The number of visits demanded per person in year t, R(t), is determined by calculating the price in year t, P(t), and the coinsurance rate, C(t), in year t. The value of R(t) is adjusted over time to account for observed trends (e.g., the decrease in the total number of GP's since 1960). Coinsurance rates by income are predetermined for year t and the price in year t is determined using a yearly price adjustment procedure which compensates for an imbalance between supply and demand as discussed below. Regression equations relating cost of a doctor visit (P·C) to the quantity of visits demanded were estimated to obtain the demand elasticities, β_m, for a given site. The elasticities are held constant throughout the simulation period. The total demand for physician visits, $V^d(t)$, is obtained by multiplying the number of consumers in each category (obtained from the consumer population submodel) times the adjusted value of the number of visits demanded by each category, $R(t)$.

The aggregate supply of physician services, $V^s(t)$, is the number of physicians at each site times the productivity of the average physician at that site summed over all sites. Estimates of the number of physicians in each specialty are obtained from the population of physicians submodel. Physician productivity, represented by the number of visits supplied per year, is determined together with the physicians' demand for three types of aides through a system of four simultaneous linear equations. The first equation in this set relates total office visits supplied to physician hours worked (hours per week), and the hourly product wages (wages divided by price of visit) for each of three types of aides (nurses, technicians, and secretaries). In the remaining three equations, the number of each type of aide employed is a function of hourly product wages and total visits produced. The simultaneous equation sets for four physician specialties were obtained from previous work by Intriligator and Kehrer (demand for aides) and Kimbell and Lorant (physican production functions). The remaining specialty equations were developed by observing the differences across specialties (in AMA data), and weighting the remaining specialty class equations accordingly.

The demand for and supply of physician services computed above are then used to determine physician fees (price) through fee adjustment procedures. It is assumed that the physician services market is typically in a state of disequilibrium (after the base year) and that the prices for services adjust in the direction of equilibrium as shown in equation 2 below:

$$P_m(t+1) = \alpha_m P_m(t) + \gamma[V_m^d(t) - V_m^s(t)] \qquad [2]$$

where $P_m(t+1)$ = price of a visit in the simulation period t+1,

$\alpha_m - 1$ = fractional rate at which prices will grow during periods of equilibrium (estimated from data),

γ = the arbitrary adjustment factor which determines speed of adjustment during periods of disequilibrium,

$V_m^d(t)$ = total quantity of visits demanded for site m (the adjusted demand per person in equation 1, times the number of people in each category), and

$V_m^s(t)$ = total quantity of visits supplied at site m (the supply of visits times the number of physicians in each speciality).

Fee adjustment equations are estimated for seven types of specialists in office practice described in the demand for visits equation (equation 1). Exogenous trends in fees determine supply and demand behavior for physician office visits in other specialties. Due to the aforementioned adjustments in the quantities supplied and demanded, the difference between these quantities ($V^d - V^s$) is zero in the base year.

Hospital Services Submodel

The hospital services submodel forecasts the demand for inpatient hospital services, the derived demand for nonphysician manpower, and the price of hospital services. The demand for short-term hospital care is developed using the same methodology that was used to develop the demand for physician services. The quantity of services demanded is represented by the hospital admissions, ADM(t), times the average length of stay, ALS(t). The equations for admissions and length of stay (equations 3 and 4 below) are stratified by age (i), sex (j), race (k), condition (ℓ), surgical treatment (s), and hospital type (m).

$$ADM_{ijk\ell sm}(t) = adm_{ijk\ell sm} \left[\frac{P_m(t)\, C_i(t)}{P_m\, C_i}\right]^{\beta} \qquad [3]$$

$$ALS_{ijk\ell sm}(t) = als_{ijk\ell sm} \left[\frac{P_m(t)\, C_i(t)}{P_m\, C_i}\right]^{\beta_{ij\ell}} \qquad [4]$$

where

ADM(t) = number of hospital admissions demanded in year t,

ALS(t) = average length of stay in year t,

P(t) = price in year t,

C(t) = coinsurance rate in year t,

adm = number of admissions in base year,

als = length of stay in base year,

β = price elasticities of admissions and length of stay,

P = price in base year,

c = coinsurance rate in base year,

t = year simulated.

As in the demand for physician services, the number of admissions in the base year, ADM (1969), equals the rate for that year, adm, and an analogous condition exists for the length of stay equation. Like the estimates of number of physician visits, the demand equations are adjusted to reconcile differences between patient-reported admissions and length of stay and the values for these variables reported by the hospitals.

The three major differences between equations 3 and 4 which describe the demand for hospital services and equation 1 which describes the demand for physician visits are: (1) consumer income and site are replaced by health condition, surgical treatment, and hospital type; (2) the price elasticity for length of stay is not dependent upon type of hospital (the analogy to site in equation 1) but upon age, sex, and health condition, and (3) the price elasticity for admissions is a constant adopted from work by Martin Feldstein and is independent of any consumer or hospital parameters. The elasticities for length of stay are estimated from regression equations in a manner analogous to the derivation of the elasticities for equation 1.

Unlike the physician services submodel, the hospital services submodel does not estimate the supply of services. The latter submodel assumes that supply of hospital services equals demand for these services and estimates the price of hospital services as a function of the average cost per patient day, occupancy rate, and outpatient visits per inpatient day (see equation 5). That is, price is not a function of imbalance between supply and demand, but a function of increases in hospital utilization represented as a mark up over average costs and increases in hospital labor and non-labor costs per patient. The price of hospital services is determined as follows:

$$P(t) = K + a_1 . OCC + a_2 . AC(t) + a_3 . OPV(t) \quad , \qquad [5]$$

where $P(t)$ = price of inpatient care in year t ,

a_i = empirically determined coefficients ,

K = constant ,

OCC = hospital occupancy rate determined exogenously,

$AC(t)$ = average cost per inpatient day (the sum of labor and non-labor costs), and

$OPV(t)$ = number of outpatient visits per hospital inpatient day and is determined in the physician services submodel.

Labor costs are determined by the wages paid each personnel category times the number employed in each category (RNs, LPNs, allied health, and other). Non-labor costs are computed as a linear combination of occupancy rate, number of hospital personnel in each category per hospital bed, average total wages, hospital assets per bed, number of surgeries per patient day, number of births per admission, and number of outpatient visits per inpatient day.

Values for the variables in the non-labor cost equation are set exogenously or obtained from the other submodels with the exception of the number of hospital personnel employed in each nonphysician manpower category (the number of physicians selecting hospital careers are identified in the physicians' population submodel). The numbers of nurses (LPNs and RNs), allied health professionals, and nonmedical personnel demanded by the hospital are estimated as a function of the numbers of outpatient visits, newborn patients, surgical operations, wages (determined in the nonphysician manpower submodel) and a time trend variable. This demand is fed into the nonphysician submodel as discussed below. Finally, the hospital capacity (total number of beds) for the next simulation period is adjusted from the current level as a function of the current number of patient days consumed.

Nonphysician Manpower Submodel

The nonphysician manpower submodel predicts the supplies of registered nurses (RNs), licensed practical nurses (LPNs), and allied health manpower which are combined with the demands for these personnel (obtained from the hospital and physician services submodels) to estimate future wages. Given the distribution of nurses by age, the stock of nurses in future years is generated by adding in forecasts of the annual number of new graduates and net nurse immigration, and then subtracting attrition due to deaths. Six equations, one for each of six aggregate age groups, provide participation rates as a function of nurse wages and other variables. Multiplying the stock of nurses by the corresponding participation rate yields the supply of nurses.

The supply of LPNs and allied health manpower and other personnel is estimated by subtracting the number employed by institutions not included in the model (e.g., public health hospitals) from estimated total employment figures for historical periods and from projections of expected supply for future periods. The supplies of RNs, LPNs, and allied health professionals are then used in the wage adjustment equations to determine future wages as shown in equation 6 below:

$$WAGE_i(t + 1) = \alpha_i . WAGE_i(t) + b \; . \; [N_i^d(t) - N_i^s(t)] \qquad [6]$$

where $WAGE_i(t+1)$ = wage paid to i^{th} type of manpower in year (t+1),

$N_i^d(t)$ = aggregate quantity of type i personnel demanded by physicians' offices and hospitals in year t,

$N_i^s(t)$ = aggregate quantity of type i personnel supplied in year t,

$a_i - 1$ = fractional rate at which wages will grow if equilibrium is reached, and

b = adjustment factor which governs the speed of wage adjustment during periods of disequilibrium.

The wages of non-medical personnel (i.e., secretaries, clerks, etc.) are treated as exogenous to the system.

4.2 *Evaluation of the HRRC Preliminary Operational Model*

The preliminary HRRC model represents the initial attempt to formalize a large scale model conceptualization (the HRRC Mark II) into an operational analytic structure in a one-year development time period. This preliminary operational model (the HRRC Mark IIA) is intended to deal primarily with the first of two key policy objectives ultimately to be addressed by the HRRC microsimulation model. These two objectives are: (1) the prediction of future manpower demands under alternative assumptions regarding federal government policy, and (2) the response of the demand for and supply of health professions education to alternative policy measures.[1] Thus, the Mark IIA does not treat the factors which influence the health professions education processes other than to extrapolate the future numbers of health manpower graduates. Since these latter factors are clearly intended to be addressed in subsequent modeling activities, the evaluation presented here will not concentrate on the model deficiencies or attributes in this area. Rather, this section will focus on the capabilities and shortcomings of the model in its ability to predict future manpower demands, i.e., the first of the above policy objectives.

It should be further recognized that an evaluation of a model termed as preliminary by the developers must itself be somewhat preliminary. That is, it is clear from VRI's review of model documentation and our discussions with the HRRC staff that the purpose of constructing an operational version of their conceptual model structure was to demonstrate the feasibility of building such a model and identify problem areas requiring further research efforts. Although the following model evaluation identifies omissions in the model specification and deficiencies in parameter estimation, the reader should be aware that such inadequacies are primarily the result of the data availability and resource constraint trade-offs which accompany any model development. These trade-off decisions are most prevalent and particularly evident in the initial phases of the construction of a large-scale model, such as the HRRC microsimulation model. The HRRC model development team appears to be cognizant of most of these problems and view the Mark IIA as an incomplete version of the conceptual

[1] Final report, Contract #NIH71-4065, *The Preliminary Operational HRRC Microsimulation Model*, 1973, page 1.

Mark II structure. They propose to use the Mark IIA to provide a basic framework which could be elaborated in subsequent research efforts to resemble the Mark II. As such, this evaluation could be used as a guideline for these efforts.

The HRRC preliminary operational model represents an attempt to specify the microeconomic processes governing health manpower demands in terms of parameters whose values could be estimated from available data. In order to accomplish such an ambitious undertaking most of the development efforts were concentrated on characterizing the demands for physicians and nurses in two health service markets -- the physician services market and hospital services market. Constrained by the limited availability of requisite data and the objective of constructing an operational model within a one-year time frame, the degree of detail and complexity of model specifications was sacrificed to produce a more manageable operational formulation. As a consequence, many of the parameters useful in policy analysis are not treated as model outputs but used as predetermined inputs to the model, and a number of factors which influence the behavior of modeled processes are omitted. Even with these limitations the HRRC preliminary operational model provides a more detailed structuring of the microeconomic behavior of health manpower processes than that found in the other models examined in this study.

The remainder of this section is organized into three subsections. The first of these subsections examines the conceptual and empirical structure of each of the HRRC submodels described in section 4.1. This evaluation will concentrate on the completeness of specification relationships and the characteristics of the estimated parameters within these relationships. The results of HRRC model verification studies and the operational prerequisites (time, resources, technical skills) for model execution are the topics of the second and third subsections, respectively. The applicability of the preliminary operational model to various analysis topics is discussed in conjunction with the applicability of the RTI model to similar topics in section 4.5.

4.2.1 Model Conceptual and Empirical Structure

This part of the model evaluation is presented on a submodel-by-submodel basis. Each of the submodels discussed is described in more detail in section 4.1.

Consumer Population Submodel

The consumer population submodel is a relatively simplistic model which is used to predict the number of individuals in each of 1032 age, sex, race, and income cohorts. Although the model generates the type of data similar to that available from the Bureau of Census tables, it has two distinct advantages over such tabulations. First, as is noted by the developers, the submodel provides a method to generate a birth rate which is specific to the mother's age and race, as well as the sex of the child. Second and more important, the existence of this model permits an examination of the effects of population parameters (e.g., birth and death rates) on the utilization of health manpower services. The principal shortcomings of this submodel reside in the model's inability to provide a more robust and hence potentially more useful characterization of the population. In particular, family size, health condition, location of residence, and education level are four attributes of the population which can significantly influence the utilization of health services.[1] By omitting family size the model ignores effects of this factor on health service utilization, particularly hospital length of stay. The absence of health condition from this population characterization limits its usefulness in predicting the demand for services, particularly in the hospital services submodel[2] which characterizes length of stay and admissions by the health condition of the patient.

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[1] In our discussion with the HRRC staff, the educational characterization of the population was omitted from the consumer population model primarily because of the difficulties in describing education attainment through time as well as the inappropriateness of educational characterization without familial relationship. For example, the educational influence on a child's utilization of health services is dependent upon the educational level of his parents and not on his own. Location of residence was also omitted because of similar difficulties in characterizing population migration through time using micro data.

[2] Although patient condition data is utilized in the hospital service submodel, it is our understanding that the consumer population submodel does not generate this information. The introduction of condition is to be accomplished in subsequent development phases.

The urban versus rural specification (i.e., location of residence) of a population can also significantly alter the estimated rate at which physician and hospital services are utilized. Finally, the educational attainment of individuals will influence their consumption of health services both in terms of the amount and type utilized.

The only parameters which are estimated in this model are male and female birth rates by age and race of mother, and mortality rates for each age/race cohort. The mortality and birth rates are derived from census data and are assumed to remain stable from 1970 to 1980. These assumptions, as well as the assumption that the current net immigration will remain constant (with immigrants distributed among cohorts in proportion to relative cohort strength), appear to be reasonable. However, since the mortality and birth rates in the model are insensitive to factors such as income, geographic location, health condition, etc., the ability of the model to estimate the number of individuals in a specific cohort with a high degree of accuracy is suspect.

The Physician Population Submodel

The physician population submodel is analogous to the consumer population submodel in that the number of domestic and foreign-trained physicians in each age/specialty/activity cohort are estimated as a function of mortality rates, medical school graduates, and immigration of foreign medical graduates. Like the consumer population model, this model provides a relatively mechanistic methodology for updating the number of individuals in the physician population. The assignment of new graduates (foreign or domestic) to specific specialty/activity classes is devoid of any behavioral component. That is, the determinants of the selection process used by physicians to choose a specialty are not included in the model.

The developers recognize this inherent limitation in the model and plan to introduce specialty choice in this model if appropriate data become available. However, even in the absence of such behavioral information, the physician population submodel could probably be improved if it were to reflect current trends in the relative distribution of physicians across the specialties, thereby providing more realistic projections of this distribution in future years.

As acknowledged by the developers, errors in the exogenous estimate of FMGs could create errors in the stock of physicians by as much as 20%. Such errors would especially affect the model's estimates of the supply of hospital services since a large portion of hospital residencies and internships is filled by FMGs. Model development in this area is severely hampered by unavailability of data and variations in the flow of FMGs (which is highly dependent on policies of professional organizations and governmental actions). In view of these difficulties, the model predictions are probably as accurate as can be expected.

The Physician Services Submodel

The physician services submodel estimates the demand for and supply of physician visits, computes the price of these visits, and determines physician demand for nonphysician manpower. In the following paragraphs we will examine these components and their contribution to the model.

The demand for physician visits (equation 1 in section 4.1.3) is a function of the number of individuals in each cohort, the annual rate at which these individuals in each cohort see physicians, and the relative change in the cost of each visit. In order to describe the degree to which changing prices affect the number of visits demanded, the model incorporates the price elasticity for specific specialty/activity combinations (see equation 1 in the previous section). Desirable additions to the specification of this equation might well include the incorporation of cross elasticities of demand for physician office visits and substitutes for these visits (e.g., hospital outpatient clinics), coinsurance rates which differ for population attributes (e.g., income and race), and price elasticities which are a function of age and income in addition to the current specialty differentiation.

By omitting cross elasticities in the demand equations the model essentially assumes that there are no substitutes for physician office and hospital visits or that any substitution effects are insignificant. Since it is reasonable to expect that hospital outpatient visits (i.e., emergency room and clinic visits) provide substitutes for physician office visits and even that the cross elasticities between outpatient and inpatient care are relatively high,[1] exclusion of these factors from the model demand equation is likely to degrade its predictive capability. This capability is also likely to be reduced because the influence of health insurance on utilization is reflected in the physician and hospital services submodels only by an age specific coinsurance rate. Since certain income/race cohorts are more likely to be insured than others,[2] the model does not portray the propensity of the higher-insured classes to utilize more health services. By not describing the effects of the changing insurance structure across income/race cohorts, the usefulness of the model in analyzing alternate provisions of proposed health insurance programs is clearly reduced.

Another factor which is not incorporated into the model which might alter the price sensitivity (elasticity) of demand for certain cohorts is the estimation of a different price elasticity for each income group. Clearly, the greater an individual's income the less sensitive he is to minor variations in the cost of services. Higher price elasticities for lower income groups would result in a greater variation in number of visits demanded by lower income cohorts with changing prices. In the current model specification, elasticity estimates are only a function

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[1]Davis, Karen and Russell, Louise, "The Substitution of Hospital Outpatient Care for Inpatient Care," *The Review of Economics and Statistics*, Vol. LIV, No. 2, May 1972, pp. 109-120.

[2]See *Building a National Health Care System*, Committee for Economic Development, April 1973.

of physician specialty/activity combinations, which in essence averages out the effects of income on elasticity.[1]

The two parameters in equation 1 which are estimated from available data are the average rates of utilization of physician services and the price elasticity of this demand for services. Estimates of average utilization rates from 1969 HIS data and the average prices for visits from 1967 HIS data are used to provide model base-year (1969) utilization rates and prices, respectively. This integration of data from alternate years to describe system behavior in a single year -- although a necessity resulting from data limitation -- is clearly an undesirable compromise. Regression estimates of the effects of income, sex, age, and visit cost on number of visits demanded are used to provide the price elasticity of the demand for visits (β_m in equation 1). Most of the estimated price elasticities are near zero (only two of the nine estimates deviate from zero by more than .10), resulting in only minimal impact on demand by price. Thus, for all practical purposes, as the model is currently estimated, the number of physician visits demanded could be considered to be a function of the size of the population in each cohort and the cohort-specific utilization rates.

The developers note that errors in measurement of the cost of a physician visit tend to bias the elasticity estimates toward zero (i.e., the model estimates of price elasticity tend to be more inelastic than in actuality). This acknowledgement, accompanied by the comment in the HRRC final report that "the price data are probably the weakest variables

[1]It should be noted, however, that the data support this model assumption (see M. Feldstein's article "The Medical Economy," *Scientific American*, pp. 151-159, Vol 229, No. 3, September 1973).

of those used to estimate the physician demand sector," contributes to a lack of confidence in the model estimates of the price elasticity of demand for doctors' office visits. The tenuous nature of these estimates is further illustrated by the confidence measures associated with the regression equations used to compute the elasticity. For example, less than fifteen percent of the variance in the demand for visits is accounted for by the four independent variables in any of the regression equations. In addition, the estimated coefficients for the income variable are negative in seven of the nine regression equations, contrary to the expected sign.[1]

The supply of physician visits is determined by the product of the numbers of physicians in each office-based specialty times the average productivity of the physicians in each specialty. The numbers of physicians are obtained from the physician population submodel. The physician productivity is determined by integrating the results of previous studies on physician production functions and demand for aides. The use of the physician population submodel to generate the total numbers of physicians in each specialty is relatively straightforward and will not be treated here. Rather, we will concentrate on the methodology used to integrate the results of other studies into the model and its impact on model validity.

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[1]As discussed in the final HRRC report, one would expect income to be positively associated with doctor visits, i.e., increased visits resulting from increased income. Again, however, the data presented by M. Feldstein contradicts this expectation (see footnote on previous page).

As the developers acknowledge, since neither of the studies adopted for use in the Mark IIA model was intended to provide input to this model, the synthesis of these results into the Mark IIA is awkward in several aspects. They also note that the current version of the supply of physician visits should be treated as strictly preliminary. These two disclaimers set the stage for the construction of the supply side of the physician services submodel, which is an attempt to gain improved insight into physician productivity through the use of recently released proprietary AMA data. The advantage gained by using the AMA data is, however, somewhat lost in the requisite manipulation and restructuring of the results of these previous studies to make them compatible with the Mark IIA specification.

The two studies utilized are a study by Kimbell and Lorant,[1] which developed physician production function estimates for each of four physician specialties, and the study by Intriligator and Kehrer,[2] which developed a set of equations to describe the demand for three types of aides (nurses, technicians, and secretaries) in physicians' offices. The Kimbell-Lorant specification of physician production functions relates the number of visits produced by four types of specialties to the product of the number of hours worked, number of aides employed, and the total

[1] Kimbell, L. J., and Lorant, J. H., "Production Functions for Physician Services," presented at the Econometric Society Meetings, Toronto, Canada, 29 December 1972.

[2] Intriligator, M. D., and Kehrer, B.H., "A Simultaneous Equations Model of Ancillary Personnel Employed in Physicians' Offices," presented at the Econometric Society Meetings, Toronto, Canada, 29 December 1972.

number of rooms (a proxy for capital). Of these variables, the number of physician hours worked is the principal determinant of physician production. As such, this factor should probably be determined within the model (endogenously) as a function of physician income and age, rather than set exogenously as currently done in the Mark IIA. As physicians charge higher prices and as physicians age, they appear to choose more leisure time (i.e., decrease the number of hours worked).[1] Thus, in order to accurately describe the future supply of physician services, the number of physician hours worked should be determined as a function of the price of services and age.

In our conversations with the HRRC staff, they noted that they had examined the effect of fees on hours and found it to be relatively minor. However, since the effects of prices on the demand for visits (which are also very minor) are included in the Mark IIA estimates for demand and since prices are also incorporated in the aide product wage terms (discussed below) in the estimate of visits produced, the Mark IIA would provide a more complete and consistent representation of physician productivity if physician hours were determined endogenously as a function of prices. In addition, since the physician population submodel describes the number of physicians in each age bracket, it appears that inclusion of age in the productivity estimates would be a feasible as well as a profitable extension of this submodel.

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[1]See Feldstein, Martin S., "The Rising Price of Physicians' Services," *The Review of Economics and Statistics*, Vol. LII, No. 2, May 1970

The second portion of the physician productivity estimates, i.e., the employment of three types of aides as a function of aide wages, utilizes results from the Intriligator-Kehrer study. This study relates number of nurses, technicians, and secretaries employed by physicians in each specialty to the hourly product wages[1] for each aide class, the capital stock available for each type of aide, the delegation of tasks, and the total patient visits produced. This work is combined with the Kimbell-Lorant study to enable the Mark IIA to predict changes in physician productivity with changes in physician hours worked and aide wages. To integrate these studies into the Mark IIA model the results of these studies were restructured as follows. First, all input variables except for physician hours worked and aide product wages were fixed at their mean value. Second, the Kimball-Lorant production functions were respecified to provide the level of aide disaggregation (nurses, technicians, and secretaries) employed in the Intriligator-Kehrer and Mark IIA structures. Finally, the Kimbell-Lorant nonlinear production functions were linearized[2] to create linear parameters interchangeable with those in the Intrilagator-Kehrer model.

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[1] Money wages divided by the price of an initial office visit.

[2] Using a Taylor series expansion about the mean values of each of the dependent variables.

By setting the capital and task delegation components at their constant mean values the Mark IIA essentially ignores the effects of these variables on physician productivity and the demand for aides. The assumption that variations in office capital have insignificant impact on the number of patients seen by a physician can be accepted with minimal ramifications; however, to fix task delegation (which is a major output of the four relationships used in the Intriligator-Kehrer study) may have more significant impact. That is, it is somewhat questionable whether the Mark IIA model produces an accurate prediction of the number of aides demanded by ignoring the effects of this latter variable.

The disaggregation of total aides employed (in the Kimbell-Lorant model) into numbers of nurses, technicians, and secretaries is in effect an arbitrary partitioning of the total contribution of aides to physician productivity across three types of aides. As a consequence, the model's estimates of the contribution of any individual type of aide (i.e., nurses or technicians or secretaries) to the physician production function lack any empirical foundation. The Kimbell-Lorant estimates of the elasticity between total physician visits supplies and the total number of aides employed are valid for some unknown distribution of nurses, secretaries, and technicians. The decomposition of these elasticities into elasticities for three types of aides (using "extraneous" estimates of wages and employment) will not necessarily reflect the specific (but unknown) mix of aides that generated the elasticities used by Kimbell and Lorant.

As noted by the developers of the Mark IIA, the linearization of the Kimbell-Lorant production function provides a valid approximation to the marginal productivity influences near the mean aide employment levels; however, substantial increases in aide/physician ratios cannot be examined by the Mark IIA since the linear approximation would overstate the contribution of aides to productivity. This limitation would particularly reduce the usefulness of the model to estimate the impact of policies directed toward increased utilization of allied health personnel in such environments as health maintenance organizations.

Since the integration of the above studies provides an estimate of physician productivity for four specialties (general practice, pediatrics, internal medicine, and obstetrics/gynecology) and the Mark IIA requires estimates for eight specialty classes, the remaining specialty productivity equations are based on the pediatric productivity. Pediatric elasticities were selected since they appeared to be more plausible. Although this translation was necessary to obtain the requisite productivity relationships it is unlikely that the productivity of the other specialties (particularly the surgical specialties), in terms of the number of aides employed and hours worked, resembles pediatrician productivity.

One of the more noticable problems with the introduction of the Intriligator-Kehrer results into the Mark IIA is that the independent variables selected explain less than 30% of the variation in the dependent variables (i.e., numbers of aides employed) and further, the estimated coefficient for nurse wages has the wrong sign in one equation. That is, the number of nurses employed by obstetricians will increase as their product wage increases -- a clear contradiction of the expected relationship in price theory. An examination of the Kimbell-Lorant regression equations reveals

[1]Although certain model components describe fourteen specialties, it is VRI's understanding that only eight are employed in model projections.

that the variables selected for these equations appear to be good predictors of physician productivity. That is, the input variables selected predict greater than 70% of the variance in physician visits supplied (with the capital measure included).

The imbalance between the total annual demand for physician visits (the annual number of visits by specialty utilized per person in each cohort times the number of people in each cohort) and the total annual supply of physician visits (the annual number of visits supplied by each specialist times the number of physicians in each specialty) is used by the Mark IIA to establish next year's price per visit. Due to discrepancies between the number of visits reported by physicians (supply) and the number reported by patients (demand), the resultant differences in total quantity supplied and total quantity demanded are implausible in the base year. Therefore the annual number of visits utilized per patient is re-estimated to be that reported by physicians. In effect this re-estimation then ignores the patient data entirely except for the determination of price elasticity. Although it is reasonable to expect the physicians to know and report accurately their specialty and number of visits provided, the assumption that they are totally correct and the patients are erroneous could create unjustified bias in model results. That is, the relative accuracy of these two estimates would depend not only on the polling procedure utilized but also on sample size, response rate, and other sampling parameters which determine the relative confidence in and inferences made from survey data. In the development of this preliminary version of the model the selection of physician data over patient reports was clearly a judicious expediter; however, in any subsequent efforts a more appropriate technique to reconcile these differences should be sought.

The calculation of the physician fee (price) adjustment is based on an arbitrary determination of the relative effects of this imbalance on price and on an estimated inflationary factor (which is divorced from any imbalance in supply and demand and from future changes in the rest of the economy). As the fee adjustment equation is currently specified, the future price of physician visits would inflate at the same rate as observed during the 1960-1970 period plus or minus an arbitrary supply/ demand imbalance factor. Thus, the model assumes that the rate of inflation of physician fees relative to the inflation of the rest of the economy will continue as in the 1960-1970 period. A more appropriate technique might be to discount future fees back to the 1969 (model base year) value since consumer income and utilization behavior is fixed at the 1969 levels.

Hospital Services Submodel

The hospital services submodel estimates the demand for hospital services, the supply of hospital services, and the demand for hospital manpower derived from the services supplied. An evaluation of the model's mechanisms for estimating each of these quantities is provided in the following paragraphs.

The relationships determining the demand for hospital services parallel the demand for physician services except that two equations -- those for hospital admissions and average length of stay -- instead of one are used to compute this demand in terms of annual hospital bed days (annual admissions times average length of stay). Although both of these equations are derived in a manner similar to that used to specify and estimate the demand for physician visits, the characterization of patients utilizing these services differs. Specifically, the demand for hospital services is allowed to vary with patient age, sex, race, health condition, and surgical treatment. This demand is assumed to be constant across different income groups -- clearly a contradiction to the expected interaction between the consumers' ability to pay and the cost of services (particularly in the case of elective services). The developers of the Mark IIA acknowledge this discrepancy when they describe the HIS income data as a poor proxy for permanent income. Permanent income (i.e., long-term income in which income losses due to hospital episodes have been averaged out over a period of years) is the desired income measure in the specification of both the admissions and length of stay equations. In addition to influencing an individual's propensity to consume hospital services (i.e., the rate of utilization), variations in income will also affect the price elasticity of this demand. The price elasticity would be different for two individuals in divergent income classes. The effects of variations in income with health insurance coverage (i.e., coinsurance rate) would also be a useful extension to the hospital services submodel for the same reasons noted above in the physician services submodel. Thus, future research should concentrate on introducing an income differentiation in consumption rate, coinsurance rate, and price elasticity factors which describe the demand for hospital beds.

Two other variables which would improve the characterization of demand for hospital services include urban-rural and marital status or family size.

Persons in urban communities are likely to differ from their rural counterparts in average admission rates as well as in lengths of stay. Employment characteristics in rural areas may require an individual to return to work sooner than his urban counterpart and shorten his length of stay in a hospital. Similarly, persons with access to dependent or home care would be more likely to seek home recovery than single or unattached individuals. By including these factors the Mark IIA would provide a more robust description of the demand for hospital services and be sensitive to variations in these parameters over time.

Another desirable addition to the specifications of the demand equations in the hospital services submodel is the incorporation of the relative impacts of alternative health care modalities or substitutes on this demand. A significant determinant of the demand for hospital care is the degree to which long-term care such as nursing home or psychiatric care can be substituted for hospital care, as well as the amount of substitution of inpatient and outpatient care, discussed previously. The substitutability of various forms of inpatient and outpatient care becomes particularly significant in the analysis of the impact of health programs for the aged (e.g., Medicare) on the relative demands for different types of care. The Mark IIA estimates the supply of long-term care (and hence the derived demand for personnel in these facilities); however, the model does not reflect the changing demands for this type of care resulting from substitution effects and changes in the demographic composition of the consumer population. The developers recognize these model limitations and express a desire to incorporate behavioral content into the specification of the demand for different forms of long-term care.

Like the demand for physician services, the key parameters estimated in the demand for hospital services are the price elasticities of the demand. Since the specification of the demand for hospital care is composed of two equations (those for admissions and length of stay), estimates of the price elasticities of admissions and length of stay are required. A single value for the price elasticity of hospital admissions was adopted from work by Martin Feldstein due to difficulties in obtaining an estimate of this quantity for the Mark IIA.[1] Since this estimate was obtained totally apart from the development of the HRRC model and is independent from any patient attribute, it may severely hamper the ability of the model to predict accurately the changes in the future number of admissions with changes in hospital costs.

The estimates of length-of-stay price elasticities vary with age, sex, and health condition (diagnosis). Due to limitations in the size of the data base, the number of age groups specified in the length of stay equations had to be .educed from nine to five. In this reduction certain age groupings were created which are incompatible with the groupings used to describe the demand for physician services -- clearly creating problems when the demand sectors of the physician services and hospital services are integrated. With this reduced patient characterization scheme, 51 estimates of the price elasticity of length of stay were produced. The estimation procedure utilized (namely, multiple regression analysis) was analogous to that employed in the physician services demand sector and resulted in elasticity estimates with similar

[1]See page 221 of the HRRC Final Report

confidence measures. The independent variables selected explain less than 20% of the variance in length of stay in 47 of the 51 estimation equations, between 20% and 30% in three equations, and 85% in one equation. In 40 of the 51 equations, the estimated income coefficients are negative; i.e., increasing income is reflected as a decrease in the length of stay -- contrary to *a priori* expectations.

The supply of patient days is determined in the model by the demand for any given year which is, in turn, modulated by increasing hospital costs. The specification of hospital costs in terms of increases in labor and non-labor costs and changes in the number of outpatient visits masks relationships and/or omits factors which should be included in subsequent analyses. First, as noted by the developers, "The determinants of hospital charges should include additional variables to adjust the parameters for the market structure which the hospital faces (e.g., the facility's beds as a percent of total hospital beds in the country)."[1] Second, the price markup equation does not account for the effects of different patient compositions on hospital costs. For example, if one hospital has more Medicare patients than another, the hospital with more private, paid patients would generally have greater cost markups. Third, the amount a hospital can markup on a private patient is in part a function of the price elasticity of the demand for inpatient care. Although these expansions are beyond the scope of the initial model development, additional research into these areas could improve model specification.

[1] The HRRC Final Report, page 251.

Other model specifications concerned with the supply of hospital services include equations for predicting the requirements for four types of hospital personnel (RNs, LPNs, allied health, and nonmedical manpower), the labor and non-labor hospital costs, and the hospital bed capacity for four general types of hospitals. Improvements to these specifications might include the incorporation of hospital size in the non-labor cost equation and refinement of the hospital capacity equation to include policy variables (e.g., Hill-Burton)[1] and to preclude the oscillations in total number of hospital beds. Since non-labor costs will probably differ between large and small hospitals as a result of various economies of scale, hospital size should be included in the non-labor cost equation. As currently specified, the number of hospital beds in any year is a function of the number of patient days in the previous year. If the number of patient days decreases, then the number of available beds decreases in the following year -- an unlikely occurrence in reality.

Most of the regression equations estimated in the supply sector of the hospital services submodel appear to provide reasonably reliable predictions of the desired outputs. In over half of the equations the input variables account for greater than 70% of the variation in the outputs, with only a few equations having R^2 values of less than 0.5 (50% of the variation).

As in the case of the physician services submodel the number of patient days demanded according to consumer surveys differs from that

[1]As noted by HRRC on page 254 of the Final Report.

reported by hospitals. To reconcile these differences the provider figures are again assumed to be the most accurate and used to establish length of stay and admission rates to determine the bed days demanded and supplied. More appropriate adjustment techniques should be sought here as in the physician services submodel.

Nonphysician Manpower Submodel

The nonphysician manpower submodel predicts the supply of registered nurses and the wages for RNs, LPNs, allied health, and nonmedical personnel in each simulated year. The demands for nonphysician manpower are input from the hospital services and physician services submodels and combined with principally exogenous estimates of nonphysician manpower supply to determine future wages. Since the nonphysician manpower submodel feeds wages back into the physician and hospital services submodels to determine physician productivity and the demand for hospital manpower, respectively, a large portion of any future research efforts should concentrate on the enrichment of this submodel. The determination of the supplies of nonphysician manpower should be refined and should consider behavioral components. For example, the labor force participation of nurses should be a function of nurse marital status, family size, income (or husband's income), etc., in addition to wage. Furthermore, similar attributes should be employed in the determination of labor force participation of other nonphysician manpower. The supply of LPNs, allied health, and other medical personnel in various cohorts should be developed by the model over time rather than the current utilization of historical tables or time trend estimates. With a more robust representation of these supplies of nonphysician manpower, greater numbers of policy variables could be explored and a more sensitive determination of the imbalance between manpower supplies and demand provided.

Submodel Feedback and Interaction

One of the major criticisms of the Mark IIA is the differentiation in the level of detail and degree of sophistication offered by one model sector versus another. For example, the population submodel produces a more detailed age distribution than is used by the rest of the model, yet does not include health condition as one of the population attributes -- a requisite input to the hospital services submodel. Similarly, the physician population submodel generates the population of physicians in 14 specialties and four activities, whereas the demand for physician visits is determined for eight specialties and two activities and the supply of these visits is essentially only estimated for four specialty categories.[1]

Furthermore, the specification of equations and estimation of the parameters within these equations are, in part, the direct result of Mark IIA development activities and, in part, the adaptation of efforts external to this development. For example, portions of the physician services and nonphysician manpower submodels adopt and in several cases modify the results of previous studies to provide descriptions of the supply of physician visits and nursing services, respectively.

[1]The model develops the supply of visits for all 14 specialties by extrapolating the physician productivity estimates.

Although the incorporation of these results into the model does not necessarily invalidate model results, it does weaken the model's ability to treat equally the various stratifications of each output parameter. These extraneous studies do not examine the exact parameters of interest to the model nor do they necessarily utilize the same data base for their development. In order to use these studies, the HRRC model must employ a number of questionable procedures to extrapolate and interpolate their data bases and results.

The disparities in model detail and variations in model sophistication are, in part, caused by the preliminary nature of the Mark IIA. The greater levels of detail in the consumer and physician submodels which increase the complexity of model interaction do in fact increase the flexibility of the model for subsequent enrichment. The adaptation of previous work is clearly the result of the combined data and resource constraints which accompany any model development of the magnitude undertaken by the HRRC group. Although these adaptations clearly weaken the model, they provide the linkages necessary to make the model operational until further modeling activity and/or data collection can be undertaken.

4.2.2 Model Validation

As noted by the developers, very limited model verification experiments were performed to assess the validity of the Mark IIA. Specifically, the model was used to describe the values for such parameters as the demand for and supply of physician visits, employment of physician aides, number of hospital bed days consumed, demands for hospital manpower, etc., for the 1960 to 1970 period. Two major problems which hamper the assessment of model validity from those experiments are: (1) the model was developed using data from the latter part of the 1960-1970 period and was then partially tailored[1] to correspond to the entire period and (2) the model outputs provide detailed descriptions for which analogous historical data do not exist. The first of these two problems is clearly the more significant in that the model would be expected to provide an accurate simulation of the period used in its development (i.e., 1967 to 1970 time frame) and provide inaccurate estimates of the health system prior to that period due to the introduction of Medicare and Medicaid. The lack of appropriate comparative data is primarily a problem caused by changes in personnel classifications (e.g., the AMA's changing definitions of physicians specialties) and general limitations in data availability.

The only similarity matchings of model descriptions with historical data made by HRRC were: (1) the comparison of the outputs from the consumer population submodel with 1960 and 1970 census data, (2) the comparison of the 1960 to 1970 physician fees from the physician services submodel with the corresponding figures of the Bureau of Labor Statistics Consumer Price Index, (3) the matching of simulated 1960 hospital utilization and 1960, 1966, and 1968 hospital manpower and costs from the hospital services submodel with corresponding estimates made by the American Hospital Association and US Public Health Service, and (4) a comparison of the 1960 through 1970 participation rates for RNs from the

[1]In the physician services submodel, the demand for physician visits was specifically adjusted to correct for changes in specialty distributions observed during the 1960 to 1970 period.

nonphysician manpower submodel with rates estimated in another research study. While most of these model outputs compared favorably with the historical estimates, several disparities were evident. First, the percent difference between the model predictions of certain age/race/sex cohorts and the data provided by the US Census reached values of up to 25%. The developers suggest that many of these discrepancies are attributable to census misreporting and inconsistencies which clearly exist; however, it is probably unreasonable to expect that a population generation model which assumes constant birth and death rates would provide highly accurate predictions of the number of individuals in each age/sex/race cohort.

Second, the hospital services submodel generally overestimates the number of bed days consumed, number of RNs employed, and total hospital costs as compared to historical estimates. This over-prediction is principally the result of the model using higher admission rate figures than those utilized in the historical estimates. That is, the increased admission rate is transmitted down the series of equations increasing both the number of hospital employees and subsequently hospital costs. As pointed out in the HRRC final report, this sensitivity of the model to the specification of utilization rates could result in inadequate treatment of hospital costs and manpower demand (either through over, or under specification). Although, as the developers suggest, this problem might be solved by using more aggregative categories of hospitals (i.e., fewer bed capacity distinctions), the ability of the model to predict these demands for hospital manpower with utilization rates which differ from those in the future is somewhat suspect.

Third, the model prediction of the 1966 participation rates of nurses compared favorably with the values estimated elsewhere except in the youngest and oldest age brackets where the model differs from other estimates by 40 and 50%, respectively. This is not unexpected since the wage factor (whose performance "appears to be relatively poor in the historical simulation"[1]) has its greatest impact on the participation of nurses in these two age groups. The poor performance of the wages for nurses and other nonphysician manpower is a particularly significant observation, since a misrepresentation of nurse wages is transmitted to the physician services and hospital services submodels where it affects the demand for nonphysician manpower as well as the supply of physician visits and the cost of hospital service. The poor performance of non-physician wages could be improved with better specification of the demand equations for nonphysician manpower in both the physician services and hospital services submodels, as the developers suggest.

Of the above comparisons the best overall correspondence was found in the comparison of physician fees to historical data (i.e., percent differences of one to three percent). This high degree of correspondence provides little if any insight into model validity since the fee adjustment equation contains two factors -- which, in effect, force model outputs to track with historical experience during the period selected for comparison.[2] Other areas where the developers note the physician

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[1] Page 290 of the HRRC Final Report.

[2] Physician fees are taken as a function of an inflation rate factor to explain fee changes in market equilibrium and an adjustment factor which translates the difference between total visits demanded and total visits supplied into fee changes. The coefficient of the first factor is estimated from 1960 to 1970 BLS data and the disequilibrium in supply and demand is reconciled over the same 1960-1970 period.

services submodel performed well were in the historical predictions of the aggregate numbers of patient visits and employment of health manpower in physician offices. However, the effectiveness of these performances is not presented in any comparative or quantitative manner.

In conclusion, we would like to reiterate the statement on page 275 of the HRRC Final Report concerning the validity of the model -- "i has not been subjected to the extensive program of verification and refinement which must be performed before we can be fully satisfied with its performance."

4.2.3 Operational Requirements

The four major resources required to operate and use the HRRC preliminary operational model are: (1) the requisite data to provide model input, (2) the computer facilities to run model programs, (3) the technical personnel necessary to modify HRRC programs and interpret model results, and (4) the time to perform these tasks. Each of the four resource requirements are individually discussed in the following paragraphs.

Requisite Data

The Mark IIA is an operational model which requires only minimal data input if it is exercised within the general framework of the scenario (environment) provided by the developers. The primary data inputs are those required to characterize the consumer, health manpower, and institutional populations and the collection of factors which govern the behavior of the individual submodels within the model. The specific lists of input data required by the model are provided in the appendix to the HRRC report. From these lists it can be seen that the actual magnitude of data required is dependent upon the degree to which the consumer manpower and institutional populations are stratified (a user option). Since specific values for these data have been determined by HRRC in previous runs, data collection and estimation efforts are reduced to a minimum if the HRRC stratifications and values for these data are adopted by the user.

Computer Requirements

The HRRC Final Report provides a brief description of the computer processing characteristics of the model. The following paragraph summarizes the salient points of this description.

The computer programs for the model are coded in FORTRAN IV and designed to run on the IBM 370/155 computer at the USC Computing Center. The current computer size requirements are about 300 K of core storage. The model consists of three computer programs -- population of consumers, physician supply, and main simulation -- each of which executes independently from the others. Both the program to generate the population of consumers and the program to generate the supply of physician manpower are executed prior to the main simulation providing some of the latter's required inputs. The main simulation consists of several subroutines which link the physician services submodel, the hospital services submodel, and the nonphysician manpower submodel in the recursive solution sequence described above. Currently, all of the numbers generated for output summary tables must remain in core until the program completes the solution for all years. The execution time for a ten-year simulation run is estimated by the HRRC staff to take less than two to four minutes on computers with speeds comparable to that of the IBM 370/155.

Since the model is programmed in FORTRAN, the most common of the scientific computer languages, and run on IBM equipment, the most prevalent type of medium to large-scale computers, the conversion and modification required by most users should be relatively minor. Users with non-IBM equipment which has FORTRAN compilers should expect only minor retailoring of computer programs. It is VRI's experience that such modifications generally require a reasonable knowledge of the model and programming logic and are best performed with the assistance of the original developers.

Requisite Technical Skills

Two types of personnel are required to exercise and use the Mark IIA. First, computer programming personnel are required to make the modifications to the model coding necessary for the HRRC programs to run on the user's machine. Second, analysis personnel with an understanding of econometrics, computer modeling and health manpower (not necessarily all in a single individual) are required to select judiciously the values of input parameters and interpret the model results. The skill level of the first type of personnel is clearly dependent upon user computer facilities (as noted above) and the degree to which the user wishes to alter the current model attributes. Analyst personnel should have sufficient training and experience to recognize the inherent limitations of the model applicability and to be able to extrapolate and evaluate model outputs in terms of real-world problems. For example, model predictions of the demand for physician services are for the most part dependent upon the demographic composition of the consumer population. Forecasts which demonstrate a significant and disproportionate increase in the demand for one type of specialty care versus another would, therefore, be suspected to have been generated by a population composition which is unrealistic. If the composition is found to be reasonable, then the analyst should have the experience to identify and examine the other less likely model parameters which could contribute to such anomalies in demand (e.g., the time trend adjustment in the distribution of physicians across specialties and the arbitrary constant which translates supply/demand imbalances into yearly fee adjustments) in order to explain the model predictions and determine their reasonableness.

Time

Time constraints are probably the most uncompromising of all the aforementioned resource constraints. The time allotted to perform the requisite analysis is often insufficient to complete a comprehensive analysis of the problem. Responses to requests for information under these circumstances must use readily available data and analytic tools. Although the HRRC model requires only minimal time to operate, the time required initially to develop the capabilities for application and interpretation is significantly longer. Depending on the level of understanding and degree of involvement desired, the Mark IIA model could probably be used by manpower planners in a three to four-month time frame. Clearly, such an estimate is also dependent on the skill levels and numbers of personnel involved.

4.3 The RTI Simulation of Hospital Utilization and Health Manpower Requirements

This section describes the background and structure of the RTI computer simulation hospital manpower model, a model to be used in the estimation of health manpower requirements. In this presentation a brief history of the development of the model from the earliest population simulation to the present manpower model is followed by descriptions of each of the three component models. Where possible, these descriptions employ the language used by the developers in their final report. Persons wishing more detailed information than is provided here are referred to Research Triangle Institute, *Simulation of Hospital Utilization and Health Manpower Requirements*, Volumes I & II, Technical Report #1,prepared for the Bureau of Health Manpower Education, National Institutes of Health, December 1972.

4.3.1 Development Background of the RTI Model

The evolution of the present version of the RTI model began in 1963 with a microsimulation model developed jointly by RTI and the Department of Biostatistics at the University of North Carolina. This work was initiated in response to the interest of the National Center for Health

Statistics in studying metholologies used in collecting information on hospital discharges, length of stay, etc. In addition to projecting admissions and length of stay on an individual basis, the early model simulated the interview process of the National Health Survey in order to study the effects of the methodology employed on the statistics that were published on discharges and length of stay. As a result of this work and other RTI modeling activities, additional support was provided to RTI in 1966 to develop a demographic population model, POPSIM. The results of these two studies were then combined and augmented with a manpower requirements study to develop the current model of hospital utilization and health manpower requirements. The early version of POPSIM was modified in the present study to include the demographic characteristics of race, family income, and residence in a metropolitan or non-metropolitan area as well as age and sex. Similarly, the hospital utilization model, HOSPEP, was expanded (from an age/sex chracterization of utilization) to include race, family income, residence in a metropolitan or non-metropolitan area, hospital insurance status, diagnosis, surgery status, and hospital bedsize classification for each generated hospital episode. POPSIM and HOSPEP were then combined to form a model for projecting utilization of short term general hospitals to provide essential inputs to the model designed to project hospital manpower requirements, HOMAN.

4.3.2 General Structure of the RTI Model

The RTI simulation model consists of three serially related component models -- POPSIM, a stochastic demographic model stimulating population generation and projection through time; HOSPEP, a stochastic model for simulating utilization of short-term general hospitals; and HOMAN, an aggregated deterministic model which converts hospital utilization data for a specific time period into the manpower required to provide particular hospital services to satisfy the simulated demand. POPSIM is composed of two parts, one to create or generate a sample population from some base population, and the other to project the population forward year by year. HOSPEP generates a hospital episodes history in terms of hospital admission and discharge dates, together with hospital diagnosis, whether surgery was performed or not, and the bedsize of hospital for each episode. POPSIM combines with HOSPEP to project the utilization of short-term general hospitals by the US civilian noninstitutional population. Finally, the output of the utilization model is input to the hospital manpower model, HOMAN, and manpower requirements in each hospital service are projected.

4.3.3 Description of Major Components Within the Model

Each of the above component models is described in the following paragraphs.

POPSIM

The demographic simulation model (POPSIM) consists of two distinct parts or phases. The first, which is used to create an initial population, produces a random sample of individuals (stratified by age, race, residence, sex, and marital status) from a hypothetical population distribution. The initial population is a random sample of individuals selected from a population register, without regard to familial relationships, e.g., a married female may be selected for the initial population, while her husband and children may not be chosen. Individuals in the computer population (initial sample plus births) are referred to as primary individuals, and marriage partners and children as secondary individuals. Since secondary individuals are not members of the computer population, information concerning them must be carried by the primary individual.

In the simulation of vital events histories (second phase of POPSIM), all events which take place are considered as events to primary individuals. All tabulations produced are counts of primary individuals, or of events which happened to primary individuals. Secondary individuals enter the model only in the sense that they influence the vital event risks to which primary individuals are subject.

POPSIM creates each initial sample population in the computer by means of a series of subroutines which use random sampling from probability distribution functions (for the most part) to assign a consistent set of characteristics to each individual. A joint probability density function is fitted by the computer for each age/sex/marital status group. The distribution function and its inverse are then computed for each of these groups. The age assignment routine then sets up the records for the individuals in each age/sex/marital status group and assigns their ages by stratified random sampling of the associated inverse probability function.

The following characteristics are assigned to each individual by sampling the appropriate conditional distribution for the specific age, sex, and marital status of the individual:

- number of living children,
- number of marriages (0, 1, 2+),
- date of current marital status,
- number of children,
- date of birth of spouse, and
- date of last birth.

As noted above, the RTI simulation model was expanded to treat certain variables of interest in hospital utilization. Three of these variables -- race, residence, and income -- were incorporated into the POPSIM model. In order to distinguish racial groups, two segments or subpopulations can be processed simultaneously, and either separate or combined tables may be printed at the user's option. Separate parameters for births, deaths, and marriages are required for each race. An individual in the simulation is stochastically assigned an initial metropolitan (SMSA county) or nonmetropolitan (non-SMSA county) residence consistent with the 1960 age/race/sex population. Finally, each individual in the population under 18 years of age and never married is assigned a family income according to his race and residence. Each individual in the population over 18 years of age or individuals ever married is assigned a family income according to his race, residence, type of household ("husband and wife," "female head," "unrelated female," or "unrelated male") and age of the head of household.

After creating the initial population of desired size and characteristics, a second program uses Monte Carlo sampling procedures to generate a vital events history for each individual. This program advances the population forward through time in a series of time intervals or steps. At the end of each step, it provides the use the option of updating the probabilities of the various events. The user must specify the total length of the simulation period and the time interval for each step. The events generated by POPSIM include marriages, births, divorces, deaths, and changes in income and residence. The probabilities of each event depend on the current characteristics and prior history of the individual.

An event-sequenced simulation procedure is used in which an individual is processed only when an event occurs to him. In this procedure, the time interval (the date) of the next vital event for each individual in the initial population is generated. Since the event to occur next is not known, POPSIM generates the time interval (or waiting time) separately for each of the competing events that can happen to the individual, under the assumption that nothing else does happen to him, The event with the shortest generated time interval becomes the next event for that individual. Only this next event and its time of occurrence are carried in the record for each individual.

After the point in t for the next event is generated, it is checked to see if it falls within the interval chosen for that simulation step. If it is, time is advanced to that point and the event processed. If not, the individual is stored and not processed again until the beginning of the next simulation interval. When the event has been processed, a new next event is generated for the updated individual. This is continued until finally an event is obtained which is beyond the time allotted in the simulation or the individual dies.

The processing required after the next event has been determined depends on the nature of the event. For example, if the event is death, the individual is marked as being dead and the event recorded in his history of vital events. If the event happens to be marriage, some further processing is required. First, a decision must be made with respect to the marital status (single, widowed, or divorced) of the partner prior to this event. Once this has been done, the age of the marriage partner is obtained from the appropriate (first marriage or remarriage) bivariate distribution of ages of brides and grooms. If the event is a birth, the population of primary individuals is augmented with the newborn infant.

HOSPEP

The hospital utilization model (HOSPEP) uses as input the event histories generated for each individual by POPSIM. The basic assumption of the model is that the distribution of hospital admissions over a period of time t is Poisson with intensity λ; i.e.,

$$Pr[N = n] = \frac{(\lambda t)^n}{n!} e^{-\lambda t} \qquad [6]$$

where N is the number of admissions in the period t, and $1/\lambda$ is the mean time between admissions. Furthermore, for any age-sex class the intensity λ is assumed to be a random variable with a Gamma distribution with parameters α and β, i.e.,

$$Pr[\Lambda \leq \lambda] = \int_0^{\lambda} \frac{x^{\alpha-1}}{\Gamma(\alpha)} \beta^{\alpha} e^{-\beta x} dx, \qquad [7]$$

where Λ is the intensity. The parameters α and β were estimated for each particular age-sex class by using the fact that the unconditional distribution of hospital admissions over a time period of length t is negative binomial. The procedure followed was to select ten samples of λ and to assign to each individual in a particular age-sex class one of the sampled intensities for that class. This procedure in effect creates a Poisson admission process for each individual.

The above description refers primarily to the first version of HOSPEP. Several modifications were made for the health manpower study. These are described in terms of the six basic HOSPEP model stages (see figure 5), as follows. First, the model determines whether or not an individual has hospital insurance[1] by sampling his conditional probability

[1]The model assumes two insurance states: insured and not insured.

Stage 1 — Assign hospital insurance or not to the individual depending on his (1) race, (2) age (3) family income

↓

Stage 2 — Generate the number of days until the individual is admitted to the hospital which depends on his (1) race, (2) age, (3) sex, (4) family income, (5) hospital insurance status

↓

Stage 3 — Assign a diagnosis for the generated admission which depends on his (1) age (2) sex

↓

Stage 4 — Assign surgery or nonsurgery to the individual which depends on his (1) age, (2) hospital insurance status, (3) diagnosis, (4) residence

↓

Stage 5 — Assign size of hospital (bedsize) to the individual which depends on his (1) diagnosis (2) surgery or nonsurgery

↓

Stage 6 — Generate the number of days until the individual is discharged from the hospital which depends on his (1) age, (2) family income, (3) hosptial insurance status, (4) diagnosis, (5) surgery or nonsurgery, (6) size of hospital

FIGURE 5: HOSPITAL UTILIZATION MODEL[1]

[1]Excerpted from Research Triangle Institute, *Simulation of Hospital Utilization and Health Manpower Requirements*, Volume I, Technical Report #1, Prepared for the Bureau of Health Manpower Education, National Institutes of Health, December 1972, p. 47.

distribution of having insurance given his race, age, and family income. Second, the parameters of the unconditional admission distribution (α and β) are dependent upon race, age, sex, income, and hospital insurance. Once the individual is in the hospital, the model assumes that his diagnosis is determined by the conditional probability distribution of diagnosis, which depends on his age and sex. To determine if surgery occurred, a distribution dependent upon age, hospital insurance, diagnosis, and residence is sampled. The size of the hospital entered is determined by sampling a distribution dependent upon diagnosis and surgery. Finally, an individual in the hospital is assigned a duration of stay by assuming that the distribution of the number of days spent in the hospital is distributed as a log-normal variate. The log-normal distribution of length of stay is a function of the individual's age, income, hospital insurance status, diagnosis, surgery or nonsurgery, and hospital bedsize.

HOMAN

The RTI hospital manpower model, HOMAN, is the third in the sequence of RTI health manpower utilization models. The model was developed to forecast hospital manpower requirements and as such utilizes the outputs of POPSIM and HOSPEP although it can be used independently of the former two simulations. The hospital services for which the HOMAN was specifically developed are laboratory, radiology, pharmacy, physical therapy, and nursing.

The assumption underlying the HOMAN model is that manpower requirements over a period of time can be estimated by the equation:

$$M_{hj}(t) = \sum_{s} \left[\sum_{i} D_{is}(t) \, R_{ish}(t) \right] P_{sh}(t) K_{sh} U_{shj} \,, \qquad [8]$$

where,[1]

- M(t) = estimated manpower requirement in year t,
- D(t) = demand for hospital services in year t,
- R(t) = care requirements or number of work units per unit demand in year t,
- P(t) = personnel performance or man-hours required to perform a unit of work in year t,
- K = personnel - man-hour ratio for converting man-hours into requirements for specific types of manpower, and
- U = personnel utilization factor for delegation of personnel to a specific manpower category;

and the subscripts are defined as follows:

- j = index for specific manpower category,
- s = index for hospital size,
- i = index for diagnosis, and
- h = index for hospital service.

Two measures of demand for hospital services, $D_{is}(t)$, are obtained from the HOSPEP model: number of admissions and number of patient days by

[1]Units for the following variables are different across hospital services.

diagnosis (18 classes) and hospital size (eight sizes). Number of admissions is used in estimating laboratory and radiology personnel. Number of patient days is used in estimating pharmacy, physical therapy, and nursing personnel. The remaining seven parameters in equation 8 are obtained through regression estimates of the parameter as a function of time or estimates of the parameters' mean value. The care parameters, R(t), are estimated as linear or log-linear functions of time using data from the American Hospital Association (AHA), Hospital Administrative Service representing approximately 2,000 hospitals for the time period July 1968 to September 1971. Since this data was not a function of diagnosis, diagnostic specific data was obtained from two hospitals[1] assuming that they typify the care requirements distribution across diagnoses for all short-term general hospitals. The specific units of the care requirements parameters are:

(1) Laboratory -- tests/admission,

(2) Radiology -- procedures/admission,

(3) Pharmacy -- dispersements/patient day,

(4) Physical Therapy -- treatments/patient day,

(5) Nursing -- days/patient day.

The performance parameter, P(t), like the care requirements parameter, is estimated to be a linear function of time. This linear relationship is estimated using the same data source noted above (i.e., AHA) and is differentiated by hospital size and service. The personnel-man-hour ratio and the personnel utilization parameters are both time

[1] Data from Charlotte Memorial Hospital was used to provide diagnostic specific care requirements for all types of personnel except nurses. Nursing care requirements as a function of diagnostic category were obtained from "A Special Study of Nursing Manpower," Vol. I, US Public Health Service, HEW.

invariant. Data for the personnel-man-hour ratio was obtained from the Surveys of Manpower Resources in Hospitals concluded during the week of 17 April 1966. To use these data RTI assumed that full-time employees work 40 hours per week. The personnel utilization parameter is a ratio which specifies the personnel mix for each hospital service. This ratio is determined by dividing the number of personnel for a given skill category within a particular manpower service class (e.g., the number of medical technicians in a laboratory service) by the total number of personnel in each service class. Data for these ratios was obtained from the same source utilized to calculate the personnel-man-hour ratio.

In summary, it should be noted that estimation of the HOMAN model parameters discussed above are those which are currently resident to the model. As RTI suggests, the restrictions placed on these parameters by these estimation procedures do not necessarily constrain a more robust collection of estimates.

4.4 Evaluation of the RTI Model

The RTI Simulation of Hospital Utilization and Health Manpower Requirements concentrates on a single major subcomponent of the health manpower system -- the demands for health care in short-term general hospitals and the consequent demands for health manpower. For the most part, the RTI efforts have been directed towards the development of a method to simulate the vital event histories of a large population of individuals, and the development of a model of the hospital episodes which confront this population. The results of efforts focused in the third segment of this model -- the translation of health service demands into manpower requirements -- are much more limited in content.

In our evaluation of the RTI model we examined the conceptual design of the model structure, the mathematical composition with its attendent assumptions, the techniques and results of parameter estimation and the reasonableness of model preductions and their validation. The results of this examination were, in general, very favorable, finding little fault with the overall structure or any of its component parts. The problems which were isolated are those associated with the narrowness of model focus (e.g., lack of any feedback mechanisms or other constraints on demand) and those which are the result of data constraints or pragmatic limitations in model complexity (e.g. the desirability of a characterization of the population education). Although these shortcomings are found in each of the three component models, they are most significant in the hospital episodes (HOSPEP) and hospital manpower (HOMAN) models. Finally, the reader should be aware that most of the model structure was presented in the 1970 Conference on A Health Manpower Simulation Model and was initially critiqued at that time. Since much of that review is not reiterated here, the reader is referred to the *Proceedings* of that conference.[1]

[1]Conference on a Health Manpower Simulation Model, *Proceedings and Report*, Volume II, Lucy M. Kramer (ed.), USDHEW, December 1970.

The following subsections present a summary of the results of our evaluation. The material presented in each subsection parallels that provided in section 4.2 in our evaluation of the HRRC model.

4.4.1 Model Conceptual and Empirical Structure

In this section we examine the structure of the RTI health manpower simulation model. In addition, the underlying assumptions, completeness or robustness and the mathematical characteristics of the structure are discussed. Included in the discussion are reasonableness of the model and the problems associated with providing input parameter (estimation procedures) to the simulation. Since the RTI health manpower model consists of three distinct components, they will be discussed separately below.

POPSIM

POPSIM is essentially a large but efficient Monte Carlo simulation. The creation of the initial population is carried out by first sampling to determine age, sex, and marital status. Remaining parameters are assigned by sampling distributions conditioned on these first three parameters. It should be noted that stratified sampling techniques are used particularly in the case of age. The primary assumption underlying this procedure is of course that appropriate probability distributions for the various parameters can be obtained and that they are appropriate discription of the process. The robustness of the structure is clearly demonstrated by the fact that the POPSIM version used in the health manpower study was modified to include additional characteristics including race and residence and mobility. Moreover, the use of input probability distributions provides the user with an extremely flexible tool for examining different populations.

Two modifications to this population generation module which could improve the characterization of the cultural-demographic influences in the demand for hospital services and health manpower are the extensions of the number of population attributes to include education level and the alternation of income classes to create more than one income level above $10,000. As noted in section 4.2, patterns of health care consumption vary with the educational level of the population. Persons who attain higher educational levels consume differing amounts as well as differing types of health services. In addition, a large proportion of the population have incomes in excess of $10,000. At the current rate of income inflation this proportion is dramatically increasing each year. Thus, the assignment of family income in future years (with new data) will result in a disproportionate number of persons in the higher income bracket, which in turn will not provide sufficient differentiation in health services utilization by persons with varying income levels in the highest bracket. Two methods of providing the necessary differentiation are to increase the number of higher income classes or to discount all income (including the income which factors govern health care utilization rates) back to some present year.

The second phase of POPSIM is the generation of an event history for each individual in the population created in the first phase. In general, the apparent operative assumption made in this phase is that the time until the next event and the type of the event can be determined by sampling a set of non-time homogeneous independent geometric probability distributions. Further, sampling is Markovian in the sense that the current state and not the trajectory completely specify the next set of distributions. For example, the probabilities of an event occurring to two individuals in the same state (i.e., age, sex, marital status, family size) are the same and are not dependent on how each individual reached that state. An argument might be advanced that these distributions are not independent and moreover are not Markovian. However, the inherent simplicity of the current procedure is appealing and it is doubtful that introducing dependence or time histories would produce significant differences in output. Also, some bivariate distributions are used, for example, those dealing with ages of brides and grooms and other exceptions exist.

A very simple Markov model is used for residence and mobility and a set of log-normal distributions is used to determine family income. The propensity to move is dependent on an individual's age, race, sex, and present residence; however, the probability that an individual will change type of residence location (i.e., urban to rural or vice versa), given he moves, is arbitrarily established due to lack of data. As noted by the developers, two assumptions which limit the model's treatment of mobility are: the assumption that movement probabilities are constant over time, and the assumption that all foreign immigrants reside initially in metropolitan counties.[1]

In summary, POPSIM is a complex Monte Carlo simulation which creates first a population and then for each individual in the population creates an event history. The mathematical procedures used in POPSIM are most certainly correct. The problem with POPSIM (indeed with any large Monte Carlo simulation of this type) is the collection or estimation of appropriate data and the difficulty in analyzing and integrating simulation output. A great amount of data does exist in population demography. However, in some cases, such as the residence mobility model, sufficient data is lacking and rbitrary estimates must be used. Nevertheless, it is our opinion that the Markov chain model of residence mobility, although simple in structure, is not inadequate. Furthermore, the structure appears to be sufficiently robust to permit the addition of any parameters deemed desirable in the future, conditional on the availability of appropriate data.

HOSPEP

It is clear from the structure of HOSPEP (and of the discussion of estimation of parameters included in the report) that HOSPEP is a model of data rather than a model of a process. This should not be interpreted

[1]It is interesting to note that log-normal distributions are used for income assignment. Another approach which would permit grater analytical tractability would be to use a Gamma distribution, thus possibly providing a complete Markov structure to the overall model. The resultant increased mathematical tractability of the model would, however, probably reduce the model's realism.

as criticism since the utilization of hospitals is a complex and difficult process to comprehend, let alone model. Thus, for example, the size of the hospital is assigned after diagnosis and surgery have been sampled. The reverse process would seem, initially at least, to be more logical.

The major problem with the HOSPEP model is that it assumes that hospital resources and facilities are limitless, and therefore all demands can be answered. This assumption contradicts the classic assumptions made in economic theory; i.e., that the amount of services demanded is a function of the market price determined by the interaction of supply and demand. Simply because the boundless supply assumption contradicts economic theory does not itself invalidate model results. Indeed, recent studies indicate that there may exist a surplus of certain hospital resources (particularly in the number of available hospital beds)[1] which might support such an assumption. However, all other things equal, one would expect that variations in the availability and hence accessibility of hospital resources would tend to affect the utilization-behavior of the hospital service consumer. Thus, the estimates of hospital episodes in HOSPEP are probably biased upwards, if one assumes that the current estimates of utilization-behavior are accurate.

[1]See *Building a National Health Care System*, a statement by the Research and Policy Committee of the Committee for Economic Development, April 1973.

Since HOSPEP is a model of short-term general hospital utilization, it essentially assumes that the proportion of the population seeking hospital services as opposed to alternate forms of health care is relatively stable over time. With the emergence of new types of health care delivery mechanisms (e.g., ambulatory health care clinics, health maintenance organizations, etc.), and the increasing impact of government programs on social behavior (e.g., Medicare, National Health Insurance), such an assumption is unwarranted. Greater numbers of new organizations, as well as increases in the number of the older forms of care delivery (e.g., nursing homes), create a competition for the care of patients who previously were solely treated by hospitals. The introduction of National Health Insurance may significantly alter the degree to which alternate forms of health care delivery are utilized and the manner in which these services are utilized (e.g., length of stay). Although certain HOSPEP admission parameters, which determine the amount of service utilized, can be altered from one simulation period to the next, the methodology used to make these adjustments over the period of the prediction would clearly require additional research.

Another basic shortcoming of the HOSPEP model is that hospital episodes of an individual are independent of that individual's medical history; i.e., the fact that an admission occurred a month ago does not effect the probability of an admission tomorrow. This is reflected in the selection of a Poisson process, a memoryless process, to describe the probability of admission to a hospital. Although correcting this would improve the accuracy with which the model represents an individual's hospital episodes, and hence the reliability of model estimates, such an extension would be extremely difficult to implement for even the simplist of medical histories (e.g., the number of previous admissions).[1]

A great deal of effort has been expended on the estimation of parameter values, dependencies among random variables and functional relationships. Each admission event was generated by sampling a Poisson distribution for which the intensity had been determined by sampling a Gamma distribution. As presently programmed, the α parameter of this Gamma distribution is assumed to be one although data consistently indicated values less than one. This assumption was necessary at the time of programming due to the absence of computer routines for sampling Gamma distributions with α less than one. In our conversations with the developers they indicated that such a routine is now available; however, a programming change would be necessary to implement this feature in the model. The length of period spent in the hospital was obtained by sampling an appropriate log-normal distribution, the two parameters of which depend upon age-sex class. Note that it is at this point that a non-Markovian random variable is introduced, thus reducing the possibility of analytic simplification.

[1]Since the model is intended to describe the average episode history of a population rather than represent the actual hospitalization history of an individual, and since the model distributions were selected and the parameters were estimated with this purpose in mind, it can be argued that such feedback interactions are absorbed and reasonably well represented by the current model structure.

HOMAN

Conceptually the hospital manpower model is simple, but discussions with RTI personnel revealed a serious lack of data in this area. Hence a structure was selected which could utilize POPSIM and HOSPEP output and simultaneously be estimated with available data. The three major assumptions which underlie the HOMAN structure are:

(1) Hospital personnel requirements are linearly related to utilization of hospital services,

(2) Personnel resources are limitless, i.e., there is always an adequate supply to meet these requirements, and

(3) The time trends exhibited in two of the parameters -- care requirements and performance -- which relate hospital utilization to manpower requirements, are linear or log linear in nature.

The first and second of the above assumptions are the most problematic, conceptually. The first assumption implies that a doubling of hospital utilization would result in a doubling in the requirements for hospital manpower -- an unlikely occurrence. The second assumption implies that if such a doubling occurred, then the supply of manpower would meet this requirement. Clearly, the HOMAN model is not intended for use in such a dramatically changing hospital services environment, but the implications that for every percent increase in utilization there will be an equal percent increase in manpower holds for minor changes as well. It should be recognized, however, that the time trend changes in the care requirements and performance parameters will moderate the effects of variations in utilization on manpower demands, provided the historical trends continue in the future. That is, the estimated time trends of these factors are developed to account for the historical changes in hospital operations and personnel productivity which have accompanied the changes in hospital utilization. The reliability of the HOMAN model predictions therefore are dependent upon two conditions: (1) that the estimated time trends in these factors are accurate and continue in the future, i.e., no dramatic innovations occur, and (2) that the change in hospital utilization increases accordingly.

The absence of effects of supply constraints on manpower requirements could result in inaccurate model estimates of future requirements, other factors being equal. The HOSPEP model predicts that if a bed in a hospital is needed, it is available. Similarly, the HOMAN model will predict that for every occupied bed, the hospital will have the requisite personnel manpower to serve the patient in that bed. Clearly, as hospital occupancy rates vary, the number of personnel per patient will vary. When the demand exceeds supply, the model will assume that this imbalance does not exist and create a non-existent bed and the associated personnel to serve it. As supply exceeds demand (a more probable occurrence in the case of hospital beds[1]), the model will predict that the larger facility does not exist and that the personnel requirements will be reduced accordingly. Furthermore, the HOMAN model ignores any economies of scale, which result from variations in hospital size or changes in technology.

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[1]See page 33 of *Building a National Health Care System*, a statement by the Research and Policy Committee of the Committee for Economic Development, April 1973.

It should be noted that these model shortcomings are recognized by the developers, who suggest that further research efforts should be undertaken to correct them.

Another source of difficulty is the use of parameters such as care requirements (number of work units per unit demand) and performance (number of man hours per work unit). Care parameters were made either linear or log linear functions of time due to lack of data. Hence the assumptions of linearity or log linearity remain unconfirmed until further data becomes available. Similarly, it was assumed that the unit of work required was an average, e.g., average number of daily tests per patient for a specific diagnosis. This assumption is also open to question, particularly for patients who differ in terms of lengths of stay or in terms of diagnoses which produce critical episodes such as surgery. Furthermore, since the estimated values of this parameter for different diagnoses were extrapolations from data available in a single hospital, the variations in care requirements under different diagnostic conditions reflect the operations of that hospital, which may differ significantly from those found across the nation.

The performance parameters have, as have the care requirements parameters, been made linear functions of time with limited justification. The linear functions for both of these parameters were estimated over the 1968 to 1971 time period -- a period of escalating hospital costs and modifications in the hospital labor force composition. Although the RTI model developers clearly must rely on the most recent data available, model users should be aware that any future departures from this period of dynamic change will decrease the accuracy of model predictions.

It is important to note that physicians have been excluded from the health manpower forecasting model and that the manpower requirements identified are for short-term general hospital inpatient workloads only. In addition, it should be noted that the model is essentially deterministic, with possible stochastic features introduced by POPSIM and HOSPEP output used as estimates of demand. The model in its present structure is most certainly robust, that is, parameters can be varied at will by the user, but it is not clear that it is complete or robust in a physical sense in that major changes in hospital manpower utilization or hospital technology would tend to invalidate the structure.

In discussing the mathematical validity of HOMAN, it is important to recognize that neither time nor resources were available to carry out process modeling or data collection. As noted above, for example, in the critical area of a diagnostic-specific care requirement parameter, data was available from only one hospital, and at that represented only a six-week period. In other areas, data was available from the American Hospital Association, Hospital Administrative Service, representing data gathered from approximately 2,000 hospitals over a three-year period; while the personnel-man-hour and personnel-utilization parameters were estimated using data from a one-week time period in 1966. The applicability of these latter estimates to future projections is somewhat questionable. Thus, the user of the HOMAN model is faced with the problem of verifying existing data or collecting data more appropriate to the time period in question.

In summary, HOMAN is a simple deterministic model for forecasting health manpower requirements. Again, it might be suggested that HOMAN is a model of data rather than a process, and thus may not be a suitable analysis tool if major innovations or other alterations are introduced into the mechanisms which govern health care delivery in short-term general hospitals.

4.4.2 Model Validation

Predictions from each of the three component models of the RTI *Simulations of Hospital Utilization and Health Manpower Requirements* were tested against historical data from the 1960 to 1970 period. The problem with validation of the HRRC model, i.e., the comparison of model predictions against data collected during the same time period as the data employed in model development, also exists for the RTI model verification. Clearly, one would like to compare model predictions which extend well beyond the data period from which it was constructed,

RTI compared the POPSIM model outputs with Bureau of Census projections. The results of the POPSIM tests reveal that the model predictions of total population compared very favorably with census data and estimates both over the historical and future time periods. The POPSIM estimates were low in every case by approximately one to four percent, much of which is attributable to the fact that POPSIM did not allow for annual net immigration. Comparing the POPSIM prediction for particular age/sex/race cohorts to 1960 and 1970 census data, the model again performed well, with model projections differing from the census by less than 10%. Furthermore, multiple runs of the POPSIM model resulted in highly comparable outputs, indicating the variance of model output is minimal and replication of model runs unnecessary.

The HOSPEP model estimates for years 1962, 1965, and 1968 (using POPSIM output) were compared to available data. To conduct these tests, the four HOSPEP parmaeters were trended over time. These four parameters are:

(1) The hospital admissions parameter, β,

(2) The conditional probability of diagnosis,

(3) The conditional probability of surgery, and

(4) The conditional probability of hospital size.

In addition, two other time alterations in parameters were made to improve HOSPEP estimates. First, the probability of hospital insurance for persons over 65 years of age was set equal to 0.98 after the advent of Medicare in 1966. Second, two estimates of the mean of the log-normal distribution of length of stay were used, one from 1960 data to project the 1960-1965 period and the other from 1968 data for the 1966-1982 period. The following briefly lists the HOSPEP tests performed and the results of these tests:

(1) Predictions of the percent of persons with hospital coverage by age compared with 1962-63 and 1968 HIS data -- results of comparison favorable with differences less than 10%.

(2) Predictions of the discharge and admission rates per 1,000 individuals by age compared with 1960-62 HDS data and 1965 and 1968 NCHS data -- least comparable results in older age groups with up to 15% differances.

(3) Predictions of number of discharges by age, surgery, and size of hospital compared with 1962-63 HIS data and 1965 and 1968 HDS data -- results of comparisons favorable in most areas with few predictions differing from data by more than 10%.

(4) Predictions of hospital discharges by diagnosis compared with 1965 and 1968 HDS data -- results vary widely across diagnoses with differences nearing 25% in some diagnostic categories.

(5) Predictions of average length of stay by age compared with 1965 and 1968 HDS data -- largest differences (14% to 17%) in 1958-60 comparisons for youngest and oldest age groups.

(6) Predictions of hospital days of care by age and diagnosis compared with 1968 NCHS data -- results of comparisons in age brackets very favorable with 1% to 3% differences, comparisons across diagnostic categories variable with some differences greater than 35%.

As can be seen from the above list, in general, HOSPEP predictions compared favorably with historical data. The model appears to be least accurate in its estimation of variations in hospital utilization caused by different diagnostic conditions, thus implying further refinement of diagnostic definitions and probabilities is required before the model can adequately treat this relationship.

An examination of HOSPEP projections of hospital days of care under two health insurance conditions -- complete coverage and current coverage level -- revealed that the model is relatively insensitive to the effects of hospital insurance on demand. In fact, in the model prediction the total bed days utilized was greater for the current coverage condition than for complete coverage -- an unlikely occurrence.

Tests of HOMAN predictions were hampered by the relative absence of manpower data on short-term general hospitals. This assessment was further constrained by the fact that HOMAN predicts the requirements for inpatients only. Under these constraints RTI obtained estimates of hospital manpower from various sources[1] for HOMAN comparisons. Predictions made for each of 12 types of manpower[2] were compared to available estimates for the years 1962, 1965, 1966, and 1968. Due to data limitations, comparisons for most manpower types were only made using 1966 figures. HOMAN predictions for that year were below other estimates in all manpower categories. Percent differences between the HOMAN estimates and the other estimates were approximately 20% for most manpower categories. Due to the problems with available data and since the comparisons were made against estimates which include both inpatient and outpatient manpower requirements, the results of these tests cannot be assessed.

Four series of HOMAN projections of US short stay hospital manpower requirements were computed for the period 1972-1982. Each of these series was based on four combinations of assumptions for the care requirements and performance parameters (i.e., both parameters fixed, the care

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[1]The actual sources are unspecified in the RTI final report. In our conversations with them they noted that these estimates were obtained from a wide variety of data sources.

[2]Laboratory technologists, technicians and aides; radiology technologists and aides; pharmacists and pharmacy aides; physical therapists and PT aides; RNs, LPNs and nursing aides.

parameter fixed with the performance time variant and vice versa, and both parameters time variant). These projections demonstrated the relative sensitivity of manpower requirements to the time trends of these parameters. In certain manpower categories the percent difference in the 1982 projection were in excess of 50%. Since the model assumptions of linear time trends in parameters are essentially unconfirmed, the results of these tests tend to raise questions about the accuracy of HOMAN predictions.

4.4.3 Operational Requirements

The four classes of operational requirements -- data, computer facilities, personnel skills and time -- discussed in subsection 4.2.3 apply to the RTI model as well. Each of these operational requirement categories is discussed below.

Requisite Data

Like the HRRC model, the amount of data required to run the RTI model depends on the user's willingness to use data resident in the current system. If the user desires to deviate from this particular scenario, the data requirements become enormous. For example, the HOMAN model while conceptually simple, becomes reasonably complex when the dimensions of the various parameters are examined. This model estimates the requirements for four types of manpower services each containing two to three personnel categories in terms of 18 different diagnoses and eight hospital size categories which HOMAN obtains from HOSPEP. HOSPEP requires two-way frequency distributions for such variables as diagnosis, age, family income, insurance status, surgery status, hospital size, and length of stay in order to generate multidimensional contingency tables. Clearly, any user wanting to reestimate these multi-variate probabilities must have a reasonably large and detailed data base. Other input data required by HOSPEP is the complete characterization of the population currently provided by POPSIM. POPSIM requires two types of input data -- that required to generate the initial population and that necessary to project the population through time. The program to generate the initial population requires substantial data input. This requirement includes such data as proportion of individuals in each sex/marital status group, proportion in each age/sex/marital status class, parameters to assign age of husband given age of wife, etc. The event history program requires such data as the monthly birth probabilities for females in each age/marital status/parity group, monthly divorce probabilities since date of marriage, etc. The input data necessary for the RTI model grow rapidly, and in several cases geometrically, as the user requirements deviate from the data resident in current model specification.

Computer Requirements

Since two of the subcomponent RTI models are stochastic Monte Carlo simulations, they require greater computer resources both in magnitude and time than the deterministic models such as the HOMAN or the HRRC model. In comparison to the POPSIM and HOSPEP models, therefore, the computer facilities required to run the HOMAN model are negligible. If HOSPEP is run without reestimation of data (i.e., contingency tables), RTI has experienced typical run times of one to two minutes on an IBM system 360/model 75 with input consumer populations totaling about 20,000 persons. If reestimation of HOSPEP parameters in the form of contingency tables is considered, computer run time may reach 30 minutes on computers with speeds comparable to the IBM 360/75. To generate a population of 20,000 consumers POPSIM requires approximately 10 minutes of CPU time on an IBM 360/model 50 and to determine the event history for one-fourth of this population (5,000 individuals) through ten years in two-year increments requires approximately 30 minutes of CPU time on an IBM 360/model 50.

Furthermore, POPSIM and HOSPEP both have relatively large computer storage requirements because of the size of the population and the number of attributes as well as conditional probabilities necessary to project the population through time and determine hospital episodes. Because of the magnitude of these storage requirements, the RTI model requires computer facilities with fairly large capacity, on-line storage devices. It should be noted, however, that RTI states that the POPSIM program can be run on systems with 100K bytes of CPU storage and two tape drives, but such minimal configurations are not recommended.[1] Programs are coded in FORTRAN for IBM system 360 computers with the exception of the HOSPEP estimation of multi-way contingency tables, which is coded in PL-1 for

[1]Page 81 of the *User's Manual for POPSIM* by B. V. Shah prepared for the National Center for Health Statistics, June 1972.

system 360 computers. Thus, the model is compatible with the hardware and software of IBM system 360 computers having FORTRAN compilers (PL-1 compiler is necessary if reestimation of contingency tables considered).

Requisite Technical Skills

The major types of personnel skills required are computer programmers and systems analysts. Of these two types of personnel, computer programming personnel resources are the most necessary. Due to the magnitude and complexity of the RTI computer programs, minor changes required to transfer programs to the user's computer facilities could require significant amounts of programming resources. Systems analyst personnel are primarily required to oversee this transfer and to design minor modifications in the model logic. Any major modifications in the model structure would require dedicated analyst's time for longer periods. VRI estimates that the RTI models could be operational on reasonably compatible hardware with two man-months of programmer/analyst effort.

Time

Similar to the HRRC, most of the consumption of time would be attributed to the transfer of the model programs to user facilities and to requirements associated with the model familiarization. However due to the stochastic nature of the model programs, the computer time required by the model to project future manpower requirements may become significant. Under conditions where decisions must be made within a relatively short period (e.g., 24 hours), the desired multiple large scale RTI model runs to test the various facets of a particular problem would easily exceed these time constraints.

4.5 Analyses Using the HRRC and RTI Models

In the foregoing sections of this chapter we have described and evaluated the HRRC and RTI models. In our evaluation of these models we have concentrated on the components which we feel could be improved through modification and/or expansion of existing structure. Although this evaluation is focused on these specific model shortcomings, it should be recognized that the RTI and HRRC models are two of the more comprehensive and detailed model structures within the current state of the health manpower modeling art. As such their potential usefulness to health manpower analysis activities should be examined by agencies performing such analysis, particularly the organizations for whom these models were designed. To perform this examination these organizations need to become actively involved in applying these models to their current problems, for it is only through such "hands on" activities that the analysis deficiencies of the model are identified.

One could continually describe additional attributes which might improve the predictions of these models; however, the most appropriate way to isolate those attributes which are essential to the planning and programing activities of these organizations is to apply the model to actual problems. Indeed, without such exercises it is questionable whether any of the above modifications or extensions should be investigated since many of these alterations may prove to be unwarranted with respect to a particular problem environment.

In this applied examination of the HRRC and RTI submodels it should be recognized that even though both models provide a mechanism for estimating future health manpower demands or requirements, they approach this projection problem from alternate perspectives and hence are applicable to somewhat different analysis questions. The HRRC model describes the behavior of health consumers and health manpower in the physician services, hospital services and nonphysician manpower markets. Thus, the model focuses on the analysis of the impact of fluctuations of parameters in these markets (e.g. prices, wages, health service demands, supply constraints) on the demands for future health manpower. The RTI model is essentially designed to provide a projection tool (similar to those developed for census projections) to estimate the future requirement for health manpower under alternate assumptions. Analyses using the RTI model focus on the consequences of changes in health care requirements, manpower productivity and personnel utilization (combined with future estimates of the demographic composition of the population and the associated utilization of hospital services) on requirements for nonphysician health manpower. It should be further noted that the HRRC model primarily concentrates on the demands for physician services and nursing personnel with only limited treatment of allied health personnel; whereas the RTI model focuses on allied health and nursing personnel requirements.

There are essentially two types of analyses which could be explored using the HRRC preliminary operational model. First, the impact of achieving certain program or policy goals on health manpower demands and health care prices could be investigated. By altering the values of input parameters to correspond to the achievement of a particular program objective (e.g. a 10% annual increase in the number of medical school graduates, a completely insured population with a preset coinsurance rate, a redistribution of physicians across the medical specialties), the model would provide estimates of what could be the consequences to the health system could be if these programs are successful. The second type of analyses addressed by the Mark IIA is the estimation of future variations in the demand and supply for inpatient care, outpatient care and nonphysician manpower which result from estimated changes in population compositions or from changes in health service prices and personnel wages.

The HRRC final report describes several potential analysis experiments, most of which fall into one or the other of the above analysis categories. These experiments include: alternative assumptions regarding birth rates; the distribution of income among consumers; physician work patterns; specialty choice patterns; number of foreign and domestic medical school graduates; variations in the supply of RNs; and the effects of National Health Insurance plans. The results of exercising the model under one or several of these analysis conditions would provide substantial insight into the relative strengths and weaknesses of the model as an analytic tool. In addition, a single run of the model using current estimations of model parameters to predict future demands for manpower would enable users to assess the model's predictive capabilities.[1] These model predictions could be examined for reasonableness and the model estimates of the demands for nurses in hospital services could be compared against similar (but not identical) estimates made using the RTI model.

As noted above the primary analysis role for the RTI model is to estimate future demands for short term general hospital (STGH) personnel under alternate assumptions. As such, this model provides manpower requirement targets for organizations concerned with modulating manpower supplies. The model also provides insight into the potential variations in these requirements which result from global changes in the health care delivery environment (e.g., a completely insured population or changes in the age composition of the population). A limited set of analysis experiments have been performed[2] by examining the consequences of maintaining current trends in hospital operating characteristics (e.g., number of laboratory tests performed per admission) and in manpower productivity (e.g., number of man hours per test) or fixing these characteristics at their current level. The results of these experiments indicate the relative sensitivity of the model and perhaps the relative sensitivity of STGH manpower requirements to these operating characteristics. Another set of experiments which might provide more useful insight into the creation of manpower planning targets or the evaluation of current targets would be to develop expected values for upper and lower limits of model input

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[1] In our conversations with the HRRC staff they noted that they plan to perform such model simulations to examine the estimated values and parameters of the model. It is our understanding that such model runs have not yet been made.

[2] Ten Year Projections of U.S. Manpower Requirements for Short Term General Hospitals in Five Personnel Categories - Final Report for Contract # NIH-71-4068.

parameters and observe the anticipated maximum and minimum requirements for STGH personnel, then design and conduct experiments in which the boundary conditions are modified by relaxing certain input limiting conditions. The outputs of these model runs could then be used to provide alternative manpower requirements with varying degrees of confidence. Thus, the purpose of such analyses would be to assist decision makers in development of more reasonable goals for manpower supply programs.

Analysis experiments could move one step farther up the RTI model hierarchy (i.e. to the HOSPEP and POPSIM models) and examine the consequences of departures in hospital utilization resulting from changes in current population attributes (e.g. variations in birth rates, income parameters, residence and mobility, etc.) or changes in the relationships between various consumer attributes and hospital utilization. Experiments in these areas are much more complicated to implement since they imply a reestimation of model parameters. Problems with data availability and computational requirements in this reestimation process could possibly be avoided by selecting reasonable hypothetical parameter values, such as birth rates, increases in insurance coverage, etc. However, for many input parameters, and particularly conditional probabilities, this selection procedure would be difficult to perform in a judicious manner. The purpose of modifying these input parameters could either be to reflect the consequences of a particular program goal (e.g., as specified in a national health insurance program) or to adjust hospital utilization characteristics which might be anticipated in the future, such as increased utilization of outpatient facilities or health maintenance organizations.

Finally, a word of caution: we anticpate that the results of the above analysis experiments will fall short of expectations and predict implausible events under certain conditions. Such an occurrence does not however imply that these exercises were of little use or that the model should be disposed of in favor of more standard techniques (e.g., manpower to population ratios). Rather, the models should be examined for specific deficiencies which led to these results -- candidate shortcomings for such an investigation have primarily been the topics of material presented in previous evaluative sections. Not only will such an investigation provide information necessary to modify or reestimate model components, but it will also provide insight into the health manpower processes which determine the state of this complex interrelated system. Furthermore, without this active participation in such model application, it is unlikely that model users will develop the requisite understanding and knowledge necessary to identify desirable attributes of subsequent modeling efforts, and as a consequence, these efforts will construct models which are relatively unresponsive to user needs.

5.0 SUMMARY CONCLUSIONS AND RECOMMENDATIONS

In chapter 3.0 we examined the ability of 56 health manpower models to address general analysis problems confronting regional, state, and national health manpower planners. Chapter 4.0 presented the results of VRI's detailed evaluation of two of these models. This chapter describes the summary conclusions and recommendations resulting from these analysis activities.

5.1 *Summary Conclusions*

The following list presents the 14 major conclusions which summarize the salient results of the foregoing analysis. These conclusions are presented in order of their appearance in the text, rather than in order of relative importance. Detailed rationales for these conclusions and discussions of other less significant insights are given in the text of chapters 3.0 and 4.0.

(1) The models examined treat a broad spectrum of health manpower analysis topics which overlap in certain subject areas and are mutually exclusive in others. For the most part, the collection is comprised of models which are the results of independent research activities and have structures that would be difficult to integrate to provide an overall representation of the health manpower system.

(2) Health manpower models generally can be classified as descriptions of three interrelated health manpower supply processes (educational choice, health professions education, and manpower resources) and/or

of three interrelated health manpower demand processes (incidence of illness, consumer service behavior, and health care delivery). Many of these models manipulate parameters describing the three economic markets (health education, health service, and health manpower) which govern the interactions among these processes.

(3) Most of the modeling activity is concerned with analysis of the demands for health manpower or the services they perform rather than with the supply and distribution of the manpower. Of the models examined in this study, the manpower demand and service delivery models outnumbered the models concerned with variations in the stock of health manpower and the distributional problems of health manpower supply by more than two to one.

(4) Demand models generally attempt to relate the demands for health manpower services to economic factors and the cultural/demographic composition of the consumer population. Models of service delivery provide mechanisms to examine the efficient utilization of personnel and other health care resources.

(5) Few models address the analysis problem of determining the impact of specific programs and policies on health manpower supply and demand. In particular, the models are not structured to analyze the numerous programs directed toward modulating the supplies of health manpower.

(6) Of the few models which treat the various aspects of program assessment, nearly all provide mechanisms for examining the impact of a successful program on global health care objectives. That is, model inputs reflect attainment of a desired program result, and model outputs provide measures of health system performance. The

associated analysis problem -- examination of the probability of program success -- generally cannot be addressed with the models.

(7) Most of the models were developed for application to a particular type of problem and are potentially useful to users with similar problems. However, most of these models must be provided with appropriate data bases or reestimated before they can be used effectively. Many of these models were developed and tested with data specific to a particular health manpower environment or were constructed with theoretic structures which require data.

(8) Health manpower models are usually descriptive rather than prescriptive in nature. That is, most models employ regression analysis or Monte Carlo simulation techniques to describe health manpower processes. Models which prescribe or recommend an optimal course of action are much fewer in number and are principally concerned with the efficient utilization of health personnel.

(9) Less than one-third of the models examined have tested their predictions against actual health system behavior. This may be due to the fact that most of the models were apparently developed for one-time use as research vehicles to try to explain how sectors of the health system operate, rather than as repetitive tools for planning.

(10) The HRRC preliminary operational model (Mark IIA) is an incomplete version of the conceptual (Mark II) HRRC model. As a consequence, the Mark IIA does not treat many of the parameters useful in policy analysis and omits a number of factors which influence the behavior of simulated processes. An associated criticism of the Mark IIA

model is the wide differentiation in the level of detail and degree of sophistication offered by one model sector versus another.

(11) The Mark IIA model does represent one of the more detailed operational models of the microeconomic behavior of health manpower processes.

(12) The RTI model is a tool to estimate future, short-term general hospital manpower requirements under the assumption that unlimited supplies of resources are available, current conditions or observed trends in the provision and consumption of hospital services remain constant, and the ratio of hospital services provided to manpower requirements is some trended constant over time. Accordingly, the validity of RTI model outputs (predictions) is highly dependent upon the degree of change experienced in the utilization of hospital services and hospital personnel management and operating characteristics.

(13) The RTI model provides reliable estimates of hospital episodes in the aggregate and may be useful as a manpower planning device.

5.2 *Recommendations*

The three principle VRI recommendations resulting from this study are:

(1) Future health manpower modeling efforts should place greater emphasis on addressing the impacts of governmental programs and policy actions on the health manpower system. That is, greater emphasis should

be placed on the development of models for use as planning and programming tools (vis a vis research or explanatory studies).

(2) A greater proportion of future model efforts for planning purposes should concentrate on describing the effects of programs aimed at increasing the supplies of health manpower services and the effective distribution of these services.

(3) Major health manpower planning agencies should attempt to employ health manpower models as operational tools. These models should be exercised on a continual basis by health planning analysts. Continual use will generate an inventory of information that can be used to address decision problems in a responsive manner. This hands-on experience will provide insights into the deficiencies of existing models and indicate where future model development efforts should be devoted. Allocation of modeling support without such experience will result in modeling efforts that are unresponsive to user needs.

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