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A SYSTEMS APPROACH TO HEALTH CARE

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1. Introduction and Background

Health care in modern society is a complex public functional system, closely interrelated with all spheres of social life. The general goals of health care are formulated in the fifth long-range WHO program, which states:

> Public health services face three major problems: carrying on medical research and accumulating medical and biological knowledge as the only feasible basis for all complex measures aimed at protection and improvement of man's health; taking comprehensive individual and public measures on diseases, prevention and environment normalization; providing all population with the opportunities of modern diagnostics in case of the emergence of diseases, appropriate treatment of these diseases and restoration of people's working abilities [15].

The above formulation of health care general objectives is a starting point for the present paper. To carry out these objectives, it is not yet possible to move on to the formalization of processes and states within a specific complex dynamic health care system and its separate subsystems. We wish to formulate a systems approach, and therefore solutions to health care problems require the elaboration of an overall strategy one could follow when formally describing and investigating a specific health care system. Without an overall strategy, such things as comparative studies of different health care systems are impractical.

In this paper the strategy of a systems approach to health care has been constructed while keeping the following in mind:

1) In modern science the most promising methodological direction in the study of large, complex developing objects (dynamic systems) is the systems approach.

2) Systems analysis of a complex developing object can be carried out in one of two ways. The analysis is either a declarative statement on the systemic nature of the object, or it is a true systems approach. The true systems approach aims both at studying the object under investigation as a whole,

with the environment, and at investigating the object's structure with the variety of interactions and interdependencies of its components.

Systems analysis of a complex dynamic object is inconceivable without application of mathematical methods and a large computer.

3) The use of a health care dynamic model implies elaboration of a man-machine dialogue procedure. This means that decision making at the highest level of health care management will not be based on primary information from the set of system parameters but based on the feasibilities of the alternative projected decisions.

4) With respect to methodology, systems analysis of a complex developing object implies, as a basic step, building a dynamic model of a real system. This model, to an approximate extent, reproduces the real system behavior in response to a number of external and internal impacts with regard to the given system.

5) This representational property of dynamic models permits us:

a) to anticipate the development of both the real system as a whole and each of its subsystems, provided that the internal and external impacts are invariable; and

b) to envisage the reactions of the system and each of the subsystems to new impacts on either the whole system or on some of its subsystems, including the reaction to alteration of the system structure.

Lately, some articles in popular scientific literature compare dynamic models to a "time machine." Despite the tenuousness of such comparisons, there is a rational kernel in them. In managing large systems, one quite often runs into situations in which top managers have to make decisions, the results of which will be seen clearly only much later. Dynamic models allow us to "foresee" major consequences before the decisions have been made. Moreover, dynamic models can show the reaction to interference, to managerial influence not only in the particular area they are meant for, but also in the relevant adjoining areas, parts and units of a large system (in the nature of an echo).

Proceeding from these general prerequisites, the main principles, approaches and phases of building the dynamic model "Population Health Protection" were formulated. The model's central part is a number of subsystems aggregated under the name of "Health Care System."

The development of economic-mathematical modelling techniques within the past decade first required the classification of research phases. In cases where one investigates a large object which is intricately organized and interacts with the environment in a complicated way (social or biological organisms, a large community of machine systems, national economic branches and, in our case, health care systems) dynamic macromodels are used. The modelling process consists of two stages: research and application, between which a great deal of work in data processing is required to make traditional data available to the model.

The major problems of the research stage are:

a) identifying the structure of the object to be modelled;

b) studying functional interrelations among the object's components;

c) identifying and formalizing causal-consequential relationships both inside the object and with the "environment" in the form of mathematical ratios;

d) identifying indices quantitatively characterizing these relationships;

e) creating a principal block diagram of a dynamic macromodel of a real system.

The major objective of the macromodelling research phase is identifying internal mechanisms of the modelled system processes to determine methods for their most efficient control. Therefore, at the research stage, the model can be fleshed out with relative numerical information which crudely reflects reality.

The results of the research phase must be:

1) increase in the volume and depth of our knowledge of the real object;

2) identification of controlled and uncontrolled variables;

3) identification of variables which are controlled but change little under the influence of external and internal factors;

4) identification of variables which are sensitive to impacts;

5) identification of information "delays" which

influence managerial decision making and the state of the whole system;

6) identification of "decisive rules" in the management unit.

The dynamic macromodel, derived as a result of such work, is a starting point for an applied phase--the solution of concrete problems posed by the scientific management of a large system. Furthermore the work required to reach the applied model stage gives an instrument which can be used for solving other applied problems of decision making.

It should now be emphasized that between the creation of an abstract or very crude dynamic model such as that for "Protection of Population Health," that is between research and its application to the solution of concrete problems, great work is required. As mentioned above, this work consists in transforming traditional statistic data which the health care system possesses at present to a form in which it is available for the model's use.

For our particular case the dynamic model "Protection of Population Health" is the highest stage in the complicated hierarchical system of processing and transforming the data circulating now in health care. This data processing consists of a number of successive phases:

a) Traditional statistical annual reports give numerical representation of mortality and sickness levels for different diseases, the degree service provision with personnel and material technical resources and other most important data. They are all included in the model as components.

b) The analysis of dynamic rows, that is annual report data for ten to twenty years, allows the modelling of <u>trends</u> and <u>tendencies</u>. Simple mathematical models such as the exponential and logistic are also necessary components of a dynamic macromodel.

c) Statistical analysis permits the verification of hypotheses pertaining to the revealed <u>causal-consequential relationships</u>.

d) A few studied causal-consequential dependencies give the opportunity to create <u>statistical submodels</u>.

e) Bringing together all the above mentioned data permits the design of an information basis of a dynamic model or, as we shall call it later, to fill in, to "saturate" a dynamic model with real data. Upon saturation with real data, the model will begin to solve a wider range of applied problems.

The second stage of the modelling process is the application of a model to the solution of concrete problems. Now, it is next to impossible to make a full list of the problems (and maybe it is not even sensible at the present) which can be solved using the dynamic macromodel "Protection of Population Health." However, using the experiences of those building similar models in economics, one can enumerate major problem sets which can be solved by means of a dynamic model:

1) a precise and motivated foundation of resource needs for a health care system;

2) the optimal allocation of funds assigned to a health care system;

3) an analysis of the current system state with an evaluation of its resources and potentialities for a large area and its subregions;

4) the possibility of obtaining predictions on system development and predicting the consequences of decisions; and

5) demonstrating the advantages of this or that health care system.

But now returning to a consideration of the research phase of the model, it, in our opinion, is only the first step of a long task. It is impossible to see the end of the task in the visible future because the established scheme of the model envisages unbounded possibilities of greater and greater detailing of the whole model and each of its subsystems and the possibility of introducing newer subsystems into the model. The model can have a feedback system built in. The only obstacle in the way will be the lack or insufficiency of quantitative data to "fill in" the dynamic model.

Obtaining necessary information, filling and developing the model will require not so much the efforts of separate health care researchers as the efforts of relevant medical institutions and systems analysis specialists. Thus, the dynamic model "Protection of Population Health" in the course of its development can and must acquire one more most important property: It must begin to perform the functions of a coordinating mechanism in the scientific process of studying health care organization and activity. The model will practically begin to "dictate" the demand for creating particular mathematical models, for identifying the relations among different, variable parameters. It will reveal the need for unavailable or insufficient data.

In other words, elaboration of the dynamic model "Protection of Population Health" will eventually have a snowballing effect, and the activity of a few enthusiasts will become the cause which will involve the efforts of all types of specialists in health care organization. Now that we have described the modelling process, let us turn to the actual model under development.

2. The Structural Scheme of A Health Care System

The health of a population is determined by living factors such as social-economic and natural conditions, and by the activity of a health care system. The health care system, in its turn, is influenced by changing conditions in the "environment," including social and economic changes in the society. The scheme describing major factor interaction in the health care system is given in Figure 1, and it contains the main unit "Health of the Population" and three influencing units.

Most thoroughly represented in the structural scheme is the unit describing the health care system itself. In the functional sense, this unit is represented by the subunits "management" (1), "science" (2), "prevention" (3) and "treatment" (4).

Each of the subunits (1)-(4) is described by the set of performed functions. The functions are also indexed, e.g. the functions of subunit (1) are marked by indices 1.1, 1.2, etc.

The health care system activity is maintained with the use of personnel and material and technical resources. Funds, assigned to health care development are allocated by the managing unit to meet the requirements of science, prevention and treatment. In addition, the managing unit (1), influences the current activity processes of the units "science" (2), "prevention" (3), and "treatment" (4). Through the managing unit the results of scientific investigation are put into practice. "Other functions" are grouped in subunit (5).

The other two interrelated units "social-economic conditions" (6) and "natural conditions" (7) are detailed to a lesser degree. These units are described by some characteristic sets, the choice and order of which can be considered tentative in the present scheme. For example, to describe social-economic factors (6) such indices are chosen as population (6.1), the country's development (6.2-6.5) and indices determining national income (6.6).

Indices of living conditions depending on the national development level and national income are also taken into account (6.6-6.11). The health of the population is determined by four index groups (demographic characteristics, mortality and prevalence of diseases, disability and physical development of the population).

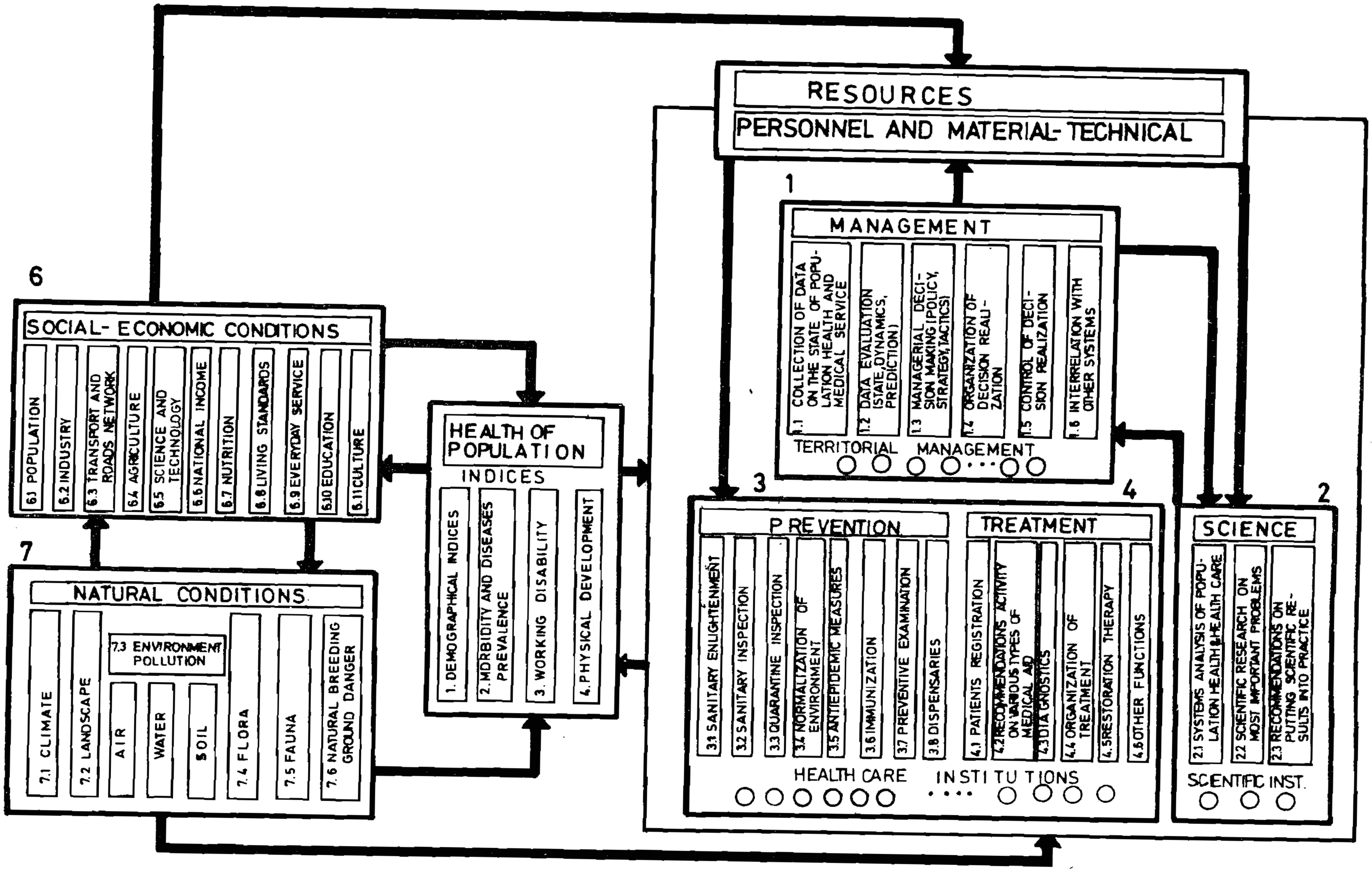

FIGURE 1. FUNCTIONAL-STRUCTURAL SCHEME OF A HEALTH CARE SYSTEM.

There are over forty elementary units in the scheme. The system of their mutual influences is illustrated by a 43 × 43 matrix which is given in Figure 2. Each line of this matrix characterizes the influence of an element upon elements of corresponding numbers in the rest of the scheme--that is the influence of these or those quantitative indices, which characterize the element under consideration, on quantitative variables characterizing the rest of the elements.

The degree of influence obtained by the use of expert estimates is fixed in the corresponding matrix cell in the following way:

- there is considerable influence: symbol 2;
- there is marked influence: symbol 1;
- influence availability is doubtful: symbol - ;
- there is no influence or it is too small: no symbol at all.

3. Health and Health Care Indices as Quantitative Characteristics of the Major Unit Activity

A group of experts in the USSR has paid a good deal of attention to the problem of quantitative description of the major unit activity in the scheme of population health protection. The types and frequencies of indicators are as follows:

a)	health of population	19
	health care resources	16
	health care management	21
	territorial management activity	15
	science	24
	prevention	40
	treatment	19
	other functions	8
	health institution activity	24
	health of population and health care (total)	186

FUNCTION OF THE SYSTEM			MANAGEMENT						SCIENCE			PREVENTION								TREATMENT					SOCIAL ECONOMIC CONDITIONS											NATURAL CONDITIONS						HEALTH OF POPULATION			
			1.1	1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	4.1	4.2	4.3	4.4	4.5	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	6.10	6.11	7.1	7.2	7.3	7.4	7.5	7.6	1	2	3	4
MANAGEMENT	1.	1.1	X	2	2	2	2	2	2	2	1																																		
		1.2	2	X	2	2	2	2	2	2	1																																		
		1.3	2	2	X	2	2	2	2	2	2																																		
		1.4	2	2	2	X	2	2	2	2	2																																		
		1.5	2	2	2	2	X	2	2	2	2																																		
		1.6	2	2	2	2	2	X	2	2	2																																		
SCIENCE	2.	2.1	1	1	2	2	1	2	X	1		—	1		1	2	1	—				1	1	—																			—	—	
		2.2	1	2	2	1	1	2	1	X	1	2	2	2	2	2	2	2	2	2	2	2	2	2																					
		2.3			1	1	1	—			X	2	2	2	2	2	2	2	2	2	2	2	2	2					1		1		1		1		1				1	—	1	1	1
PREVENTION	3.	3.1										X			1	2	2	2	2	1				1							1		1		1			1					—		1
		3.2			2	2	2	1		1	1	1	X	1	1	2	1	—	—							1	1	1			1		2					1			2				
		3.3			2	2	2	2		—		1	1	X	1	2	2	1	1	1	1	1	1			1	1	1			1		2					1			2		1		
		3.4						2					1	1	X	1	—								1						1	2	1			1	1	2	2	2	1	-	1	-	1
		3.5						1		1	1	1	1	1	1	X	2	1	—	1	1	-	1	—	2	1	1	1			1		1					1		1	1	1	2	—	
		3.6															X				1	1	1																			1	2	1	
		3.7											1	1		1	1	X	2	1	—			1																			2		
		3.8														1	1	1	X	2	2	1	2	2																		1	2	2	—
TREATMENT	4.	4.1														1	1	1	1	X	1	1	1	1																			1		
		4.2															1	1	1	1	X	2	2	1																					
		4.3															1	1	1		1	X	2	1																			1		
		4.4														1			1				X	1																		2	2	2	—
		4.5																	2					X																		—	—	2	
SOCIAL ECONOMIC CONDITIONS	6.	6.1	—	—	—	—	—	—														-			X	1	1	1	1	1	1	1	1	1	1			2	1	1	1	2	2	2	2
		6.2	1		1	1		1											1						2	X	1	1	1	2	1	2	2	1	1	2	1	2	2	2	1	1	1	1	1
		6.3	1		1			1								1			1	1			—		—	—	X	1	—	1	1	2	2				1	2	1	1		2	1	1	—
		6.4						1											1						1	1	1	X	—	2	2	2	—	—	—	1	2	1	2	2	1	1	—		1
		6.5	1	1	1	1	1	1	2	2	2				1											2	2	2	X	1	1	1	1	1	1			2	2	1					
		6.6			1	1		1	1	1	1				1	1									1	1	1	1	1	X	2	1	1	1	1							2	—	1	
		6.7						1															1	1	1						X	2										1	1		2
		6.8						1		1		1												1	1					1	1	X	1	1	1							2	1	1	1
		6.9						1					1	1	1	1	—		—												1	1	X		2		1	1	—	—	—		1		
		6.10			—	—		1	1	1	1	1						1	1					1	1	1	1	1	1	1	1	1	1	X	1							1	1		
		6.11						1	—	—	—	1	1												1				1			1	1	1	X							—	—		—
NATURAL CONDITIONS	7.	7.1										—	1	1	2	1		1	—					1	1	1	1	1	1		1	1	1			X	1	1	1	1	1	1	1	—	1
		7.2										1	1	1	1	1		—	—						1	1	1	1	1	—	—	—	—			1	X	1	1	1	1	1	1	—	1
		7.3										1	1	1	2	1	1	1	1						1				2				1			2	1	X	1	1	1	—	1		
		7.4													1										1	—	—	1		1	1					1	1	1	X	1	1	1	1	-	1
		7.5										1	1	1	1	1	1	1	1						1			1		1	2	1	—			1		—	1	X	2		1		1
		7.6										2	2	2	2	2	2	1	1						1			1	—	—			1	1	—			1	1	1	X	—	1		
HEALTH OF POPULATION	8.	1	1	1	1	1		1	1	2	1	1	1	1	1	1	2	1	1	1	—	—		—	2	1	1	1	1	1	1	1	1	1								X	2	2	1
		2	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	2	1	2	2	2	2	—	—	—	—				1	—									1	X	1	1
		3	1	1	1	1		1	1	1	1							1	1	—	1	—	1	2		1	-	1				1	—	1	1							1		X	1
		4	1	1	1	1		1	1	1	1	1	1					1	1	1	1	—	1	1	—	1	1	1	1	-	1	—	—	—	—								1	—	X

FIGURE 2.

MATRIX OF DIFFERENT FUNCTIONS INTERRELATION.

b) social-economic conditions (total) - 120

c) natural conditions - the indicators are not included.

4. On Some Approaches to Health Care Modelling on a National Scale

Health care system managers in countries with different economic systems base their decisions regarding system development on different strategies. The simplest strategy is based on intuitive knowledge of the system process development and consequences of the decisions made.

But an intuitive model, being non-rigorous and subjective, does not permit consideration of different project variants of strategic decisions. Because of this inability, the need for studying different strategic variants of health care system development with regard to the system's interaction with other social-economic and natural subsystems has become very pressing. This need accounts for the current heightened interest of health care managers in the systems approach to studying relevant processes.

For our purposes, the most important aspect of a systems approach is the modelling of process dynamics in the health care system (HCS). Now let us review some national health care modelling approaches attempted by others. In his paper on the Austrian health care system, P. Fleissner [8,9] has studied a model that permits us:

- to predict the mortality level in the country for a period of up to twenty years;
- to base necessary expenditures on index dynamics, the strategies of HCS development being different; and
- to study the influence of demographic structure on index dynamics in HCS.

The model consists of the following subsystems:

a) economic subsystem;

b) demographic subsystem;

c) health care system proper; and

d) management subsystem.

The model is run under the conditions of different given strategies of branch development, and the strategies are considerably conditioned by the social-political system.

In the first run, the "reformist," HCS is supposed to be financed by the state; there is an inclination toward preventive medicine. In the second, the "conservative" system, HCS financing is private, and preventive medicine is deemphasized. In the third, "revolutionary" system, production and medical services distribution come from the needs of society; HCS is financed by the state. In the fourth, "reactionary" variant, HCS management is decentralized, and contains no prevention component. Qualified medical aid does not encompass the entire population. In the fifth, "standard" variant, it is presumed that branch policy is not quite certain. The tendencies of the branch development are conservative. The state of each of the above subsystems is characterized by a certain set of indices.

The interrelation of different subsystem indices is identified in the structural scheme and is represented by a system of equations whose total number in Fleissner [8,9] is over one hundred.

Following are some of the major indices which describe the HCS behavior. The demographical unit of the system contains the birthrates and mortalities in different sex and age groups. The economic unit is described by the level of individual and public consumption, the price level, income per capita, etc. The health care unit contains indices which characterize the number of hospital beds, medical personnel, the registered mortality for different diseases, etc. The nature of the index interrelations is postulated by the author. The interrelation parameters are usually determined by means of statistical analysis of the corresponding initial data. The research carried out with the use of this model allows the author to study the effect of different HCS development policies on the indices of mortality, physicians employment, resources, demands, etc.

At present, a few people (G.J. Deboeck [3,4], M. Piot and T.A. Sundersan [7], Sundersan [13,14] are carrying on research on national health care modelling under the aegis of WHO. Their approach to modelling is also based on studying interrelations in HCS and the related social-economic subsystems.

Their main difference from Fleissner consists in the fact that they use other model variables, and take into consideration and postulate different types of interrelationships.

Other researchers have introduced still different approaches. For example, Abernaty et al [1] present a calculation procedure for medical institutions allocation in a given region. The procedure allows one to give recommendations on optimal allocation for these institutuions from the points of view of different criteria. A. Letourmy [12] investigated the impacts of medical service volume and the environment on the population mortality in the fixed region. The type of variable interrelations is given in the form of the Cobb-Douglas function. Unknown coefficients are estimated.

From the methodological point of view, one can see certain likenesses among different approaches to HCS modelling. The likenesses are in the fact that the authors do not consider HCS in isolation; but, in interrelation with other social-economic subsystems, they describe a model functioning by means of similar variable sets characterizing the HCS state (indices).

5. Dynamic Model of a Health Care System

The proposed dynamic model of a health care system (HCS) is meant for making predictions on the system development, elaborating policy variants in health care and serving as a subsidiary instrument for making decisions which will ensure admissable activity for this system. The initial material needed is statistical population health data and indices of the state and dynamics of the social-economic subsystem and natural environment subsystems. It also includes experts' evaluations of those characteristics which are difficult to quantitate at present.

The model, in accordance with the indicators given in Section 3, consists of the following major units: demographic (or population unit), health care unit, unit of science and two units modelling the environment, the social-economic conditions unit and natural conditions unit.

The population unit in the proposed model is described by the set of interrelated indices characterizing the state and dynamics of health and the population demographical structure. The population is represented by four categories of people. They are conventionally divided into practically healthy people, unregistered patients, registered out-patients and registered in-patients. There is an exchanging process among different categories the intensity of which depends on the indices of development and policy both in HCS and in external subsystems. All the categories are characterized by a demographical structure and patient-categories are characterized by a disease profile.

Increase and decrease of population are represented by the subunit of new-born children which is characterized by a certain rate of population increase and decrease from the above four categories and the new-born subunit. Increase and decrease rates depend on the development indices of HCS and external subsystems. The type of these dependencies is identified on the basis of experts' procedure data.

The health care unit is a set of interrelated indices which describe the HCS state and development. The unit consists of out-patient and in-patient services characterized by service capacities. The system's capacities depend on the number of physicians and medical personnel, technical equipment, medical service availability. Changes of the corresponding levels are provided by setting these change rates or by the rate of rate changes depending on the HCS development policy and available resources. The rates of level change (speeds), or the rates of rate change (speeding-up) are inputs of the model. Giving these inputs, one can study different variants of the HCS development.

Medical service availability depends on its allocation, transport and roads network development and also (essential for capitalist countries) on the populations's income and the cost of medical services.

The HCS capacity determines the intensity of the transition of the unregistered patients into the registered patients category. The quality of treatment, determined by the state of medical science, regulates the intensity of registered patients transition into the healthy category.

The medical science unit represents a set of interrelated indices characterizing the development of prevention and treatment means. It also contains indices which describe the development of management organization forms. The science unit indices determine both the HCS capacity and quality of treatment. The type of these dependencies is identified by experts. The unit of social-economic conditions is a set of interrelated indices of the state and development of the social-economic subsystem which influence the state of population health and the state of HCS. The natural conditions unit represents the state and dynamics of indices which characterize natural environment and influence the above mentioned subsystems.

The described model is represented by the block diagram (see Figure 3) in which rectangles are levels, that is values of the corresponding indices, and circles are rates of changes of these indices. Functional interrelations are marked by arrows. If two circles are connected by arrows such interrelation means that there is a positive rate of the rate of change of the corresponding index. It is anticipated that the personnel exercising the model can set the rates by running various situations on the model.

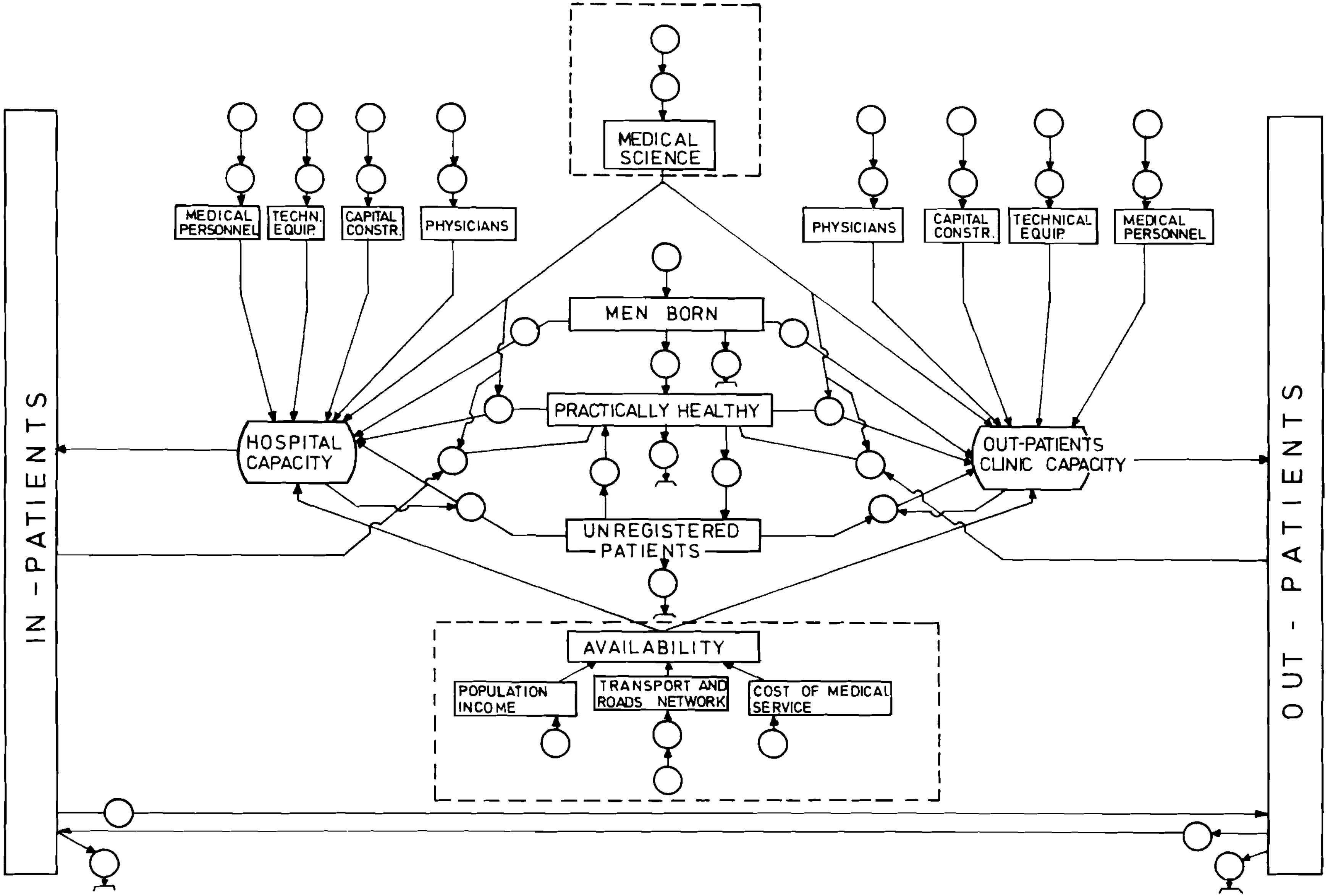

FIGURE 3.
BLOCK DIAGRAM OF HEALTH CARE SYSTEM DYNAMIC MODEL.

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