Working Paper

ALTERNATIVE APPROACHES TO MODELING HEALTH CARE DEMAND AND SUPPLY

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WP-80-80

International Institute for Applied Systems Analysis
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FOREWORD

The principal aim of health care research at IIASA has been to develop a family of submodels of national health care systems for use by health service planners in a planned or market economy. The modeling work is proceeding along the lines proposed in the Institute's current Research Plan. It involves the construction of linked submodels dealing with population, disease prevalence, resource need, resource allocation, and resource supply.

This paper investigates different possibilities for health care demand-supply modeling, taking into account the varying structures of health care systems and the differing availabilities of statistical data.

Related publications in the Health Care Systems Task are listed at the end of this report.

Andrei Rogers
Chairman
Human Settlements
and Services Area

ABSTRACT

In many developed countries the problem of allocating resources within the health care system is the main aspect of health care planning. These resources are usually allocated within different groups of population according to age, sex, disease, income, etc. Taking into account the differences in health care systems, the availability of medical information, and the period of planning, this paper analyzes the alternative ways of modeling the flow of patients between categories and the related health care demand-supply problems.

CONTENTS

ALTERNATIVE APPROACHES TO MODELING HEALTH CARE DEMAND AND SUPPLY

1. INTRODUCTION

In modeling a health care system (HCS), it is important to describe the main components of the system, such as the health of the population, the demand-supply relationship, and the utilization of the health resources, as well as the interaction among these components.

As pointed out by Venedictov (1978:90):

> Proceeding from the understanding of health as it is interpreted in the WHO Constitution, the proposal to regard it, not as a static state, but as a continuous process of maintaining an optimal balance between the organism and the surrounding social and natural environment is very valuable and promising.

Unfortunately, at present there is not a single index for the health status of a population that can estimate the biological, social, and behavioral aspects of this "balance". There is, however, a set of different indices (life expectation, natality, morbidity, mortality rates, etc.) which can help to estimate the health status of the population and the changes that occur due to the influences of different external systems.

The problem of defining "need" in health services is also difficult. The official report of WHO on the working definition of health service functions and terminology contains the following statement: "The needs in health may be defined as scientifically (biologically, epidemiologically, etc.) determined deficiencies in health that call for preventive, curative and eventually control of eradicate measures". The accuracy in determining the needs of health services depends on the level of medical science, the knowledge of personnel, laboratory techniques, etc. in the country or region.

Therefore, in practical terms it is possible to speak about professionally defined needs for health services which reflect the present status of all the above-mentioned aspects. It is very important also to define perceived needs as a need for health services expressed by individuals. The accuracy of perceived needs for health services depends on such variables as the behavior of the individual, his educational level, and his perceived value of the use of services (Figure 1).

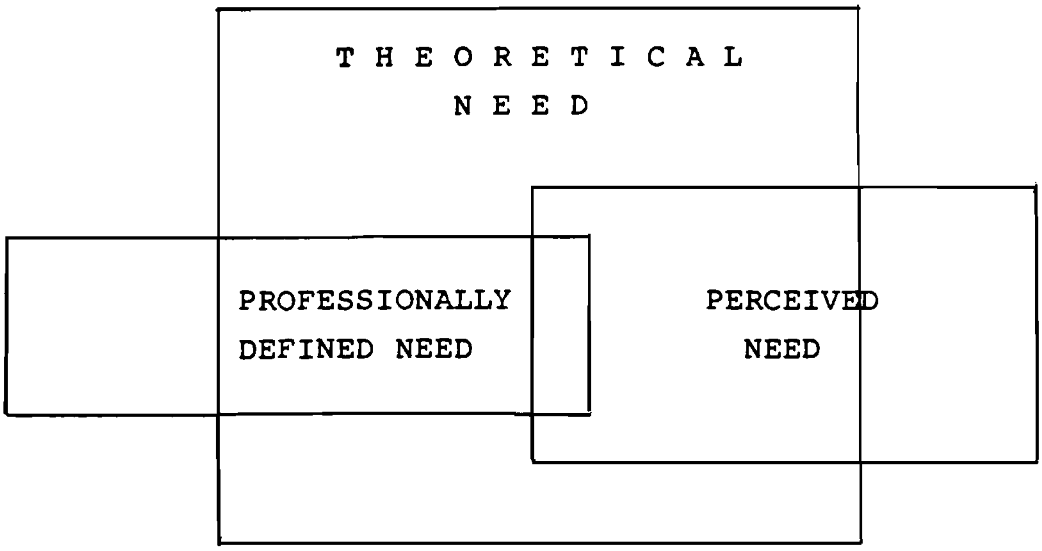


Figure 1. Interrelation of the individual's needs for health services.

The demand for health services is usually estimated in terms of the actual utilization of the services. As Lee (1978) mentioned in his book *Economics and Health Planning*, "Each demand is a need by someone of something for some purpose" (p.52). In this context, "someone" could be a patient, a doctor, or a state with a set of regulations (e.g., vaccination requirements). The supply could be defined as a share of the total expenditure spent on health care services. The amount of the supply received depends on many factors such as the availability of health resources or the patient's income. The "utilization" - the interaction between health care demand and supply components - reflects the use of medical services. This utilization is also closely related to management. All these interactions can be graphically illustrated (Figure 2).

2. HEALTH CARE DEMAND AND SUPPLY INTERACTIONS IN VARIOUS COUNTRIES

The interactions described in Figure 2 vary in practice according to the organization of the health care system in the particular country discussed. Health services vary in

-- Centralized or non-centralized HCS
-- Planned or non-planned economies
-- Countries with different kinds of compensation to medical staff
-- Countries with varying controls on the quality of the medical staff
-- Countries having problems of confidentiality of individual medical information
-- Countries having ownership of medical facilities

2.1. Governmental Systems

In socialistic countries the health care system is centralized, planned, controlled, and financed by the state through the national and regional infrastructure. The ownership of practically all medical establishments is public and service is free-of-charge. All medical information (for the

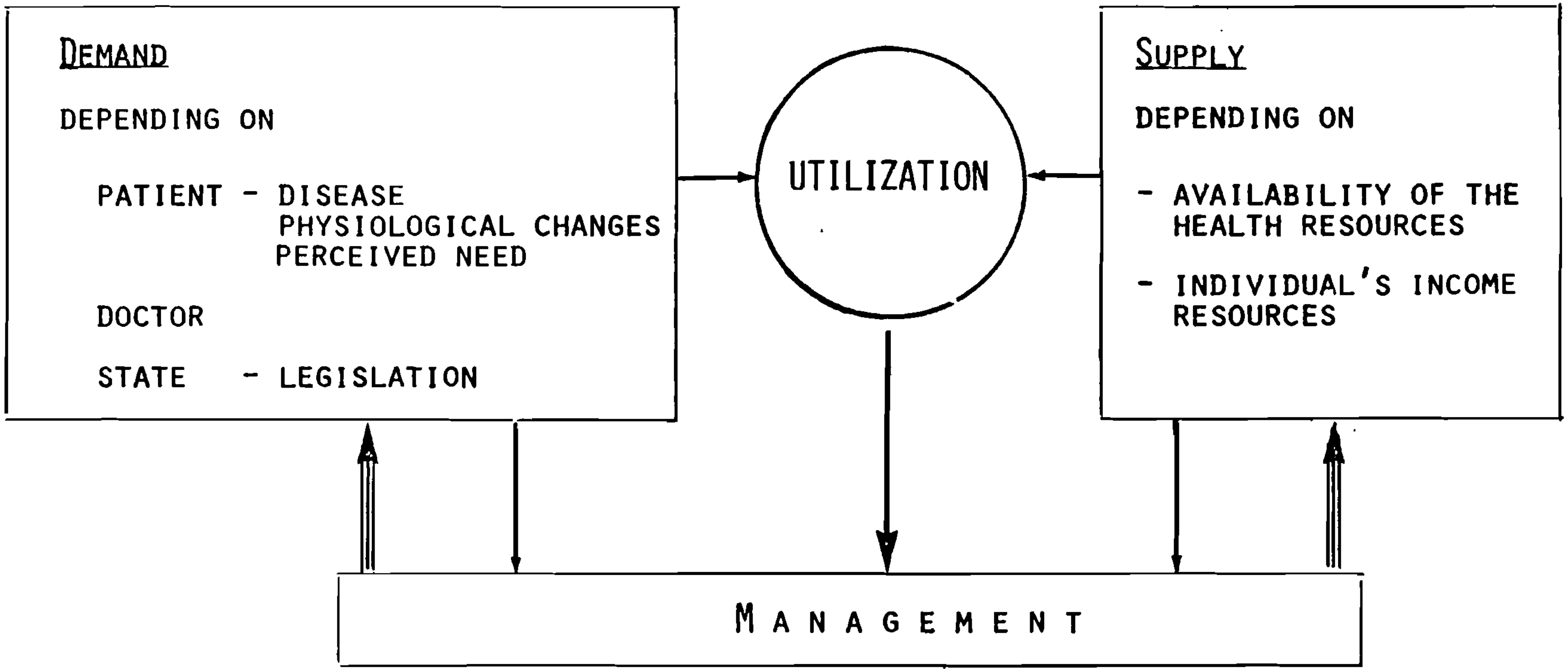


Figure 2. A block-scheme of the interaction between demand and supply in the health care system.

individual, or in general) is available for research purposes, and is used in evaluating the quality of the medical performance by medical authorities, trade unions, or other social organizations.

In contrast to this system of health care is the system used in such countries as the US.

> In the United States nearly two-thirds of the health care funds come from direct payments by individuals or from private, voluntary insurance; ownership of two out of three general hospitals is in private hands; and planning, coordination and control of services rest mainly on the voluntary initiative of the providers. Despite a far greater degree of government involvement than prevailed even two decades ago, it is still essentially a free enterprise system. (Boldy, 1975:7).

In a system such as this, there are usually some difficulties in obtaining medical information on the individual for research investigations and in estimating the quality of medical performance. Between these two different systems, many countries can be clustered and allocated.

2.2. Health Care Compensation

The compensation for health services also plays an important role in the demand and supply of health care in a country. There is much evidence of an artificial increase of health services related to a financial stimulation. At the same time, patients are very sensitive to the variation of prices for health services. For example, in California medical co-payment experiments, where individuals share expenses with their insurance companies, proved that the charge of $1 co-payment per out-patient visit resulted in a decrease of 8% of office visits per person, per quarter and an increase of 17% in length of stay in the hospital (Helms et al. 1978).

There are three different types of "payments" between patients and medical personnel (Figure 3):

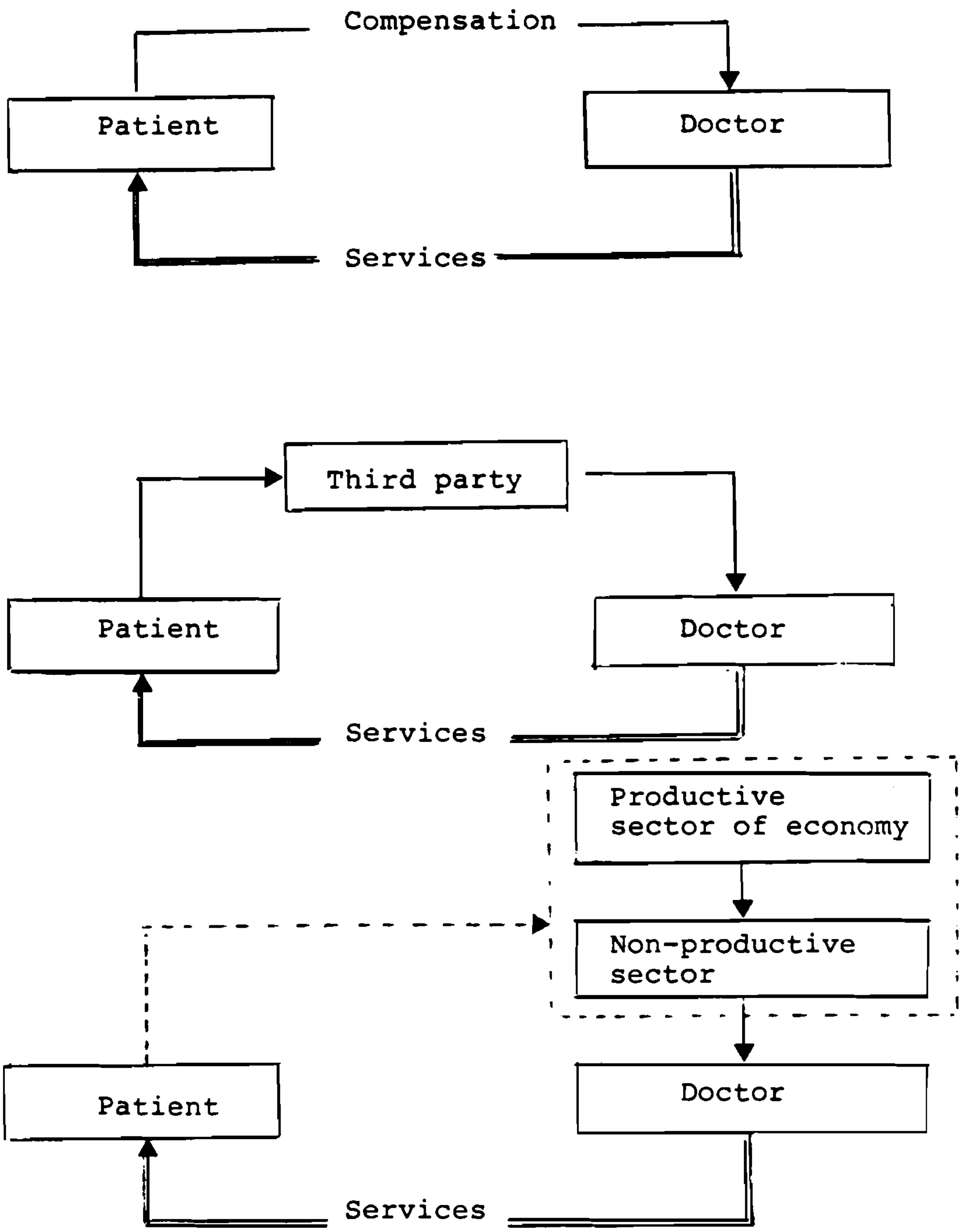


Figure 4. Different remuneration systems for health services

a. <u>Direct Payment</u> -
Simple interaction between two parties. The doctor provides services, and the patient pays money to the doctor as a compensation for his services.

b. <u>Payment through a third party</u> -
This payment could be made through a national or private insurance company, or a governmental body.

c. <u>Payment through the State</u> -
In socialistic countries, doctors receive a stable salary for their work. This salary comes from the "non-productive" (public) sector, which in turn receives money from the productive sector of the economy. A small amount of money is added to the budget indirectly from taxes.

2.3. The Individual's Income

The income of the individual also plays an important role in the health care demand-supply interaction in many countries. There is a great deal of information on the influence of income on the health of the population. For example, family income has a strong influence on the rate of disability days (Rosser and Mossberg, 1977). There are also differences in the amount and quality of health services received among families with income variations (Table 1).

Table 1. Distribution of persons receiving services from selected practitioners, according to family income.

Family Income ($)	Percentage of population receiving services from the following medical practitioners				
	Physician	Dentist	Chiropractor	Pediatrist	Physical Therapist
-5.000	58.7	33.5	3.2	2.8	2.0
5.000- 9.999	60.9	39.6	3.8	2.2	1.8
10.000-14.999	65.0	51.8	4.1	1.9	1.3
15.000 +	68.4	64.1	3.5	2.7	1.4

SOURCE: U.S. Department of Health Education and Welfare (1978:295).

2.4. The Availability of Health Care Resources

The availability of HC resources also plays an important role and should be taken into account during the investigation of health care demand and supply. Fuchs and Kramer (1972) estimated the demand problem for physician's services and found a positive elasticity (0.39) of physician's services related to the number of available physicians per capita. Davis and Russel (1972) proved that increased physician availability results in a greater use of hospital out-patient facilities as well as higher in-patient admission rates. In several Dutch studies (Rutten,1978, van der Gaag and van de Ven, 1978) the dependence of health care activities on availability of health resources are also emphasized. It was found, in particular, that for out-patient specialist care, with respect to the number of specialists, the elasticity was around 0.3, while the elasticity of bed-day utilization with respect to bed supply, was between 0.8 - 0.9. In several publications in the USSR there is some evidence showing the influence of the health care activity not only on the availability of the health resources, but also on the allocation of these resources to the particular area [see Popov (1976)]. The problem of accessibility of health resources and medical establishments is important because of large distances, geographical hinderances such as forests and mountains, and variations in population density.

2.5. Research Approaches

There are many approaches used in different countries to estimate the demand for health services. Official annual reports on health care systems provide information about the utilization of health resources as well as some data about the health of the population (mortality, temporary disability, hospital morbidity, etc.) In all developed countries, special investigations are made from time to time on the utilization of health resources in order to have a better understanding of the behavioral aspect of the health care system. Quantitative results of these investigations such as the management of resources are very important in the modeling process.

In some countries where there is a problem in obtaining individual medical information even for research purposes, interviews are conducted with patients and their relatives. Such studies help to better understand the needs perceived by the patient, the behavior of the individual, and his reasons for requiring health services (Table 2). According to the DHEW study, patients with an excellent or good self-assessment of their own health, visit the physician 4.2 times annually, those with a fair or poor self-assessment, visit the physician 10.9 times annually (DHEW, 1978:261). Because such studies (interviews, household surveys, etc.) are important in evaluating perceived needs and health care activities and in modeling, there has been developing research directed at the estimation of the reliability of such sources of information. For example, the investigation conducted by the National Center for Health Statistics in the USA compares the information derived from medical records with data from interviews (Table 3).

Such surveys are important for countries with a strong price stimulus for health care services. They are also important where the problem of confidentiality of personal information exists and researchers are forced to rely on interview data for investigating the behavioral aspect of health resource utilization. Many such studies also analyze the use of medical services [e.g. May (1975), Reinhardt (1975), Rutten (1978)]. For example, one typical study (Rutten,1978:75) examines the influence of different factors on the utilization of health care resources (Table 4).

In socialistic countries and countries with a centralized planning system, it is common to use comprehensive health care surveys incorporating examinations made by teams of medical specialists and including laboratory tests. These surveys help in the estimation of the health status of a sample of the population and in the formulation of the needs for health services as described by professionals. The purpose of these investigations is to describe all the important "blocks" of

Table 2. Self-assessment of health, according to sex, and family income: United States, 1976.

(Data are based on household interviews of a sample of the civilian noninstitutionalized population)

Age, sex, and family income	Self-assessed level of health				
	All levels[1]	Excellent	Good	Fair	Poor
	Percent distribution				
Total[2]	100.0	48.2	38.9	9.6	2.8
Sex					
Male	100.0	51.3	37.1	8.5	2.7
Female	100.0	45.3	40.7	10.6	2.9
Family income					
Less than $5,000	100.0	31.9	42.0	18.0	7.6
$5,000–$9,999	100.0	40.4	43.4	12.2	3.7
$10,000–$14,999	100.0	49.7	40.3	8.0	1.6
$15,000 or more	100.0	59.6	33.8	5.3	1.1

SOURCE: DHEW (1978:234).

Table 3. Number and percent distribution of conditions reported in medical records (PVRS)* and proportion reported in interviews, by type of match code, according to number of visits to SCPMG**.

Number of visits to SCPMG[1]	All conditions in (PVRS's)		Conditions reported in interview				Conditions not reported in interview	
			Match code A		Match code B			
	Number	Per-cent	Number	Per-cent	Number	Per-cent	Number	Per-cent
Total	6,140	100.0	2,306	37.6	1,053	17.1	2,781	45.3
1 visit	3,081	100.0	821	26.7	543	17.6	1,717	55.7
2 visits	1,281	100.0	495	38.6	181	14.2	605	47.2
3 visits	643	100.0	288	44.8	132	20.5	223	34.7
4-5 visits	639	100.0	359	56.3	114	17.8	166	26.0
6 visits and over	496	100.0	343	69.0	83	17.0	70	14.0

[1]For a relatively small number of conditions for which large numbers of routine visits were being made, such as injections for allergy, the condition was noted only once on the PVR.

SOURCE: DHEW (1967:43).

*Physician Visit Records Summary (PVRS)

**Southern California Permanente Medical Groups (SCPMG)

the demand and supply of the health care system. For example, a typical health care demand-supply survey in the USSR can be shown in an outline form (Figure 4).

As we can see from this scheme, one of the outputs of this study is the development of a set of planning standards, which could be used for normative planning for the future 5-year period. When defining these norms, one should take into account not only the present health care demand-supply utilization status and economic situation, but also the opinion of experts on health status trends and the utilization of health resources in the immediate future.

2.6. Concluding Remarks about Differences in Health Demand-Supply Interactions in Various Countries

As a conclusion to this section, it is necessary to emphasize that there are some positive as well as negative sides to the different health planning systems.

The centralized planning system together with the smooth

Table 4. Estimation results: regression coefficients. absolute T-values (between brackets) and elasticities for the number of referrals per 1000 publicly insured (1)
(C = constant, R^2 = corrected multiple correlation coefficient, N = number of regions)

	ASI x10⁴	DENSI x10⁻¹	GP x10³	SPECO (2) x10³	PINS	SPECU x10³	C x10³	R^2	N
1) linear	0.60	0.21	-0.27	0.25	2.75	-0.35	-0.15	0.48	75
1971	(1.4)	(6.3)	(2.2)	(3.2)	(3.3)	(4.2)	(0.9)		
elasticities	--	0.10	-0.30	0.25	0.61	-0.05			
2) loglinear	0.72	0.13	-0.07	0.28	0.67	-0.09	5.01	0.62	75
1971	(1.3)	(7.0)	(0.5)	(4.2)	(3.8)	(5.2)	(2.7)		
3) linear	0.79	0.16	-0.23	0.10	2.80	-0.25	-0.21	0.49	66
1973	(1.4)	(3.3)	(1.7)	(1.5)	(3.4)	(4.2)	(1.0)		
elasticities	--	0.06	-0.26	--	0.64	-0.05			
4) loglinear	1.29	0.08	-0.11	0.15	0.54	-0.07	6.71	0.59	66
1973	(1.6)	(3.6)	(0.6)	(2.0)	(2.8)	(3.8)	(2.5)		
5) linear	1.25	0.15	-0.43	0.16	2.73	--	-0.36	0.33	72
1973	(1.8)	(2.9)	(2.3)	(2.2)	(2.5)	--	(1.2)		
elasticities	1.68	0.06	-0.43	0.19	0.55	--			
6) loglinear	1.20	0.09	-0.23	0.15	0.58	--	6.41	0.42	72
1973	(1.4)	(4.1)	(1.3)	(1.7)	(2.8)	--	(2.2)		

(1) ASI — An age-sex index of the publicly insured adjusted to the consumption to be explained.

DENSI — Average population density weighed by the population shares in the municipalities.

GP — The number of general practitioners per 1000 population.

PINS — The percentage of publicly insured population

SPECO — The number of specialists providing outpatient care per 1000 population.

SOURCE: RUTTEN (1978:75).

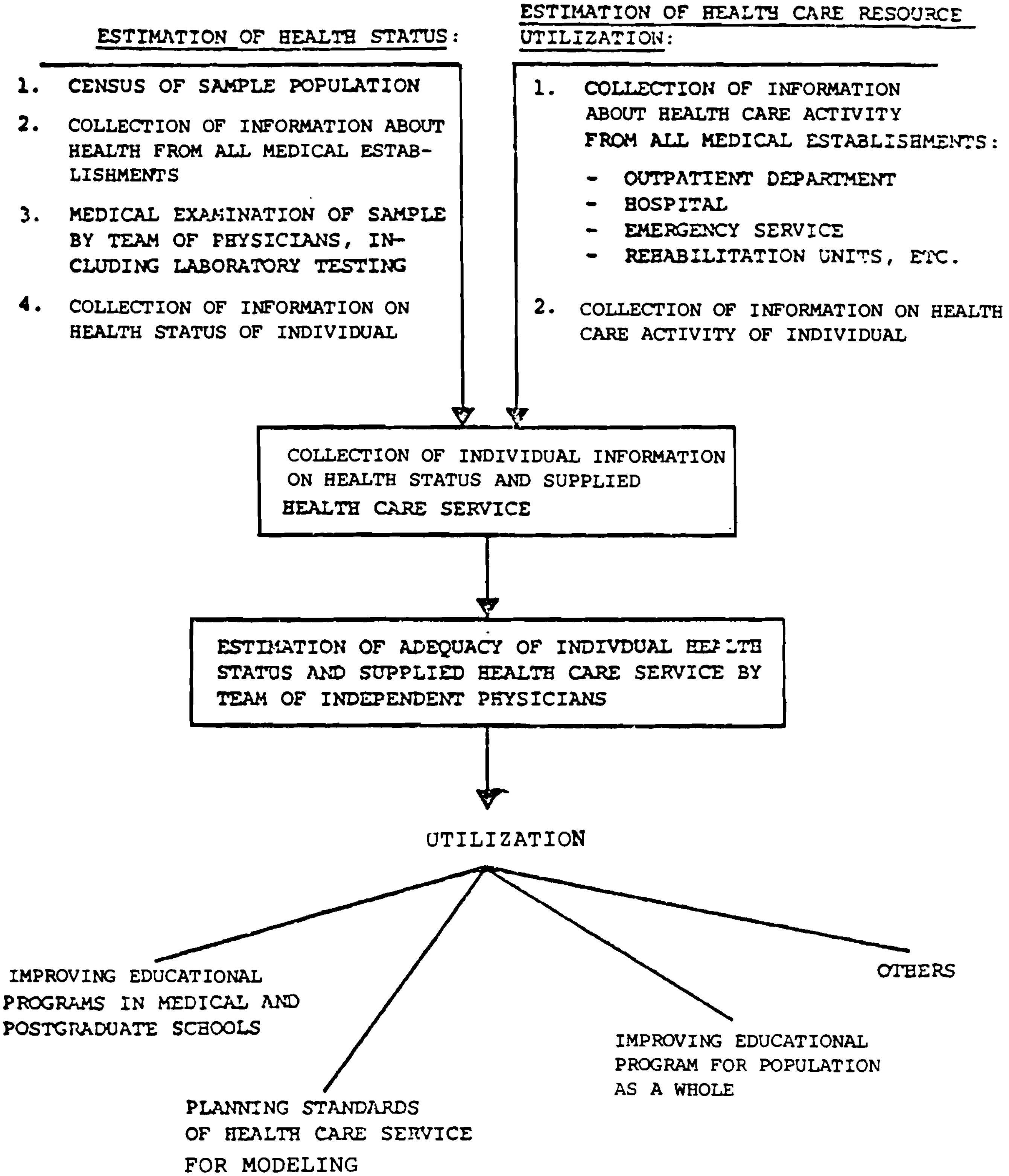


Figure 4. Scheme of a comprehensive study of health status and health services and how well they correspond.

development of health care services and equity in obtaining health care for different groups of population, has some problems (I. Pustavoy, 1976). First, there are difficulties in compiling, coordinating and making changes in current plans. Second, there are differences between the average (official) set of standards and the local(specific) standards. Third, it is difficult to test different planning alternatives.

In the case of a decentralized planning system, the regional authority has an opportunity to make more extensive investigations of health care demand-supply interactions in the particular region. He can operate more quickly with local resources but is constrained by the difference in equity of health services among the regions. At the same time, regional and central authorities have difficulties in balancing their interests.

In the case of mixed health care systems when different private insurances and state subsystems are functioning together with a positive goal such as a quick response to the first appearance of a demand or to better health resource utilization, there are some problems.

-- The total HC system is affected by the different levels of health services for different groups of the population depending on non-medical factors.
-- The HC system also has a strong dependence on private organizations, and it is necessary to keep a financial reserve for cases when these private contributions could be transferred to other sectors.
-- There always exist difficulties in organization, coordination, control, and long-term planning for HCS.
-- There is also a problem of an excess of medical resources in residences with a high-density population.

As can be seen, there are large differences in health care demand-supply interactions among countries: differences in objectives, differences in types of surveys, and differences in modeling activity.

3. TRENDS IN THE DEVELOPMENT OF HEALTH CARE SYSTEMS

Although there are large differences in health care systems among countries, it is possible to recognize some common trends in their development.

a) Health expenditures are constantly increasing in most developed countries which can be seen when these expenditures are compared to the GNP (Table 5). There is also an increase in medical manpower, hospital beds, and other medical facilities in many developed countries.

b) Planning has become an increasingly important tool in the development of health care systems. "Planning becomes considered as a means to give an opportunity to limit an abnormal increase of health expenditure" (Pustavoy,1976:55).

c) There has been a decreasing proportion of direct payments and an increasing proportion of payments made by third parties in general and especially by state authorities in particular (Table 6). Some countries are now studying the possibility of a national insurance plan which would cover practically the entire population of the country.

d) There are tendencies towards the centralization of some management functions in countries with decentralized systems. At the same time, countries with a strong centralized planning system are more and more interested in taking into account local factors, in developing not only national standards, but also regional standards. This means that the problem of balancing both the central and regional interests could be very useful for many developed countries.

e) There has been a definite turnover from general practice to narrow specialization in health care in many developed countries. The tendency toward narrow specialization is not only in manpower but also in hospital facilities.

f) There is a trend toward the interaction between doctor and patient becoming less confidential and more open

Table 5. Health expenditures as a percent of gross national product: Selected countries, selected periods, 1961–75

(Data are compiled from a number of government sources)

Country	Health expenditures					
	World Health Organization estimates		Social Security Administration estimates		Organization for Economic Cooperation and Development estimates	
	Year	Percent of gross national product	Year	Percent of gross national product	Year	Percent of gross national product[1]
Canada	1961	6.0	1969	7.3	1973	6.8
United States[2]	1961–62	5.8	1969	6.8	1974	7.4
Sweden	1962	5.4	1969	6.7	1974	7.3
Netherlands	1963	4.8	1969	5.9	1972	7.3
German Federal Republic[3]	1961	4.5	1969	5.7	1974	6.7
France	1963	4.4	1969	5.7	1974	6.9
United Kingdom	1961–62	4.2	1969	4.8	1975	5.2
Australia	---	---	---	---	[4]1975–76	6.5
Finland	---	---	---	---	1975	5.8
Japan	---	---	---	---	1975	4.0

[1] Percent of trend gross domestic product at current prices, 1974 or near date.

[2] Figures differ slightly from official Social Security Administration estimates because of adjustment to account for expenditures in medical education.

[3] Excluded from World Health Organization study. Figure for 1961 is Social Security Administration estimate.

[4] Fiscal year 1975–76.

NOTE: The countries are ranked by percent of gross national product for health expenditures from the largest to the smallest.

SOURCE: DHEW (1978:381)

Table 6. Aggregate and per capita national health expenditures, by source of funds and percent of gross national product, selected years, 1929–77

Year	Gross national product (in billions)	Health expenditures								
		Total			Private			Public		
		Amount (in millions)	Per capita	Percent of GNP	Amount (in millions)	Per capita	Percent of total	Amount (in millions)	Per capita	Percent of total
Ending June—										
1929	$101.3	$3,589	$29.16	3.5	$3,112	$25.28	86.7	$477	$3.88	13.3
1935	68.9	2,846	22.04	4.1	2,303	17.84	80.9	543	4.21	19.1
1940	95.4	3,883	28.98	4.1	3,101	23.14	79.9	782	5.84	20.1
1950	264.8	12,027	78.35	4.5	8,962	58.38	74.5	3,065	19.97	25.5
1955	381.0	17,330	103.76	4.5	12,909	77.29	74.5	4,421	26.47	25.5
1960	498.3	25,856	141.63	5.2	19,461	106.60	75.3	6,395	35.03	24.7
1965	658.0	38,892	197.75	5.9	29,357	149.27	75.5	9,535	48.48	24.5
1966	722.4	42,109	211.56	5.8	31,279	157.15	74.3	10,830	54.41	25.7
1967	773.5	47,897	237.93	6.2	32,026	159.15	66.9	15,853	78.78	33.1
1968	830.2	53,765	264.37	6.5	33,725	165.83	62.7	20,040	98.54	37.3
1969	904.2	60,617	295.20	6.7	37,680	183.50	62.2	22,937	111.70	37.8
1970	960.2	69,201	333.57	7.2	43,810	211.18	63.3	25,391	122.39	36.7
1971	1,019.8	77,162	368.25	7.6	48,387	230.92	62.7	28,775	137.32	37.3
1972	1,111.8	86,687	409.71	7.8	53,214	251.50	61.4	33,473	158.20	38.6
1973	1,238.6	95,383	447.31	7.7	58,715	275.35	61.6	36,668	171.96	38.4
1974	1,361.2	106,321	495.01	7.8	64,809	301.74	61.0	41,512	193.27	39.0
1975[1]	1,454.5	123,716	571.21	8.5	71,348	329.42	57.7	52,368	241.79	42.3
1976[1]	1,625.4	141,013	645.76	8.7	80,831	370.16	57.3	60,182	275.60	42.7
Ending September—										
1975	1,487.1	127,719	588.48	8.6	73,238	337.45	57.3	54,481	251.03	42.7
1976	1,667.4	145,102	663.06	8.7	83,560	381.84	57.6	61,542	281.22	42.4
1977[2,3]	1,838.0	162,627	736.92	8.8	94,185	426.78	57.9	68,442	310.13	42.1

[1] Revised estimates.
[2] New Federal fiscal year.
[3] Preliminary estimates.

Source: *National Health Expenditures, Fiscal Year 1977.* Gibson and Fisher (1978:5) for investigation, therefore, providing an opportunity to estimate professionally defined needs. For example, in the USA health insurance authorities collect information regarding the quality of medical care (Table 7); sometimes there are organizations especially founded for this purpose. The national peer review system to monitor medical care (Professional Standards Review Organizations, PSROs) was established with the passage of PL 92-603 (amendment to the Social Security Act) in 1972*. In socialistic countries the review of medical quality is the usual work of the medical supervisor (chief of medical department or hospital), and medical information is available for professional research.

g) There exists a growing interest in research activity due to dynamic and long-term studies.

4. MODELING HEALTH CARE DEMAND-SUPPLY INTERACTIONS

There are different approaches to modeling health care demand-supply interactions according to the management problems of the different types of health care systems and to the structure of existing information and its availability to modelers. For example, in highly developed countries with private health care systems such as the US and the Netherlands, the modeling approach must incorporate specific aspects of the system. Due to a relative resource saturation, an absence of a national HCS planning body, and confidentiality of individual medical information, the main research attention must focus on the short-term behavior of health care service management in an equilibrium situation. The modeler must take into account the possibility of a changing equilibrium in accordance with a changing resource level or environmental condition.

In countries with national health care systems that depend on the level of centralization, the aim of health care modeling consists of the creation of tools that can be used in HC planning

*See DHEW (1978:122).

Table 7. Health care coverage status, according to type of coverage: United States, 1976

(Data are based on household interviews of a sample of the civilian noninstitutionalized population)

Type of coverage	Health care coverage status			
	Number of persons in thousands	Cumulative number of persons in thousands	Percent of population	Cumulative percent of population
Private hospital insurance[1]	159,957	159,957	75.9	75.9
Medicare coverage only[2]	7,756	167,713	3.7	79.6
Medicaid coverage only[3]	12,162	179,875	5.8	85.4
Other programs only[4]	5,084	184,959	2.4	87.8
Private hospital insurance, but kind of coverage unknown	1,624	186,583	0.8	88.6
Unknown if covered	861	187,444	0.4	89.0
No coverage	23,200	210,644	11.0	100.0

[1] Includes all persons with private hospital insurance coverage whether or not they have other coverage (e.g. Medicare) as well.

[2] Includes persons over 65 years of age who have Medicare with no private coverage and persons under 65 years of age who have Medicare with no other public or private coverage.

[3] Includes persons who did not have private insurance or Medicare, and reported either (a) receipt of Medicaid services in the previous year, or (b) eligibility for Medicaid as a reason for not having other coverage, or (c) receipt of benefit payments under Aid to Families with Dependent Children or Supplemental Security Income in the past year.

[4] Includes military (Civilian Health and Medical Program of the Uniformed Services), Veterans Administration, private surgical coverage only, and professional courtesy as reasons for holding no other type of public or private coverage.

NOTE: In order to avoid multiple counting of individuals, these estimates were derived by assigning each individual to one coverage category only. Persons with both private insurance and Medicare, for example, were placed in the private insurance category. As a result, Medicare and Medicaid estimates do not correspond to counts available from those programs.

SOURCE: DHEW (1978:403)

on regional or national levels. This leads to the study of not only the static (or equilibrium) situation, but also the dynamic behavior of the health care system.

We do not pretend to make a comprehensive analysis of existing HCS models here, and shall mention only (Culyer et al. 1977), a bibliography of work done in English on health economics and IIASA publications (Fleissner and Klementiev, 1977, and Shigan et al. 1979) which allows us to propose a possible classification of health demand-supply models (Figure 5). We would like to consider several approaches of HCS modeling which illustrates the differences as well as the common features of health care management problems in various health care systems.

As mentioned above, HC modeling is based mainly on differences in the possible influences on demand-supply interactions and on differences in the structure of available information. The differences in demand-supply interactions lead to a variation in the length of the planning period:

a) Short-term planning or
b) Long-term planning

The differences in available information are:

a) Routine statistics
b) Routine statistics and periodical comprehensive studies
c) Linkage record studies: collection of medical information on an individual during his lifetime

In the framework of this paper, we would like to outline the certain directions of health care systems modeling related to the features mentioned above.

4.1. Econometric Approach

An econometric approach usually is used for short- or long-term planning (a),(b) and is based on routine statistics (a). This approach falls into broad categories relating the allocation of resources between health care facilities to health care facilities themselves. The first problem is mainly tackled with

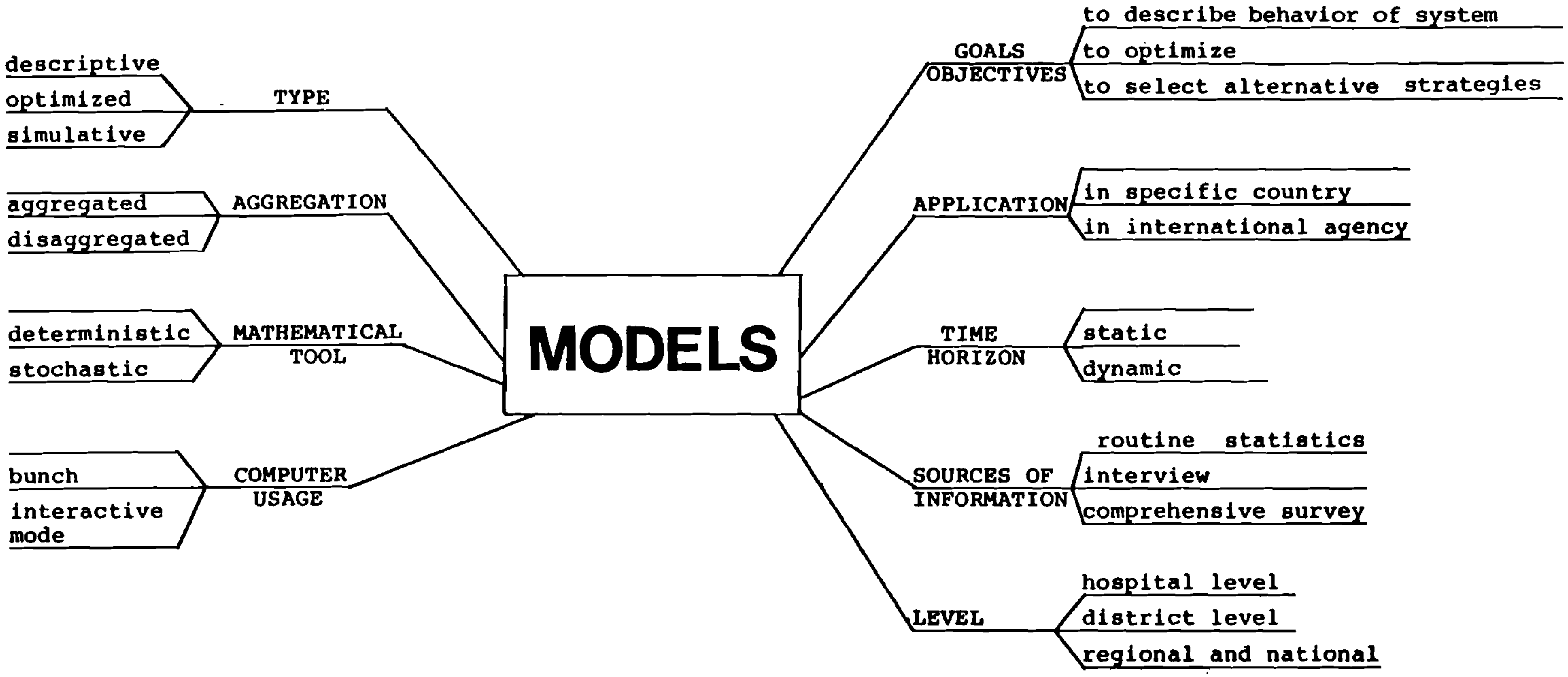


Figure 5. Classification of health care demand-supply models.

economic theory, using econometric methods to qualify relations in behavioral type models. Problems of management and efficiency within health care institutions are usually solved by modelers with operations research methods, where some objective functions are optimized under certain restrictions (Rutten, 1979).

In econometric modeling the different curves of health services demand (linear, loglinear, semilogarithmic, logarithmic, double-logarithmic, polinomial, etc.) which describe resource demand as a function of different social variables and available resources are used. Several models of this type of analysis of the use of health care facilities in the Netherlands and the analysis of physician fees and care can be found in the doctoral thesis of Rutten (1978), in the publications of the Urban Institute, Hadley and Lee (1978), and in the monograph of Yett et al. (1979). Of course the concrete models are very different in terms of exogenous and endogenous variables, but in general they focus on the determination of the relation

$$y = f(x_1, x_2, \ldots, x_n)$$

where y and x_i, $i = \overline{1,n}$, are some specific variables. For example, when describing the level of primary care the following relation is used in Rutten (1978:46,48):

$$PF1 = f(PCHO, GP, DENS, PINS)$$

where PF1 : the patient flow towards the first level of care (measured as the number of first visits to the general practitioner per 1000 publicly insured)

PCHO : a vector of characteristics of the publicly insured

GP : the number of general practitioners per 1000 population (a proxy for the capacity of first level care)

DENS: the population density

PINS: the percentage publicly insured of the population

For a description of the patient flow from the first to the second level of medical care, a similar relation is used:

PF2 = f(PF1,PCH1,GP,SPECO,DENS,PINS)

where PF2 : the patient flow from the first to the second level of care (measured as the number of referrals to the specialist per 1000 publicly insured)

PF1 : the patient flow towards the first level of care

PCH1 : the patient characteristics of the patient flow to the first level of care (characteristics of PF1)

GP : first level capacity: the number of general practitioners per 1000 population

SPECO: second level capacity: the number of specialists providing outpatient care per 1000 population

DENS : the population density

PINS : the percentage publicly insured of the population

The problem is to determine the function which is usually considered as given with unknown parameters. These parameters can be found with the help of least-squares techniques.

The difference between this approach and the one proposed by Reinhardt (1975), is the consideration of some of the utility functions as characteristics of physician behavior; but in general, the modeling approach is much the same. Such an analysis is usually static and often does not include any health indices as econometric variables. As mentioned in DHEW (1976:9) it is clear that such models "cannot mirror the complex changes that are taking place in the health care systems today. What is required is a generalized model of the health care system". An econometric analysis should be considered as an important and necessary step in the construction of dynamic health care demand-supply models. "The model should be comprehensive; it should be sensitive to the interaction of the variety of economic, cultural and demographic variables which affect the demand for health services" (DHEW, 1976:9).

4.2. Deterministic Dynamic Modeling

Deterministic dynamic modeling is used for the same planning aim (a),(b) as the econometric approach and is based not only on the routine statistics but also on periodical comprehensive studies (b). Routine medical statistics are in some way an extension of demographic statistics. They include such indices as sex, age, place of residence and also medical indices which reflect the health status of individuals. This is the reason why existing dynamic HCS models either include demographic sub-models or are extensions of demographic models that include health status elements (see for example, Fleissner and Klementiev, 1977 and Shigan et al., 1979).

The main feature of such models is the consideration of the fact that the population can be classified in different groups for receiving health services. These groups can be distinguished by age, sex, income, type of insurance, type of disease, stage of disease, etc. For the case of HCS in the US, physicians are viewed as treating four types of patients:

1. Medicaid
2. Medicare assigned
3. Medicare non-assigned
4. Non-medicare; non-medicaid

as shown in Hadley and Lee (1978:9). These four groups are then aggregated into subgroups according to demographic classifications such as age and sex. When the results of comprehensive studies as well as routine statistics are available, some "unobservable" categories can be introduced to the model to describe the dynamics of the individual's behavior in the HCS. In this case, in addition to demographic categories, it is possible to consider the following health categories:

- -- Healthy
- -- Latent
- -- Out-patient
- -- In-patient

These categories may then be divided into subcategories, according to the type of disease, stage of disease, or type of service required [see for example Petrovsky et al. (1978), and Lave et al. (1974)].

From the mathematical point of view, the dynamics of the population group can be equally described by a system of partial differential equations or by the ordinary difference equation. A further example of this type of modeling (Zemach, 1970) considers the cost of personnel, building space, technological equipment, and health requirements for the individual. We are not going to deal with the detailed description of these models. For the purpose of this paper, it is more important to emphasize the main problems which arise at the evaluation stage of such models.

The first problem is the identification of the rate of change from one category to another using annual routine data available in most countries. Using these data, one can determine relatively easily the exchange rates and which model is appropriate for the implementation of such rates in order to allow us to forecast the size and extent of these population groups. However, if we consider this problem from a resource need and allocation point of view, we will encounter at least two problems. First, it is very difficult to estimate the transition rates (among the health categories) as the function of resources used in given categories, and hence it is difficult to use such tools for the direct modeling of resource allocation. Second, the same transition rates between the population categories can be obtained (from annual data) for completely different "individual" transition rates. This may lead to an incorrect estimation of resource needs, because the particular resource need strongly depends on the number of individual transitions from one type of service to another.

The latter problem is closely related to problems in social demography [Taeuber et al. (1978)] especially in the study of morbidity and multiregional migration. To overcome these difficulties, it is necessary to consider the possibility of stochastic modeling which can take into account the behavior of individuals and from this find the natural combination of data and a logical aggregation of results from linkage record studies.

4.3. Stochastic Dynamic Modeling

Stochastic dynamic modeling is used for long-term planning based on routine statistics and linkage record studies. As mentioned above, in many cases it is necessary to take into consideration the fact that each individual can change "groups" many times during his lifetime. A person moves from one age group to another, he can be affected by different diseases, or he can be covered by different types of health insurance. All causes of movements from one group to another could be divided into two types: subjective and objective. The subjective type includes such causes as the desire of the person to change groups, i.e. the type of health care service that he has. The objective type reflects the development of the individual's health status depending on the aging process or the stage of disease.

In developing a pathological analysis, there are several stages: healthy, latent, disease, and death. Each individual could be allocated to one of these stages with the help of different methods. These methods can be divided into two groups.

-- The first method is the use of international classifications of diseases in order to divide the population into several subcategories after a classification has been made by multiphase screening, medical examination, and laboratory testing. The precise list of the ICD three-digit categories would be included in the model, and since the ICD code is internationally accepted, it is a feasible approach for an international comparison, model-building process.

-- The second method includes the use of a set of different socio-economic, biological, and other risk-factors in order to estimate mathematically the probability of having a disease or dying and to classify the population into risk groups. But unfortunately this approach, which is more accurate for specific regions and time, strongly depends on how many and which factors are selected for classification. These factors could be very important for one locality and not so important for another, or they could be important for the present but not for the future.

Depending on the aging process, the development of illness, the appearance of new diseases, or the different risk-factors, individuals could move from one group to another in either direction, excluding the terminal groups (Figure 6).

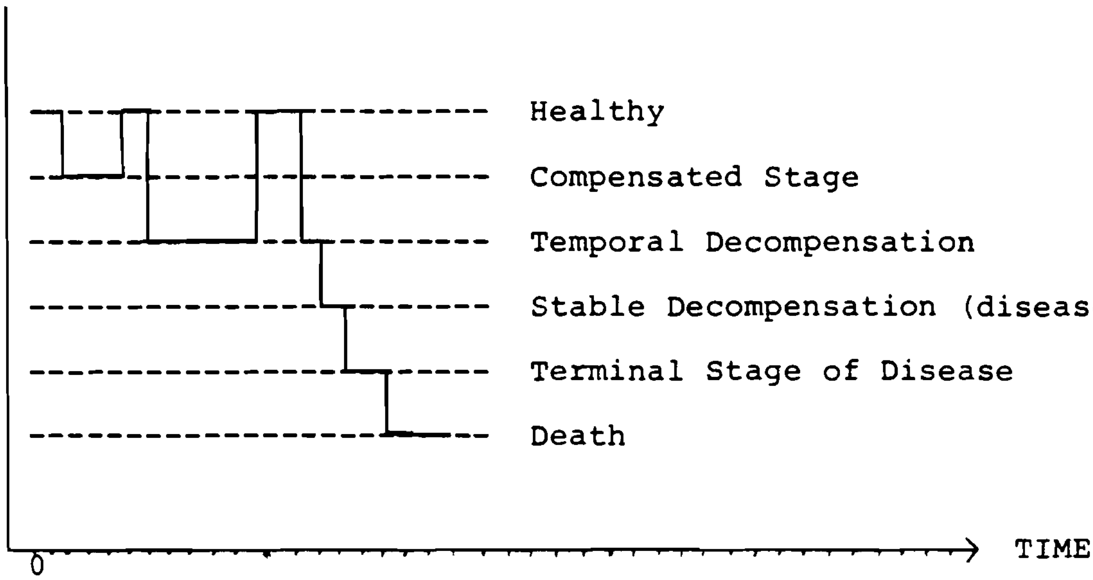


Figure 6. The profile of an individual's health history.

Linkage record studies allow one to obtain statistics about all persons being considered in the analysis. This information can then be used to estimate the classification of the whole population into different groups over time.

What type of mathematical model should be proposed for a formal description of the real process of an individual's health history as shown in Figure 6?

Taking into account two main features of this process, i.e. random moment of group exchange and piecewise trajectory, we inevitably come to the conclusion that such processes should be described by a so-called step-wise process. In fact, in the theory of social demography [Taeuber et al. (1978)] and in the modeling of social processes [Bartholomew (1973)], the Markovian step-wise processes are widely used for description of population mobility. The necessary condition required to apply Markovian models is knowledge of transition probabilities. It is one of the main tasks of mathematical modeling to define the probability properties using available sampling data. Let us consider an example [see also Yashin and Shigan (1978)].

Denote by ξ_t the history of the individual's transitions among the m health categories and the set of transition-intensity matrices $\{\lambda_{ij}^{\theta}\}$, whose elements depend on the unknown parameter θ, and accept one of the n possible values, with certain *a priori* probabilities P_i. This parameter is chosen just to distinguish the different possible intensity matrices $\{\lambda_{ij}^{\theta}\}$.

The question is how can we estimate the intensity matrix (e.g. the transition probabilities) from the history (linkage record study of individual) for a given time interval [o,t]. It is possible to show that under the Markovian assumption, *a posterior* probability distribution $\pi_j(t) = P(\theta=\theta_j/\xi_o^t)$, where ξ_t is the observed realization, can be found as the solution of the following equation:

$$\pi_j(t) = \pi_j(0)+\int_0^t \pi_j(s-)\left\{\lambda^{(\theta_j)}_{\xi_{s-},\xi_s} - \bar{\lambda}_{\xi_{s-},\xi_s}\right\}ds$$

$$+ \sum_{\tau_i\leq t} \pi_j(\tau_i-) \frac{\left\{\lambda^{(\theta_j)}_{\xi_{\tau_i-},\xi_{\tau_i}} - \bar{\lambda}_{\xi_{\tau_i-},\xi_{\tau_i}}\right\}}{\bar{\lambda}_{\xi_{\tau_i-},\xi_{\tau_i}}} ,$$

where $$\pi_j(s-) = \lim_{t\uparrow s} \pi_j(t)$$

here τ_i is moment of transition from one group to another, and $\overline{\lambda}_{i,j} = E(\lambda_{i,j}^{\theta}/\xi_o^t)$ is the conditional expectation of intensity λ_{ij}^{θ}. We then have

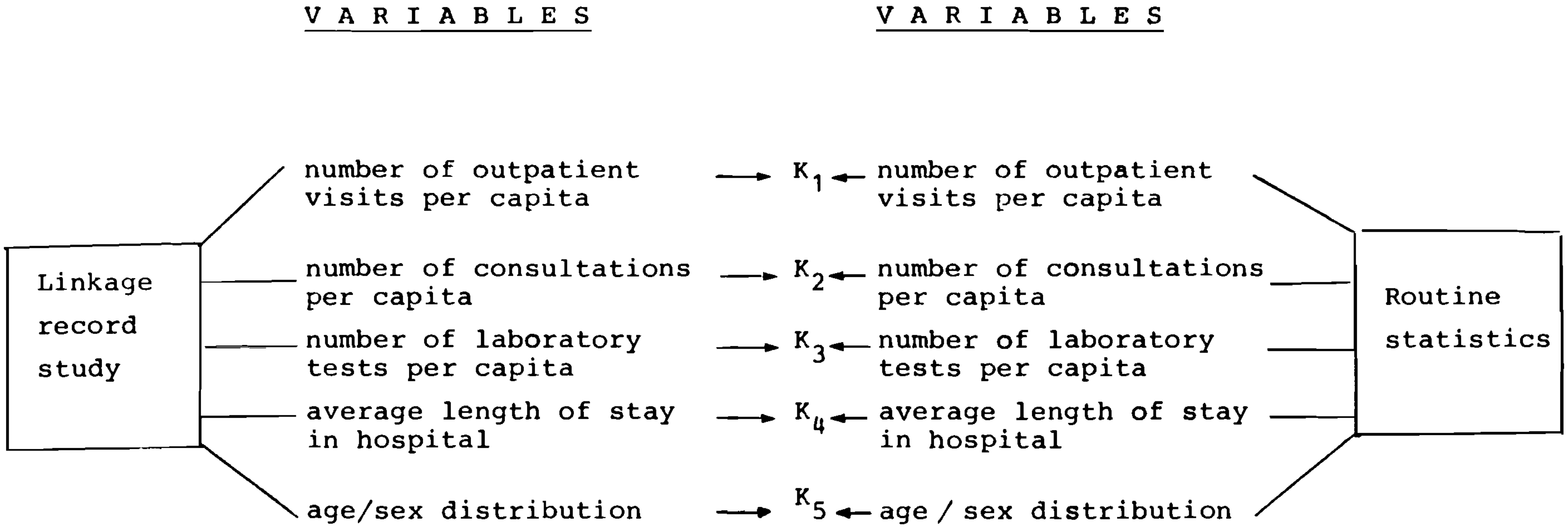
$$\overline{\lambda}_{ij} = \sum_{k=1}^{m} \lambda_{i,j}^{\theta k} \pi_k(t)$$

A similar equation can be obtained in more general, even non-Markovian cases. Using this approach, we can select the correct transition matrix. The comparison of different transition matrices, which can be obtained for different resources of treatment in various regions, will allow us to obtain the real measure of resource efficiency and the dependence of exchange rates on the resource supply in different regions in an aggregative model.

The consideration of this approach is only an example of how data can be used in individual health care demand-supply modeling. We would like to emphasize that different methods can be used in the creation of a stochastic dynamic model which will forecast population health tendencies by region, and thereby supply information that will aid in the allocation of health resources and test several planning alternatives.

Unfortunately, a linkage record study is very expensive and difficult from the managerial point of view. That is why even in developed countries, there are not many examples of such ongoing permanent investigations. Nevertheless, models of this type are still beneficial when routine data are used (Figure 7). Comparison of these indices and their distributions leads to the estimation of the correction coefficient which can then be used not only for building dynamic models of health care systems in specific regions, but also for the estimation of health demand-supply interaction for other regions.

The general scheme of health care demand-supply interaction as it is now being studied at IIASA is shown in Figure 8. In addition, such a model allows us to estimate health care systems in regions other than those having linkage studies.



K = Coefficient for correction

Figure 7. Comparison of variables taken from comprehensive studies with official reports.

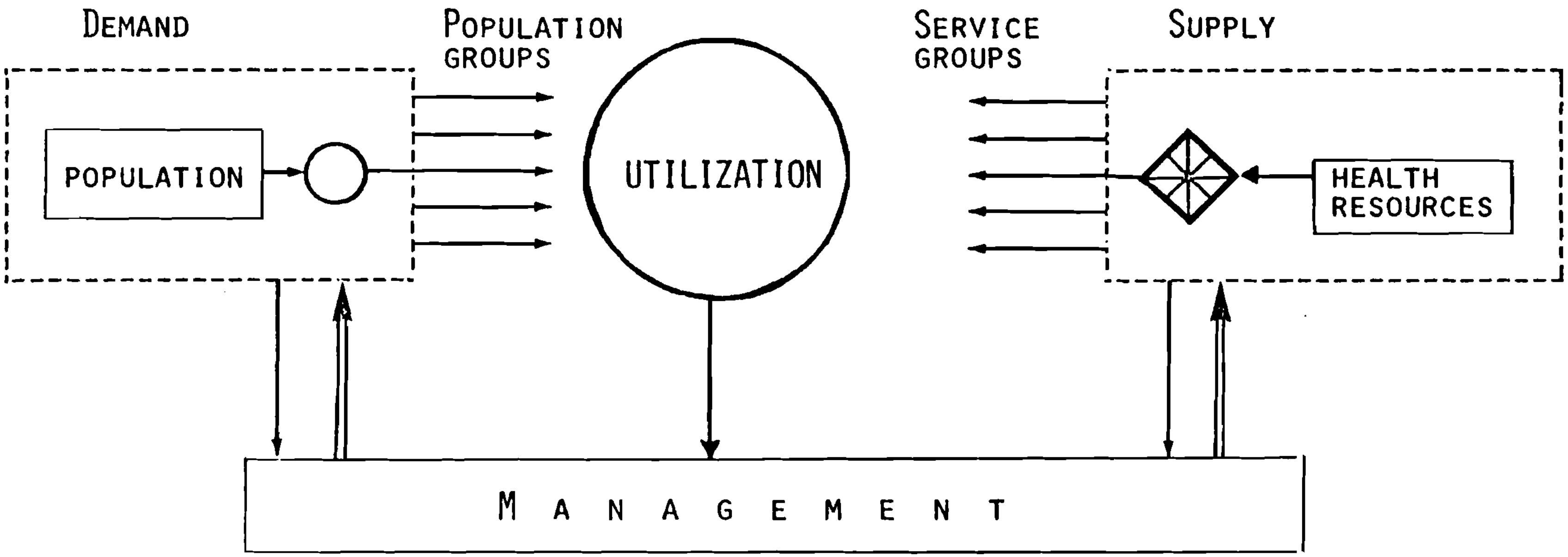


Figure 8. The scheme of health demand-supply interaction.

5. CONCLUSION

In spite of many differences in organizing health care systems, there are some features that create a basis for the development of a common approach which can be applied to the modeling of health care systems. The advantage of this approach is that for all countries, populations are divided into groups according to their health care needs and resources.

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