HEALTH SYSTEM MODELING AND THE INFORMATION SYSTEM FOR THE COORDINATION OF RESEARCH IN ONCOLOGY

PROCEEDINGS OF THE IIASA BIOMEDICAL CONFERENCE, DECEMBER 8-12, 1975

D. D. VENEDICTOV, Editor

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International Institute for Applied Systems Analysis
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PREFACE

The International Conference on the elaboration of a dynamic health model and the information system for the coordination of research in oncology was held in Moscow (USSR) and Laxenburg (Austria) from December 8 to December 12, 1975, under the auspices of the Ministry of Health of the USSR, The World Health Organization (WHO) and the International Institute for Applied Systems Analysis.

The subject discussed at the Conference--the application of systems analysis and mathematical modeling to health and medicine--attracted prominent scientists, experts in health administration, mathematicians, economists and oncologists.

Among the participants of the Conference were 37 scientists from 12 countries. A list of participants and an agenda are appended.

Discussion at the Conference was centered on the material presented by a group of Soviet scientists on two topics:

- Modeling of health care systems;

- Long-term program of international cooperation in the field of cancer research.

The present publication includes the main papers submitted by the organizers of the Conference, reports by the participants and a summary of the discussions which took place at plenary and section meetings.

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GENERAL PLENARY SESSION

Welcoming Address

N.N. Blokhin

It is for me a great pleasure and high honor to welcome you here today at the Oncological Center of the Academy of Medical Sciences of the Soviet Union to the conference on health system modeling and the information system to coordinate research in oncology.

We live in a period when international cooperation in the field of medicine and public health has become a necessity. In some medical fields there is very active cooperation. I observe with great satisfaction that oncology has now become the leading branch of medical science in the field of international cooperation. This is not by chance, because cancer control has become a problem of great concern for the whole of mankind: attempts at cooperation in this field were first made as early as the beginning of this century. International congresses, the establishment of the International Union against Cancer, to which the majority of countries belong, and of a number of other international organizations, including IARC in Lyons, have all served to promote the development of international cooperation in oncology. However, many other fields of medical science are also extremely important in terms of international cooperation. The WHO unites members of the medical profession throughout the world and is responsible for the organization of cooperation which is of great importance for the development of medicine and health in the world.

Our conference has been organized thanks to the initiative and active participation of three major organizations: the Ministry of Health of the USSR, the WHO and IIASA. We are happy to welcome you here as representatives of the many scientists working in international and national health institutions and, particularly, in oncological institutions.

If international cooperation is necessary, it shows that unified programs and approaches to the analysis of the programs, to planning, coordination and evaluation of the results are essential. We live in an era when mathematics and cybernetics are acquiring an ever increasing significance in different fields of science, providing a scientific basis for planning and modeling activities and for studying the results of cooperation. It is the aim of our conference to discuss these topics. I consider it to be an extremely important occasion.

I should therefore like to welcome all the participants of the conference and convey my cordial wishes of success in the work.

Welcoming Address on Behalf of WHO

A.S. Pavlov

I am very pleased to welcome you to this Conference which is discussing the elaboration of an International Information System for the Coordination of Cancer Research. Dr. Mahler, the Director-General of the World Health Organization has asked me to convey his greetings and best wishes for the success of your deliberations. I should also like to take this opportunity to express our thanks to the Government of the Soviet Union for holding the meeting in Moscow to discuss this very important topic.

The world is now undergoing very rapid development which has brought about problems of urbanization and urban growth as well as new industries and the rapid growth of population.

As regards society, the health of the population is of the greatest significance; interacting with socio-economic factors, the environment, working conditions and so on. It is a very sophisticated problem. For this reason it is important to adopt an optimal approach to promoting health. WHO has closely cooperated for a long time with many countries in preparing the establishment of national public health services. It is laid down in the constitution of WHO that "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity".

An appropriate way of attacking these problems is to apply modern systems analysis which permits a comprehensive approach to the whole health sector. We hope that this meeting will take some important steps forward in the development of these approaches, by helping to promote mathematical health modeling.

The second session is devoted to international cooperation in cancer research. WHO Resolutions in the 26th, 27th and 28th World Health Assemblies directed the Director-General to develop long-term planning of international cooperation in cancer research. WHO is now in the process of preparing this program. It is not necessary for me to point out how important this program is for most countries. Many of them devote considerable resources and manpower to cancer research. The program is also very complicated, with multiple interactions between basic research, clinical research and cancer health services. The importance of the problem is emphasized by the fact that the matter has been under consideration by non-medical conferences such as the Conference on European Security and Cooperation, at which cancer was singled out as one of the most promising spheres for international cooperation.

The control of cancer is a reasonable objective for the application of systems analysis, because only in this way is it possible to establish a rational strategy to fight the complex disease conditions involved.

We hope that we will enjoy close cooperation with IIASA in the future, and look forward to fruitful developments.

May I wish you a very successful meeting and a pleasant stay in Moscow.

Welcoming Address on Behalf of IIASA

R.E. Levien

Allow me first to express my pleasure at having the opportunity to speak here on behalf of our Institute to address a meeting in Moscow. It is a great honor. We hope that the work of the Conference will be interesting and strikingly successful.

Our Institute has now entered a new stage of its development. I see here many familiar faces of people who are already acquainted with our work, but I also see many people whom I have not previously met. I should like, therefore, to give you a short account of the foundation of our Institute and to tell you about its work.

Our Institute may be described as a three-year old child which was born after a five year pregnancy, which started about 1966. If you wish, you may regard this date as a milestone on the way towards building a bridge between East and West, since the idea of establishing an Institute to work at investigations of benefit to the whole world, and to all peoples, is now an accomplished fact.

It was preceded by a long period of negotiations between the United States, the Soviet Union, and a number of other countries. Today, we can say that our three-year old child has survived its first and most difficult period.

At present we have members from 12 countries. Our first meeting was held in London. Among those who signed the main document were the Union of Soviet Socialist Republics, the United States, Poland, Japan, Czechoslovakia, Federal Republic of Germany, Bulgaria, France, German Democratic Republic, Italy and the United Kingdom. Soon after the signing of the document, we were given a remarkable palace, in Austria, which had formerly belonged to the Habsburgs, as the place to organize our headquarters.

Our Institute is a non-governmental organization. I should like to stress that the participants are not governments but national academies of sciences or other scientific institutions.

As to financial support, the Soviet Union and the United States each contribute US $1 million while the other countries each contribute US $160,000, giving us a present budget of about US $3.5 million a year.

I may mention that quite recently we voted for a 20 percent increase of our budget.

You may know that the activities of our Institute are very diverse.

At the beginning of 1973, the first scientist arrived at our headquarters and we started on our first research project. Since then the number of scientists at our headquarters has been constantly increasing and at present there are about 70 of them working on 17 research projects. This is a great advance within a period of three years. As can be judged by our activities, we are rapidly developing into a multidisciplinary institution.

Some scepticism may occasionally be expressed about us but we are making progress in our work and development.

I should like to tell you about a new trend in the activities of our Institute. During the three days that the Conference is being held here, we shall undoubtedly learn much new and useful information. Nevertheless, practical steps are required to enable our Institute to work according to a broad plan of investigation which will be of benefit to us all.

To begin with, we shall be primarily concerned with applied research. First, there are problems of a global nature, which can be solved only by international efforts.

Secondly, there are problems of a general or universal nature, which are encountered in a number of individual countries. The activities of our Institute must therefore be both global and universal.

We have identified one global and one universal problem on which to concentrate our research efforts in the near future.

At the global level we shall carry out research about the various sectors of the world economy. We have started with the energy sector. This work has been initiated in the Federal Republic of Germany. We shall be dealing here with the whole system of energy resources in terms of technology, consumption and their consequences.

Later, we shall be dealing with population, food resources and consumption, etc.

In the case of problems of a universal character, we shall be concerned with specific branches of the economy in specific economic regions, including the problem of developing new territories with vast and viable resources. Such areas are with coal resources, for example, to be found in Poland, and, in the USSR, in Siberia.

One should not consider industrial or human relations separately but the whole complex nature of these problems, including the medical aspect. This is the field in which the research activities of our Institute will be conducted.

We allocate one quarter of our budget to a global problem and one quarter to a universal problem. The remainder will be allocated to the study of problems of a more specific character.

In this connection, I would like to revert to the question to which I referred at the beginning. What kind of programs should our Institute adopt in its study of the energy resources of today and tomorrow and the building of economic models in the field of medicine, including cancer research?

Many people tell us that we should be concerned with the problems of the environment; such as the connection between health and energy resources; but, perhaps it would be more reasonable to direct our research towards regional problems: what should we be concerned with in the field of health and medicine?

There is also a question of the form our activities should take. We can carry out research work in several different ways.

First, there are internal investigations, conducted within our Institute; $6 million have been allocated under this head.

However, the scope of our projects is somewhat limited. Projects with common themes on which 20 scientists might well be engaged, have 4 or 5 scientists working on them at the Institute.

The second kind of investigations is carried out by teams of scientists, and we hope to organize some main groups at the Institute so that the scientists could be at the head of the research work.

Finally, we try to facilitate research work by organizing symposia at the headquarters of the Institute.

We shall adopt the last mentioned approach in the field of medicine and systems analysis.

Once again I would like to express my gratitude to you for discussing these problems in order to help us and I also wish to thank our hosts for providing us with good working conditions.

Welcoming Address on Behalf of IARC

J. Higginson

To begin with, I should like to express my sincere gratitude to the organizers of the Conference for having brought together in this hall the representatives of two forms of sciences: I mean the scientists who work out new ideas and, on the other hand mathematicians, specialists in planning and specialists in administration.

I think this symposium will provide us with the opportunity to see to what extent such an initiative is justified and later we shall be able to exchange our opinions on the subject.

We consider the organization of this conference timely because it will make our tasks more exact and definite.

What are the aims of our Agency? It is an organization standing between scientists working in the fundamental sciences and scientists dealing with essential health problems for the benefit of man.

Due to a limited material basis and budget, our Agency has to select its activities carefully.

We have come to the conclusion that there is a number of lines along which it is advisable to carry out research. These lines were first thoroughly studied by the scientific council.

The proposed program of projects was submitted to the Government which approved these plans. We shall evaluate the results in order to improve future work. We have decided to concentrate on the key problem of the primary prophylaxis of cancer. Therefore we have devised a program covering areas where computers can be used to give significant results.

Unfortunately, during the processing of data, we discovered that the epidemiology of the disease does not provide a sufficient basis for the solution of the problem without a study of the biology of cancer. We have therefore worked out a project on cancer epidemiology, specifically concerned with the comparative analysis of different factors.

One of our programs was a seven-year research effort carried out by experts in the field. I may add that earlier similar programs had shown that the experts had consistently failed to establish whether the initial data for the problem were precisely defined. Today the only rational approach seems to be that an evaluation in biological terms, which would result in reducing the age groups at risk of cancer. Cancer morbidity in the older groups will then markedly decrease. Experiments carried out in this field show that the average expectation of life (44 years) will be increased by at least 11 years.

Information is urgently needed on this subject, particularly complex information which can be used universally.

I think that this Conference should clearly state that the list of topics under discussion should be research oriented; it should indicate which are suitable for immediate study and which may be of future use and along precisely what lines the work should be carried out.

The importance of the correct evaluation of initial data must be stressed.

Our mathematicians and statisticians have carried out fairly complete investigations and have established good contacts with WHO and representatives of other countries and organizations. We think it desirable to attract a greater number of mathematicians and statisticians in other countries to undertake similar work and to render assistance to the specialists.

At present, work is under way on the preparation of new visual aids, together with the accompanying literature, to be completed by 1980. By this time a number of the current visual aids and publications will have become obsolete and we should increasingly promote work on the prophylaxis of cancer, which must be carried out on a larger scale than previously.

From our own experience we can say that the most serious problem impeding the progress of research is lack of information due to insufficient attention to the question.

Welcoming Address on Behalf of the WHO Regional Office for Europe

L. Caprio

I would like to say a few words on the activities of the WHO Regional Office for Europe in Copenhagen where work on the study of applied systems analysis is performed.

I would like to give you some examples of the work in which the European Regional Office is engaged. There are some programs primarily oriented towards European problems in environmental and mental health, the training of medical personnel and health education. We are also dealing with such everyday family problems as abortion, etc.

Of late, our Office has paid relatively little attention to the problems of cancer control but in our next long-term six-year program, which will begin in 1978, this matter will receive greater attention. Dr. Pavlov recently spoke on the subject at a meeting of the countries of the Region.

Lately, a number of interesting events have taken place which have increased the possibilities of WHO activity on problems which I would call problems of international unity.

You are aware of the world-wide belief that the World Health Organization should be concerned primarily with the problems of the third world; we also share this opinion. We are aware, however, that in the field of health, we should be concerned not only with the health problems of the third world, but also with those of the developed countries, because the problems which the developed countries are facing now will, in the near future be encountered in the developing countries as well--I refer to oncological problems.

One of the events illustrating this approach was the decision to establish the International Institute of Applied Systems Analysis as an institution to combine fundamental and applied research. This Institute was organized on the basis of multilateral coopertion with organizations like WHO. The fact of the matter is that WHO participation in the activities of an institute organized on a bilateral basis would have been impossible.

The Conference on European Security and Cooperation has enabled its participants to participate more fruitfully in scientific and cultural exchanges, and in particular to develop and extend work in the field of medical research. As far back as

December, our Office took a decision on this question and I have given instructions that special attention is to be paid to such aspects of our activities.

In terms of WHO activities, the coordination of research at the level of regional problems will be decentralized to some extent.

It is essential to improve the potential for scientific research of the developing countries in every possible way. Nevertheless, that does not rule out the possibility that within the European Region we should select a whole range of problems on which the efforts of the European countries will be concentrated. That is of considerable interest to our Conference, because one of the important tasks of our Office is operational research, epidemiological studies and the investigation of the most rational way to structure health systems.

Our desire to see WHO play a greater role is caused by the fact that health services are concerned with the effect of environment on health. At the same time, through WHO research programs, we must involve the representatives of other sciences--molecular biology, social medicine and law, particularly with regard to abortion and coordinate these programs at the level of the European Region.

We must also, with an eye to future social developments, study the causes and consequences of traffic accidents. Why, for instance, is road safety much greater in London than in other cities with smaller populations?

It is necessary to develop and strengthen health education. One of the problems is smoking. We know a great deal about the problem of smoking but so far we have failed to reduce the number of smokers. We have carried out some investigations on smoking and its effects in weakening the human organism.

We hope to be able to develop further the coordination of research within the European Region and to strengthen the contacts of WHO with other organizations. Much attention will be given to establishing contacts with third world countries.

I hope that my brief address has given you an idea of the Regions's problems and its range of interests.

Welcoming Address

D.D. Venedictov

We are happy to see here such a representative group of scientists of different specialities from a number of countries, who have gathered at this working conference on the problems of systems analysis and its application to medicine and public health. We take it as evidence of the fact that systems approach and systems analysis, dynamic mathematical modeling today have been recognized, as never before, as important concepts for the understanding and solving of a number of complicated biological, medical and medico-social problems at many different levels, from molecular to international and global.

Since we are here as part of a biomedical IIASA project we may recall, with, I hope, a pardonable pride, that it was in biology and medicine that the systematic perception of the environment and living organisms first came into existence and the first terms and concepts emerged; I shall not enumerate them--they later became the property of a number of sciences--both natural sciences and sociology, economics and others.

It is in medicine and biology that the concepts of complex integral and functional systems merge to the greatest extent, whereas in public health, the biological and social methods of systems approach and analysis merge.

I may point out that different paths and different specialities and problems have brought us to this Conference, but our meeting here under the auspices of three great organizations--WHO, IIASA and Ministry of Health of the USSR--is quite natural and justified.

IIASA has held a number of meetings and conferences, including one at Baden in 1974 on the systems aspects of public health planning. The scientists engaged on the biomedical project had undertaken a number of specific, although interesting, studies on traffic accidents, cervical cancer screening, kidney insufficiency statistics, assistance to people with defective vision and so on, but gradually they have been forced to admit the necessity of concentrating their efforts on the most complicated but universally important problems--systems analysis of the public health system per se and of medical science.

One cannot help noticing that it has taken a long time to reach this conclusion and as the leader of the project, although virtually an "extra-mural" one, I must take the blame upon myself. Nevertheless, this aspect has been covered to a considerable extent thanks to the inexhaustible energy of Alexandre Kiselev, whom you all know, and the understanding shown by Howard Raiffa and Roger Levien.

This Conference, however unofficial in character, should provide the answers to many important questions. The main question is whether the members of the medical profession, health administrators, oncologists, systems technologists and mathematicians are able to make an essential and new contribution in this field.

In the course of the Conference we shall have a frank discussion of our problems and we shall listen to a number of interesting scientific presentations. I would like, however, to draw your attention to the two main reports to be presented, which were prepared by a group of Soviet specialists as a possible basis, or suggestions towards a basis, for the IIASA Biomedical Project.

I refer to the reports on systems modeling of public health and the informational basis of the long-term international oncological program which the WHO has adopted the decision to implement.

These reports will be submitted by Professor Kiselev, Dr. Klementiev, Dr. Klimenkov, Dr. Olshansky and by Professor Petrovsky. I have been advised that in some sections of the reports the text no longer reflects the progress that had been made, but we ask your indulgence.

As far as the dynamic health model as a social system is concerned, it is principally based on those terms and concepts which have been repeatedly discussed at WHO and are accepted either officially or as working terms; they were also the subject of discussion at the IIASA Biomedical Conference in August 1974. Public health is regarded as a dynamic social system including as an integral part the development of medical science as the basis on which scientific knowledge can be applied to the prophylaxis and treatment of disease.

The primary aim of such a system is to protect the health of the population. It has three tasks: science, prophylaxis and treatment, and these can be successfully tackled only if there is a rapidly developing economy and sufficient manpower.

There are universal problems of health and universal modern conditions of public health functioning.

In almost all countries, the public health system is operating under conditions of rapidly changing external factors. They include progress in economy and agriculture, intensification of all the processes of urbanization, population growth, environmental pollution and demographic shifts.

There are internal factors as well, which are also virtually universal. These are rapid progress in biomedical science and its increasing cost, control of epidemics caused by transport problems, increasing cost of medical services, lack of medical personnel and uneven distribution of medical services.

There are also global problems starting with the question of international coordination of medical science; in addition to studies on cardio-vascular, oncological and other diseases and protection of the environment, it also includes effective assistance to public health in the developing countries. Finally, there are questions of population dynamics, resources and nutrition.

The application of systems analysis and computers to public health and medicine has by now acquired great importance (see Figure 1).

A dynamic health model is of considerable interest to all. We cannot solve a number of urgent problems without it.

Today, the correct development of science is possible only on an international basis. But progress of science is impeded by a number of factors affecting international coordination, namely, the rapid development of different branches of science in different countries, with medicine developing at a different rate from the others.

1. SPECIFYING AND MEASURING HEALTH STATUS
2. SPECIFYING PUBLIC HEALTH LINKS WITH OTHER SOCIAL FACTORS
3. SPECIFYING THE ROLE PLAYED BY PUBLIC HEALTH FACTORS IN THE HEALTH STATUS OF THE COMMUNITY
4. ANALYZING CRITERIA OF PUBLIC HEALTH EFFECTIVENESS
5. PROVIDING INFORMATION SUPPORT FOR PUBLIC HEALTH
6. FORECASTING AND PUBLIC HEALTH PLANNING
7. FITTING TOGETHER PUBLIC HEALTH "MICROMODELS"
8. DEVELOPING INTERNATIONAL COOPERATION

Figure 1. Uses of systems modeling in public health.

However, our greatest handicap is the inadequate provision of information which it is difficult to pool owing to the variety of information systems in use in the world.

The second great obstacle is differing methodology, using different terms, different criteria for evaluation and different diagnostics. All these obstacles must be overcome.

The third obstacle is social and ethical which is not so easy to overcome. We must solve the problem of their effect on man and his scientific destiny. Today science in all countries is concentrating on the solution of the main problems, which are important to everyone, such as cardio-vascular diseases, cancer, viral infections and the effect of endocrine factors and of the environment.

First of all, methods of scientific information must be made accessible to all those interested. To this end, we suggest an information system which is used in the USSR. It differs somewhat from the current international system, but in our opinion, it is convenient and easy and can be accepted by scientific workers as a basis for planning and research.

It provides the state with the necessary information to determine its policy for scientific development and decide where efforts should be concentrated. We understand that at present there are no effective international methods which would enable us to combine our efforts and obtain advance information in order to elaborate international information. A feature of our system is that for the first time an opportunity has been provided to combine the efforts of medical scientists and mathematicians thereby making it possible to predict the directions in which science is likely to develop and, to establish priorities. This has become possible in the course of implementing large-scale international and national programs on oncology. No such possibility existed three to four years ago.

Their programming methods and systems were introduced and large information centers were established to provide the data required. If these ideas are agreed upon, they can be used universally. We shall be able to speak in terms of international health systems and create the first international programs concentrating our efforts on the diseases and along those lines which are of primary importance to us.

Systems Approach to Decision Making in the Organizational Systems

A.M. Petrovsky

Systems analysis in health has been studied at the Institute for Control Sciences in the four consecutive stages which correspond generally to the methodology of systems approach. The first stage is that of component analysis; at this stage the properties of the elements comprising the system are studied.

The second stage is concerned with the study of the kinds of activity of the elements comprising the system. In other words, the functional analysis of the system is carried out at this stage.

The third stage is the structural analysis of the system, i.e. the study of the rules regulating the connections between the elements of the system.

The fourth and final stage is that of integrative analysis. The essence of this stage is to study the system of elements as an integral whole, in other words, to determine the essential things that differentiate the system from a simple aggregation of elements.

This method of studying a fairly complicated subject, by means of stages by applying systems analysis to public health as a non-productive sector of the economy, has enabled us to distinguish three main problems in the creation of a dynamic model of the system.

The first problem relates to the study of the information basis required for the practical functioning of a dynamic system. It is well known that the forms of reporting currently employed in public health and the statistical data to be reported are incomplete and vary greatly. Direct use of these data in a dynamic model turns out to be difficult.

There are two alternative methods of solving this problem:

- The method based on a qualitative description of the cause and effect relationship to define the functioning of the model. This kind of verbal definition may be obtained relatively simply from the existing statistical data and forms of reporting.

If this method is adopted, the model itself is built in the form of a matrix of the cause and effect relationships, the size of which is the object of management. Naturally, such a model will be approximate, but this should be regarded as a positive rather than negative quality of a model.

If no attempt is made to modify the data bank on which the model is based, one cannot expect it to exhibit high quantitative efficiency in view of disadvantages of this particular bank, which have been mentioned above.

- The method based on the description of the functioning of the model by means of algebraic and differential equations. This kind of model can provide more definite quantitative results; however, in order to make it function, it is necessary to obtain much fuller initial data than is required if the first method is adopted.

It is not yet clear whether researchers would prefer one of these methods or would use both.

The second problem relates to testing out the model. This is a matter of having confidence that the person responsible for decision making will engage in a dialogue with the model on its own terms. We think this problem is of great importance as it poses a number of psychological questions; for instance, that of the subjective responsibility of people making high-level decisions. This problem, like the first problem, is at the stage of its initial development.

The third problem relates to the elaboration of adequate languages to describe complicated systems. Contradictory demands are made on these languages: on the one hand they must be acceptable in terms of the traditional management of complicated organizational systems, i.e. they have to be relatively simple for the user--the decision maker. On the other hand, these languages should be sufficiently perfected to permit effective man-machine dialogue in real time. We have studied this problem fairly thoroughly and the results of our investigations have already been successfully applied in building one of the model variants. The development of a dynamic health care model is being carried out with due regard for the above mentioned factors and with two main objectives:

- Development of a model as an apparatus for making management decisions in public health. This means specifically decision making about the allocation of limited resources between different services--for example, between prevention and treatment--about manpower training and the organization of large-scale research, etc.

- Development of a model as a link in a chain of systems, the functioning of which largely depends on the functioning of the system in question. Thus, the public health system is heavily dependent on the system of environment protection, the system of distribution of energy resources, the system of urban development, etc. The quantitative characteristics of these connections, and often their qualitative aspects, can be defined only through dynamic models of the existing systems. An essential prerequisite is a uniform methodology for building models for the different systems. In our opinion, the essential purpose of this methodology is to deal with practical issues--the substance of which is contained in the three problems described above.

A few remarks should be added in connection with the organization of large-scale research work. Progress in public health and medicine is largely dependent on the progress of medical science. We have selected the international research for cancer control as a subject for systems analysis as applied to the problem of organization. A specific feature of this program is the great number of participants with different scientific potential and of scientific problems and subjects of investigation. In cancer research, flows of information which were largely predetermined make their appearance, focal points of scientific interest come and go and other procedures are followed which in some cases result in a delay in the timely exchange of scientific information or difficulties with regard to forecasting and research planning. The systems approach in this field is based on the mathematic apparatus of structural analysis and experimental graphs elaborated at the Institute for Control Sciences.

The following working procedures are used in carrying out these investigations:

- monitoring the existing information structure based on questionnaires drawn up by competent and highly qualified specialists;

- analysis of references in scientific publications in the field of oncology.

Both these procedures require the use of large capacity computers at the final stages of data processing (ICL-470 computer).

MODELING OF HEALTH CARE SYSTEMS

Methodological Problems of Constructing A Health Care Macro-Model

A.S. Kiselev

In many countries medical information systems have been developed including mathematical models of subjects at the level of individual units or small regions. Accumulated experience has made it possible in some countries to start the development of more complex medical information systems and macro-models at the national level or at the level of large regions. Such studies are being carried out in the USSR, in some socialist countries and in Canada, Japan, Sweden, and other countries.

Development of a public health care model at the national level is an enormous task both by reason of its complexity and in organizational terms. It will take many years and the combined efforts of scientists from various countries.

Each later version will give a more accurate description of the behavior of the system being simulated. It is likely that a whole family of macro-models will appear which will be of a more or less specialized character. These models will be used to increase the efficiency of medical care, to control the structure and functions of the public health system, to make health care cheaper, and to improve public health management.

The public health care systems of various countries is a convenient subject for applied systems analysis owing to its clear-cut structure, well-defined functions, and social significance.

The analysis of the public health care system should be comprehensive and take into account its dynamic properties. Hence, the public health care model should be dynamic in character.

The public health care system is not an isolated entity; it forms a part of a system ranking higher in the national hierarchy.

The outside world exerts various effects on the public health system. Hence, the dynamic model of public health care should include a number of external blocks such as demographic and economic factors, geographical conditions, environmental pollution factors, etc.

In developing a public health care model, the first question is whether the methodology of macro-model development is universal or whether there is a specific methodology for each country. If the methodology is universal, there are good prospects for international cooperation in developing it.

Public health care systems in countries with different socio-economic conditions may have different features. The differences may be due, primarily, to differences in the concept of public health management, in the establishment of the objectives of the health care services, and in the ways in which the public health resources are provided. For example, in countries with centralized public health management, resources are appropriated from the national budget. In other countries, resources are provided by a system of medical insurance or by contributions from patients or by various combinations of the above systems.

However, there are undoubtedly a number of general characteristics which are typical of the public health system as a whole, irrespective of country. The following may be mentioned: the dependence of morbidity on the particular age and sex structure of the population; the economic development of the community; the preventive health programs, and the methods of treatment; the dependence of the volume of medical services on the available resources; and the effects of progress in medical science on the indicators of the medical service.

In countries with centralized public health management, the planning unit can use the public health model as an analytical tool for evaluating various versions of long-range development programs. The model can be used for optimizing the allocation of resources in the public health system in accordance with changes in external factors.

In countries with noncentralized public health management, the model may be used by local authorities or even medical insurance companies interested in obtaining forecasts of morbidity rates.

Careful analysis is needed to determine the extent to which the public health macro-model is universal or specific to one country. However, it is possible even now to delineate a fairly extensive range of problems which can be studied within the framework of international cooperation.

In the USSR, systematic studies have been carried out for some years with the aim of developing an extensive complex of medical information systems at the national level. This complex comprises information systems for collection of data on the therapeutic and preventive activities of the medical services, and on the epidemiological and hygienic situation, and medical statistical data; it also includes information on the systems of finance planning and on the pharmaceutical network and some other systems. The mathematical models being developed are based on the information provided by these systems.

A group of scientists from some of the institutes of the USSR Ministry of Health and from the Institute for Control Sciences of the USSR Academy of Sciences have started a large-scale program to develop a public health macro-model.

Development of the macro-model comprises three stages: the verbal model, the mathematical model, and the dialogue model.

At the verbal model stage, the objectives in developing the model, the conceptual framework and the functional organization are formulated.

The mathematical model starts with models of the blocks "treatment", "prevention", "science", "resources", and "management", i.e., the blocks which themselves make up a model of the medical services. At a later stage, mathematical models of the blocks that are external to the public health care system are developed or models, which are already available in other fields of science or for other countries, are linked to the public health care model. In the course of this work, algorithms and computer programs are developed.

At the third stage, the mathematical model of public health care is transformed into the dialogue model (man-machine, simulation, game). Various experiments with the model are carried out and the model is adapted to the needs of the users.

At the present time, the group of USSR scientists working in close contact with IIASA have completed the development of the verbal model and the first version of the mathematical model.

The main objective of developing models is to enable a decision maker to analyze and predict the behavior under changing external conditions of the public health care system in terms of various management versions and to work out alternative versions of public health management in order to reach the predetermined goals. This very objective makes it essential to develop the public health care model as a dialogue model.

The functional organization of a public health care system is shown in Figure 1.

The arrows in Figure 2 show the model's complicated interrelationship with a particular population, represented in the form of a demographic pyramid. Every population and age group is known to need a certain percentage of medical care. In developed countries, new born babies are given 100 percent medical care, whereas people in the 35 to 45 age group need 50 percent medical care. On this basis, patient flows to medical units develop.

The patient flow is considerably reduced at the outset by the effects of public health preventive measures for the whole population, for example, a number of diseases, including

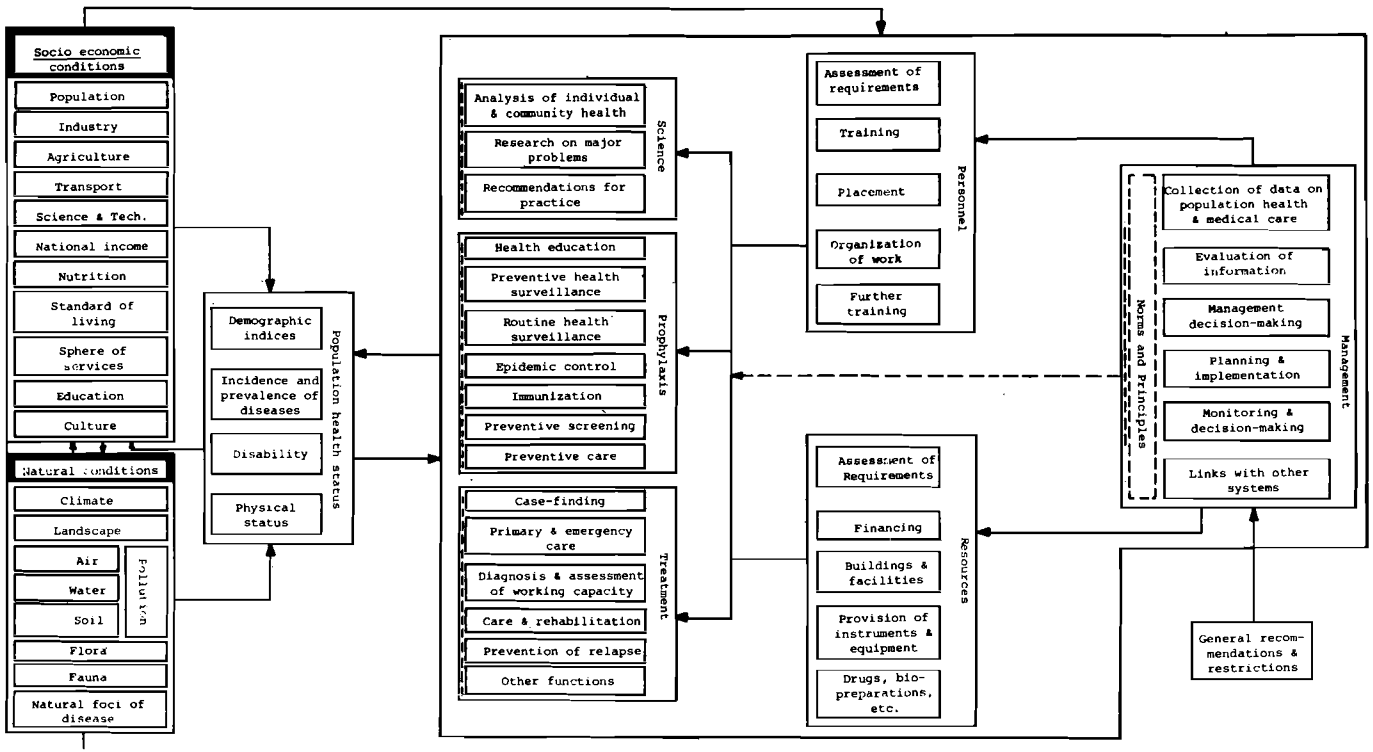

Figure 1. Functional chart of a public health system.

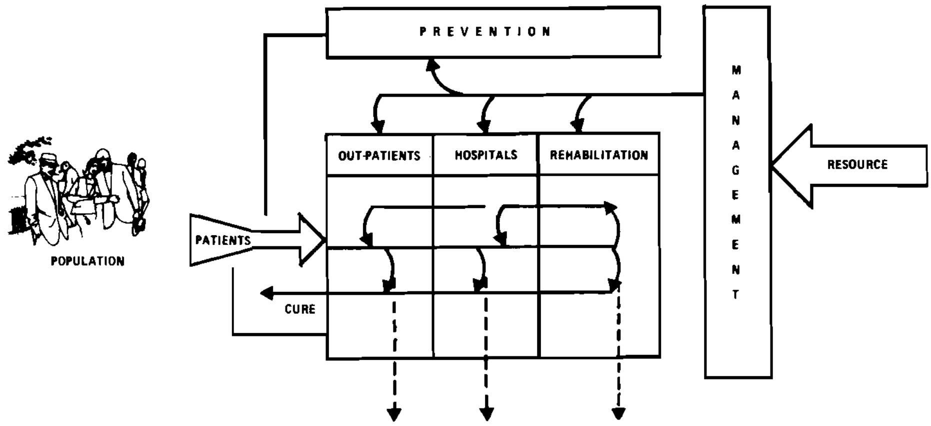

Figure 2. Interrelationship of the health care service with the population.

smallpox, have been prevented by immunization. The diagram also shows the process whereby latent diseases are discovered in persons who did not know they were ill; this increases the patient flow. The patient flow meets the situation that public health care resources are insufficient to process it so that a proportion of would be patients receive incomplete treatment or none at all.

Once inside the public health care system, the patient flow becomes very complicated. Some of the patients get well during out-patient treatment and return to the healthy group and some die. The patients with more severe diseases go into hospital where a similar process occurs. The final stage is rehabilitation of disabled patients.

Resources coming into the public health system are represented by the arrow on the opposite side of the diagram. They include material supplies, manpower, technology and intellectual resources in the form of scientific innovations. Resources are supplied through a special service and their allocation to the various public health care units calls for many decisions about optimization of use.

Thus, the two flows--patients and resources--meet in the public health care system and a very complicated interaction takes place. This interaction is not random in nature. It is regulated by that part of the public health care system which we have called the management block. The main task of this block is the allocation of resources throughout the public health care system. Since there is a great number of possible versions of resource allocation, the management block must include the formulation of public health objectives under specific conditions which may be attained in various alternative ways. Decision making in national public health policy is such a complicated process that it cannot be automated completely. For this reason, a decision maker is introduced into the model at the final stage of development so that a man-machine system is constructed. Of course, "the decision maker" is an arbitrary concept. In fact, it is probable that this role will be played by a group of experts who will analyze, with the help of the model, possible policies and their consequences. The man-machine interaction allows high flexibility. The decision maker, taking into account certain limitations, selects various resource allocation policies according to their structure and duration and observes the resultant changes in the public health care model. If they are not acceptable, he can study other scenarios until he gets the desired result.

The flexibility of the man-machine interaction is a great asset for international cooperation in developing the methodology of macro-models for public health care systems. The methodology provides for the fact that in different countries the decision maker will have different objectives and will proceed from different premises; it also provides for different types of decision makers. We believe that the development of this methodology for building macro-models of the public health system should attract the combined efforts of public health administrators and systems analysts from various countries and of the international organizations concerned with public health.

IIASA can become a center for experience sharing and discussion between the national institutions engaged in this complicated task. Such an international division of labor can bring nearer the time when the public health care macro-models can be used by the public health administrators in various countries to promote the welfare of the sick, which is our common concern.

The IIASA Biomedical Project is seeking collaborators in this important work.

Some Principles for Creation of a Health Care System Simulation Model

A.A. Klementiev

THE GENERAL CONCEPTS

In recent years, popular demand for highly-qualified medical care has significantly increased, giving rise to new demands on the use of health care resources, hence the need to organize the health care system (HCS) at the level of a large region, as, for example, a country, so as to provide its population with the best possible medical care.

HCS management is characterized by the fact that some of the effects of managerial action become apparent only 10 to 20 years after the related decisions have been taken. The administrator cannot foresee or sometimes even approximately estimate all the possible consequences of his decisions owing to the complexity of the object of management, the dependency of its behavior on external systems, etc. Under such circumstances it is rather difficult to make the best, or, sometimes, even an acceptable, decision. Simulation by a model of the development of the real HCS makes it possible to determine general development trends in terms of management policy and the likely behavior of external systems.

An analysis of the model's behavior provides a basis for managerial decision making.

The concept of the development of the HCS may be stated as follows:

- First, changes in the total volume and proportions of HCS resources (in particular, manpower resources) in accordance with changes in the total population, the structure of disease prevalence, methods of preventing and treating disease, etc.;

- Second, changes in base standards owing to advances in medical science affecting methods of treatment and prevention;

- Third, increased proportion of preventive activities within the sum total of HCS operations.

Synthesis of the dynamic simulation model of the health care system (DSMHCS) calls for the development of mathematical models for the above-mentioned three interrelated aspects of HCS development, the working out of a set of programs for the model and the development of a procedure for dialogue between the DSMHCS and the decision maker (DM).

Thus, the aim of developing the DSMHCS is to provide the DM with an instrument to test and make a preliminary selection of the possible management decisions related to the above-mentioned aspects. It is assumed that in generating management policy, the DM starts from a given objective of HCS development and takes into account the various constraints on its attainment.

DEFINITIONS

The number of newly registered cases of a disease per 1000 of population per year is called the *incidence rate* of that disease.

The total number of patients suffering from that disease at a given time is called the *prevalence* of the disease at that time. Not all cases receive medical attention immediately after the onset of the disease. Therefore, only a proportion of cases come within the ambit of the health care system. This proportion is described as the *registered prevalence;* the remaining cases are described as the *latent prevalence* of the disease.

Three different variants, corresponding to the three basically different types of disease are being developed within DSMHCS.

Type I diseases are characterized by a weak onset which often passes unnoticed by the subject and a long development period, exhibiting the following characteristic phases: A-phase--the subject can work; he may not notice any signs of disease. This is the initial phase of the disease during which treatment may result in complete cure. B-phase--the subject is temporarily or permanently unable to work. The disease steadily pursues its course. Treatment at this phase may be effective in returning the disease to phase A. C-phase--the subject's inability to work becomes fixed. Irreversible pathological changes occur.

Among Type I diseases are alcoholism, certain malignant tumors, etc.

Type II diseases are acute infectious diseases, such as smallpox and poliomyelitis, against which effective vaccines have been developed.

Type III diseases are distinguished by the fact that their early diagnosis is impossible or ineffective and immunization against them is impracticable, for example, accidents, poisoning, etc.

Let us now define the main aspects of HCS operations as reflected by the DSMHCS.

Treatment activity is represented in the DSMHCS by the interaction between registered patients and HCS resources. This interaction results in the consumption of a certain amount of resources and a change in the dynamics of the disease.

Two aspects of *preventive activities* are represented in the DSMHCS: first, early detection of disease and referral of the cases concerned to medical treatment and second, prevention of disease by immunizing the healthy population. In both cases, some HCS resources are consumed and the structure of the prevalence of disease is altered.

The DSMHCS analyzes the following types of administrative activities: staffing policy, population screening policy and policy for health standards.

Staffing policy involves management decision making about the total number and ratio of doctors. It is assumed that existing standards would make it possible to calculate, on the basis of the number of doctors, the amount of other resources being used (hospital beds, nurses, etc.).

An effective *population screening policy* is determined, generally, by the following considerations. On the one hand, an increase in the number of occupational screenings yields a relative increase in the number of cases registered with initial symptoms of a disease. Since treatment of such cases is more effective, this contributes to a greater efficiency in HCS treatment activities. On the other hand, increased screening leads to increased expenditures under that head. Thus, an effective policy must be a compromise which takes into account other criteria, not necessarily the cost-effectiveness.

A policy for health standards in the HCS establishes a rational balance between the various resources, on the one hand, and the changing structure of popular demands for medical care, on the other. Standards are also updated in accordance with advances in medical science.

The following types of resources are reflected in the DSMHCS.

1. Technological resources for the preventive care activities measured in money units.

2. Manpower resources employed in preventive care.

3. Manpower resources employed in out-patient clinics.

4. Manpower resources employed in hospitals.

Resources of types 2, 3 and 4 are measured both in physical units, i.e., in the man-days spent by a doctor in the HCS on a particular activity (prevention, out-patient treatment, hospital treatment) and in money units, i.e., the cost of that activity.

Management policy is understood as simulation of administrative activities in the DM-DSMHCS dialogue.

Effectiveness criteria of the selected management policy are the HCS development indicators which are significant to the DM. It is assumed that the DM will select a management policy such that it will "improve", in some sense, these indicators. The list of criteria is determined by the DM.

DESCRIPTION OF THE MODEL

This report describes a variant of the DSMHCS simulating only the processes that take place in the HCS in the case of Type I diseases. The general structural scheme of the model is shown in Figure 1. Such external characteristics (1) as the living standard, educational level, climate, quality of food, etc., influence both the sex-age structure of the population (2) and the incidence of disease in these sex-age strata (3). In turn, the sex-age structure and the incidence rate determine the prevalance of disease in the population (4). The latter also depends on the HCS preventive and treatment activities (5). Disease prevalence is taken to constitute the demand of the population on HCS preventive and treatment resources. Development of HCS resources is simulated by block (6). Consumption of resources (preventive and treatment activities) takes place according to HCS standards. Consumption of resources results in a change in the disease prevalence structure. Characteristics defining the quality of preventive and treatment activities depend on the level of medical science (7). Among such characteristics in the model are the time and cost of treatment during a given phase of disease, the cost of a single screening examination, etc.

At this level of development, the model is not concerned with HCS management processes. If we wish to study management processes, the DM-model dialogue mode should be used. In this case, the DM block (8) in Figure 1, will determine the HCS development goal and formulate the corresponding effectiveness criteria (10). Next, this block will formulate management policy, taking into account given resource constraints (9); it may also formulate some general hypotheses about the state of the external systems. This information is formalized in terms of the model. The computer then calculates the model's behavior under these conditions. The results will be fed to block (8) for analysis of the quality of the selected management policy.

In the first version of the model, the entire population is divided into three groups, each group being classified into strata according to sex, age, and phase of disease. Group HP represents the healthy population, group LD, the latent sick cases and group RP, the registered patients, i.e., patients consuming HCS resources. The number of people in each stratum is recalculated at each discrete time step, in this case, one month. The dynamics of the population within the groups and between the strata is represented by Equations (1) - (3) in the Appendix which are discussed below. Transition from group LD to group RP takes place according to the availability of the corresponding HCS resource, ADR (15); this is determined by the variable REAP (18). A proportion of the population receiving medical care, AAS (17), consists of latent cases admitted at their own request, AT (7) and latent cases detected through screening SD (9). The total productivity of medical screening (the number of people from groups LD and HP who were screened per unit of time) depends on the equipment of the screening service, ARS (21), and the manpower resources of this service, SDH (11). The ratio between the treatment manpower resources, TDH (12), and the screening manpower resources, SDH (11), is defined by the variable TJP determined by the DM block (8) on Figure 1. The ratio of manpower employed in out-patient clinics to manpower employed in hospitals is defined by the variable ATDH. The capacity of treatment manpower resources, as represented by a physician's standard workload, is given by the variable ADR (15). Underutilized treatment manpower resource, REA, is obtained from (16). The model takes into account time delays arising from the training of physicians, STD, loss of manpower due to retirement of physicians and delays in delivery of equipment for screening activities, RETR (20). The current and total expenditures of the HCS for the period of time under study are represented by the following variables: FEXRS, FEDS, FEDT (current) and EXRS, EDSS and EDTS (total).

CONCLUSION

The DSMHCS model, discussed above, is only an initial version; work will be continued along the following lines:

- Development of models of external subsystems and consideration of their influence on the behavior of HCS;

- Modeling of the development of medical sciences to take into account their influence on the structure of HCS resources and the effectiveness of preventive and treatment activities;

- Development of the model to take into account the characteristics of Type II and III diseases;

- Study of the stability of the DSMHCS.

Moreover, a number of particular methodological problems, stemming from the high dimensionality of the model, the lack of necessary initial data, etc., remain to be solved.

However, the variant of DSMHCS described above yields significant results which could assist in making a rational allocation of resources between treatment and prevention activities. Experiments are currently being carried out in this field.

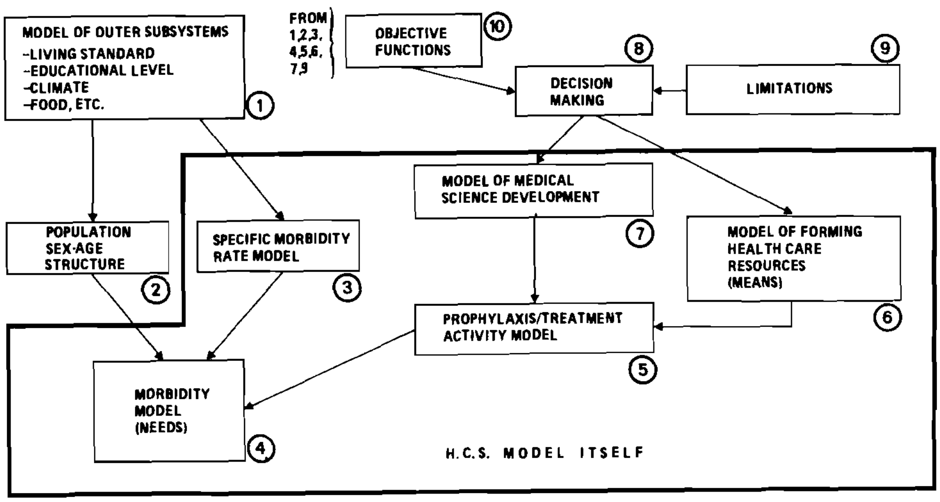

Figure 1. General structure of interconnections in the model.

Appendix I

The following notation is used in the present work:

I - number of sex-age group (stratum), I = 1,2,3;

J - index of phase of disease incidence, J $\in$ {A,B,C};

T - current (present) time.

If FUN is a certain function of the variables (I,J,T), then the notation FUN(I,J,T) everywhere below should be understood as the value of FUN at the moment in time T for the sex-age stratum I for phase J of the disease.

SPECIFICATION OF BASIC VARIABLES

HP(I,T) - number of healthy individuals;

DSR(I,T) - incidence of disease;

DHD(I,T) - number of patients who have recovered;

DR(I,T) - mortality;

TMOY - discrete time step in the population part of the model;

TRHH(I,I+1,T) - number of healthy individuals transferred from stratum I to stratum I+1;

LD(I,J,T) - number of latent sick individuals;

TRHL(I,J=A,T) - number of people in the initial phase of the disease;

TRLI(I,J,T) - additional number of sick individuals from the group of latent sick, transferring from other strata;

REAP(I,J,T) - number of latent sick individuals transferring to the group of registered patients, i.e. those consuming HCS resources;

TRLO(I,J,T) - number of latent sick individuals having transferred into other strata within the group of latent sick individuals;

RP(I,J,T)	- number of registered patients, i.e. those consuming HCS resources;
TRRI(I,J,T)	- additional number of registered patients transferred from other strata within the group of registered patients;
TRPO(I,J,T)	- number of registered patients transferred to other strata within the group of registered patients;
HPS(T)	- total number of healthy individuals subject to screening examination;
LDS(T)	- total number of latent sick individuals;
CDL(T)	- "concentration" of latent sick individuals;
AT(I,J,T)	- number of latent sick individuals admitted to treatment at their own request;
ATP(I,J)	- portion of latent sick individuals who spontaneously seek medical assistance;
AA(I,J,T)	- number of latent sick individuals who have requested medical assistance;
SD(I,J,T)	- number of registered patients detected by screening;
GPS(T)	- general productivity of screening resources;
SDH(T)	- physician-manpower resources employed on screening activities;
TDH(T)	- physician-manpower resources employed on treatment activities;
RPS(J,T)	- total number of registered patients;
TDHT(J,T)	- physician-manpower resources corresponding to disease phase J;
ADR(J,T)	- general physician workload, expressed in terms of the standard number of patients of physican-manpower resources involved in treatment activities;
REA(J,T)	- unutilized physician-manpower resources;
AAS(J,T)	- number of latent sick individuals who have requested medical assistance;
REAP(J,T)	- number of latent sick individuals having transferred into the category of registered patients;
GDH(T)	- general physician-manpower resources.

EQUATIONS

(1) $HP(I,T+1) = HP(I,T) + DHD(I,T) - \{HP(I,T) * DSR(I,T) + HP(I,T) * DR(I,T)\} * TMOY - TRHH(I,I+1,T) + TRHH(I-1,I,T)$

(2) $LD(I,J,T+1) = LD(I,J,T) + TRHL(I,J,T) + TRLI(I,J,T) - LD(I,J,T) * DR(I,T) * TMOY - REAP(I,J,T) - TRLO(I,J,T)$

(3) $RP(I,J,T+1) = RP(I,J,T) + REAP(I,J,T) + TRRI(I,J,T) - RP(I,J,T) * DR(I,T) * TMOY - DHD(I,J,T) - TRRO(I,J,T)$

(4) $HPS(T) = \Sigma\ HP(I,T)$

(5) $LDS(T) = \Sigma\ LD(I,J,T)$

(6) $CDL(T) = LDS(T)/\{LDS(T) + HPS(T)\}$

(7) $AT(I,J,T) = ATP(I,J) * LD(I,J,T)$

(8) $AA(I,J,T) = AT(I,J,T) + SD(I,J,T)$

(9) $SD(I,J,T) = GPS(T) * CDL(T) * TMOY * ASD(I,J)$

(10) $GPS(T) = SNOR(T) * ARS(T) + SNOD(T) * SDH(T)$

(11) $SDH(T) = GDH(T) * TSPS(T)$

(12) $TDH(T) = GDH(T) * TSPT(T)$

(13) $RPS(J,T) = \Sigma\ RP(I,J,T)$

(14) TDHT(J,T) = TDH(T) * ATDH(J,T)

(15) ADR(J,T) = TDHT(J,T)/DLN(J,T)

(16) REA(J,T) = ADR(J,T) - RPS(J,T)

(17) AAS(J,T) = Σ AA(I,J,T)

(18) $$\mathrm{REAP(J,T+1)} = \begin{cases} \mathrm{AAS(J,T)};\ \mathrm{REA(J,T)} \geq \mathrm{AAS(J,T)},\ \mathrm{REA(J,T)} > 0 \\ \mathrm{REA(J,T)};\ \mathrm{REA(J,T)} \leq \mathrm{AAS(J,T)},\ \mathrm{REA(J,T)} > 0 \\ 0;\ \mathrm{REA(J,T)} \leq 0. \end{cases}$$

(19) GDH(T) = DOC(T) * TSD(T) * TMOY

(20) RETR(T) = DELAY2(XRS,DES)

(21) ARS(T) = DELAY2(YRS,DSR)

Health Care: A Systems Approach

D.D. Venedictov, et al.

INTRODUCTION

The main requirements of man to prolong life, health, and normal physical and cultural development are food, clothing, housing and a favorable natural environment (air, water, etc.).

The concepts of health and its opposite, disease, have had various interpretations in history, and the most widely spread current definition is that in the WHO Constitution: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity".

With the emergence of socialism a new attitude was engendered to the health of working people, women, children and youth as being something of important social value. "Public health" became one of the main goals of social development and an important condition for successful economic and social progress. Socialism also put forward and was the first to implement the principle that health is an inalienable right of man, and that the guaranteeing of this right is one of the most important tasks facing society. This is now recognized everywhere and in the years since the Second World War it has been reflected in a number of important international documents, first in the WHO Constitution ("The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition"), and in the Universal Declaration of Human Rights adopted by the United Nations in 1948 ("Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing and medical care and necessary social services"). An important principle is contained in the United Nations General Assembly resolution 1386 Declaration of the Rights of the Child ("...Every child has the right to a name and a nationality, to an equal status upon birth, to a maternal and family care, to the protection of health, to adequate nutrition, etc."), in the UN Declaration on granting independence to previously oppressed countries and peoples, and in statements and declarations by many governments and political parties. For instance, the summary report of the Third Conference of Public Health Ministers of Latin American countries (1972) notes that "health is a universal right which distinguishes a civilized society from an uncivilized one". At the same time, there is in many countries a great gap between the declarations on "the inalienable rights of man" and their real implementation.

From existing publications (UN yearbooks, WHO reviews, WHA documents) one gains an extremely varied, contradictory and far from complete picture of the number, dynamics, age-group structure of the population in different countries, birth rates, mortality and morbidity, medical establishments, methods and traditions of training specialists, the organization of medical practice, pharmacies, sanitary-epidemiological services and so on. Requirements for the protection and strengthening of health are constantly increasing, as the pace of modern life sharply increases nervous and psychological stress, and has a direct influence on cardiovascular, cancer and viral diseases, metabolic disorders, etc.

The health of man also depends on the development of health care services. WHO's Fifth General Program of Work for the period 1973-1977, states: "In this emergent framework of political, economic, social, cultural, technological and psychological systems, superimposed on the geophysical environment, health has to be brought about. Public health is implicated in each of those systems and, being a part of the total matrix, influences it by its own dynamics" (*Off. Rec. Wld Hlth Org.* 1973, Annex 11).

Many countries have accumulated considerable experience in the field of effectively protecting human health; but it is necessary to develop this further and to improve the methodology of management. The absence of an internationally agreed theory of health care management (and of a common understanding of the social essence of public health) is being felt more and more acutely, and this is reflected in a wide variety of socio-hygienic and medico-organizational literature.

Some specialists favor the concept of "pluralism" in social development and express doubts about the possibility of working out a single model of health care management, because of the great differences between countries, their traditions and forms of State structure. We consider these doubts unfounded, since health care systems in all countries are developing, not only in a particular national way, but in accordance with general laws governing the development of medical and socio-hygienic science and practice, and in response to national and international problems. Protecting the health of the population in any country demands effective use of national and international experience and national systems for health care are developing as components of a single (although rather shapeless) international system. Elaboration of a general theory of health care management in contemporary and rapidly changing conditions is especially necessary for the developing countries of Asia, Africa and Latin America, which must build up health systems with extremely limited resources and facilities: they need really reliable recommendations. The scientific elaboration of health care is necessary also in economically highly developed societies, where the new economic, organizational and political situation arising from the intensification of economic and social progress have great quantitative and qualitative effect on the economy and social life.

Among the most important "external" changes, which affect the activity of health care establishments are:

- Changes in the economy; increasing complexity of international economic ties and the uneven industrialization of certain countries and regions; increase in the speed of communications and transport; the scientific and technological revolution and the aggravation of social and class distinctions.

- Rapid urbanization; general increase in education; psychological stresses due to the increased pace of life.

- Rapid growth of population; involvement of women in social labor. Significant changes in the age-group structure of the population.

- Rapid chemical, physical and biological pollution of the environment.

- Changes in the state of health of the population; changes in nutrition; harmful habits: smoking, alcoholism, drug addiction and so on.

Among the "internal" changes are:

- Increased complexity and uneven development of medical knowledge; rapid growth of expenditure for medical research.

- Successes in the control of epidemic and communicable diseases in economically developed countries, and at the same time their wide distribution in the developing countries; changes in their global distribution in connection with the development of high-speed transport and population migration.

- Increase in the cost of medical care: the elaborate new methods, increased level of technical equipment, improvement of medical establishments.

- Insufficient (in many countries) number of skilled doctors, scientific and auxiliary personnel and the low training rate; the development of team methods for providing medical care; the negative effect of the "brain drain" from developing to highly developed countries.

- The uneven distribution of medical aid between urban and rural populations, and (in many countries) between different social strata; the activities of trade unions and other organizations in recognizing the need to even out medical care.

A whole range of theoretical and practical problems in medicine which previously interested only workers in the medical profession and governments of individual countries have now gone beyond this framework and have become of worldwide interest; their solution depends on the joint efforts of the governments of many countries and international organizations.

These problems include:

- Accelerated international coordination of medico-biological scientific investigations.

- The control of dangerous epidemic diseases.

- Prevention and treatment of widespread non-epidemic serious diseases (cardiovascular, cancerous, hereditary, etc.), and serious parasitic diseases endemic to tropical countries (onchocerciasis, schistosomiasis, filariasis and others).

- Medical aspects of protecting the environment.

- Ensuring effective control over the quality, safety, efficacy and side effects of drugs and over the misuse of narcotics, psychotropic and other drugs.

- Providing aid to the developing countries for national public health systems and for training national personnel.

- Study of the dynamics of population changes.

Such a broad range of medico-social problems makes international cooperation in the field of medicine and public health necessary and in particular, calls for a single or similar terminology and mutual compatibility of certain links in national public health services.

In recent years many countries have accomplished a great deal in the system-structural analysis of public health and there have been many publications by WHO, WHA, etc. on the subject. Here we emphasize the significance of systems analysis and modeling of health care services, not just relating parts of systems, but primarily constructing a generalized conceptual model ("macro-model") of national health care systems which could be utilized in various countries to obtain a better understanding of the development of this system and its management. We have repeatedly pointed out in WHO the need for such a general model just as one might refer to a basic model of an automobile, an aircraft or some other technical system. It should make provision for all the basic blocks and the main elements of their interrelationship.

The following sections elaborate a macro-model of national health care produced by a group of Soviet specialists in social hygiene, public health organization, systems analysis and mathematical modeling of complex biological and social systems. This work has been conducted under the guidance of the Council on Systems Analysis in Medicine under the USSR National Committee for Systems Analysis.

The macro-model is accepted for further international elaboration and study within the Biomedical project of IIASA in close collaboration with WHO.

HEALTH CARE AS A DYNAMIC SYSTEM AND ITS MODELING

Health care is a complex social dynamic functional system created and used by society for carrying out social and medical measures for protecting and improving health and for the continuous accumulation of medical knowledge.

If the tasks of medicine are threefold: to understand the human organism and possible diseases, to prevent these diseases and, if they do occur, to treat them, then public health should have the following main goals:

- The development of scientific medical research;
- Individual and community prevention of diseases, with priority for the health of the younger generation, and control over the environment;
- For the entire population, access to timely diagnosis and skilled treatment of diseases which occur.

Recognition that these three important tasks are inseparable not only in theory but in practice remains difficult for representatives of those countries where these functions are "traditionally" separated. The obvious impossibility of solving questions of protecting and improving the health of the population in a private, personal or semi-social way led far-sighted public health functionaries in all countries to a correct understanding of the mutual ties and complexity of the tasks confronting public health.

For the successful development and functioning of public health as a social system certain socio-economic and organizational conditions are required:

- An approach to the protection of the population's health not as the private affair of each person, or the professional affair of doctors, but as a most important task of society and the State, demanding not only specific actions by medical workers, but the rational use of all available means of society.

- Accelerated social and economic development of the country and utilization of economic, industrial and scientific achievements as the basis for strengthening the technical basis of public health.

- Finally, the accelerated growth of education and culture of the population necessary for training a sufficient number of skilled medical personnel who regard the cause of protecting man's health as an important social duty, and who would like to involve the masses in protecting and improving natural conditions, leading a healthy way of life and participating in solving public health questions.

The Twenty-sixth World Health Assembly gave the basic principles for developing national health systems:

> Among the most effective principles,...confirmed by experience in a number of countries [and recommended] to all Member Countries, having regard to their own historical, social, economic and other conditions, [are]...the proclamation of the responsibility of the State and society for the protection of the health of the population...the establishment of a nationwide system of health services...the administration of training of national health personnel at all levels...the integration of curative and preventive services in all medical and health establishments and services, emphasizing the protection of health of mothers and children...the provision for the whole population...of the highest possible level of skilled, universally available preventive and curative medical care, without financial or other impediments...the extensive application in every country of the results of progress in world medical research and public health practice...the health education of the public and... personal and collective responsibility of all members of society for protecting human health.

From here we may proceed to a functional-structural analysis of the health care system and its management within the framework of some definite administrative-territorial unit (State, republic, city, etc.). Each of these territories has always had some more or less developed network of health care bodies and establishments with different degrees of centralization. The report of the National Consultative Council on Medical Personnel in the United States (1967) declares:

> The word system is convenient for our purposes, but we realize that this term is inaccurate, if we understand it as the presence of an organized, coordinated and planned aggregate of actions. Medical aid in the United States is rather a collection of bits and pieces (with overlapping, duplicating, big

gaps, high costs and wastage of efforts) than an integrated system in which needs and efforts are interrelated.

But even so, this aggregate of establishments with different functions is a system, and this was vividly expressed by W. McNerny (1974) who said, "If this is not a system...then try to break it".

In socialist countries as well as in Great Britain, Sweden and others the structure of medical establishments and their functions is more orderly; however, in this case what is most important is not the degree of orderliness, but that in practically any country it is possible to distinguish several main types of medical establishments including (Figure 1): scientific research establishments (institutes, laboratories, groups, etc.); higher and secondary medical educational establishments; sanitary-antiepidemic establishments ensuring preventive and routine sanitary surveillance and conducting antiepidemic measures; curative and preventive inpatient and outpatient establishments which provide various types of medical care to the local population and to visitors; pharmaceutical, technical, supply, repair and other services and organizations. Finally, each area has a health management body which combines subordination, according to territory, to the corresponding local bodies of State power, and, according to branch and function, to higher-ranking public health bodies.

All health care establishments located in a given area, irrespective of their subordination, must orientate their functions on the needs of the population living in that area, and at the same time, ensure the goals and tasks of the entire system of national public health are met. Also they must be part of different centralized hierarchies of systems. In spite of the obvious interconnection and need for all these functions and establishments, significant contradictions and lack of coordination are, in fact, not infrequently encountered in the activities of individual health care establishments and services. At present the question of centralization or decentralization of public health management is a politically acute question for many countries.

Coordination and planning of scientific studies and training of personnel are important functions, and basically of a centralized nature. Preventive and antiepidemic services must be brought as close as possible to the population, but should be capable of being rapidly mobilized and centralized if necessary on a national or international level. Curative and preventive aid for the population is built up best of all on the principle of stage-by-stage diagnostic and curative services.

Modeling health care services is a complicated matter, and the model proposed here is abstract and conditional. However, it is sufficiently universal and applicable to the situation in any country: likewise, it may be used for comparative analysis

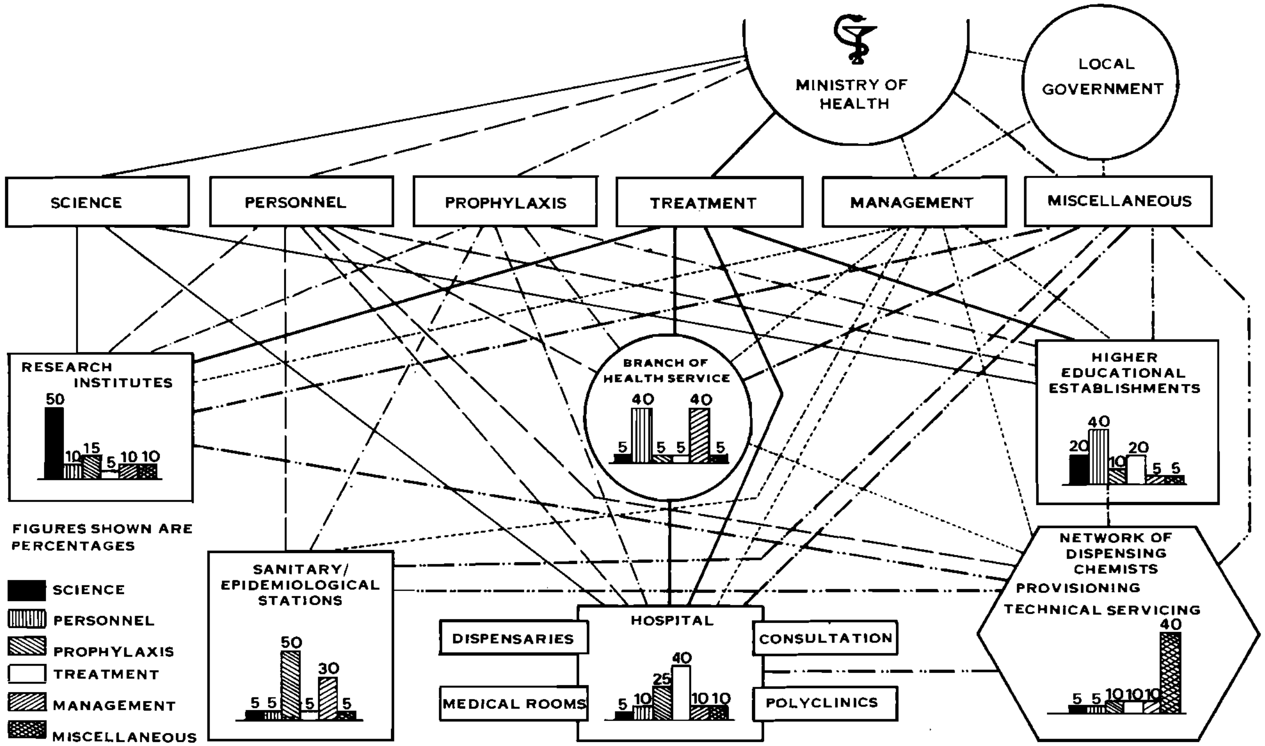

Figure 1. Administrative structure of the health services.

of health care services and functions in different countries. Such an analysis should bear in mind the historical evolution of each type of establishment in the various countries, and also contemporary legislative acts and projects, making it possible to identify more clearly the common features of such health care bodies. Otherwise an attempt to compare, for example, the USSR and the USA would be greatly complicated by the socio-economic and political differences.

A working group convened by the WHO European Regional Office (Copenhagen, 1972) to study the experience of health care planning in Europe noted that socialist countries have centralized public health systems; plans for public development form an integral part of the overall State plans for socio-economic development. Other countries (Belgium, the Netherlands, Great Britain, Turkey, France, Sweden and certain others) have fairly extensive planning processes, but these plans are used more as basic guidelines. The third group of countries (Austria, Italy, and Spain) has only limited elements of public health planning.

The general conceptual model for a health care system proposed may also be used for devising more detailed health care models of increasing operational complexity, both downwards (to individual establishments), and upwards (to the entire public health system of a country). An important feature to be considered when modeling health care systems is the complex multilink nature, and the exceptionally large number of quantitative indices used for health care administration. These are difficult to take into consideration when using traditional methods of management. The complexity is aggravated by the significant delay (5-10 years) in the effect of most management decisions.

The next step in specifying the basic functions of a health care system is to divide each function into several tasks; a block diagram of a health care system can then be built.* The blocks reflect the basic functions of health care and are divided into over 40 subblocks, all of which are component parts for realizing the corresponding health care functions and which sometimes reflect the sequence in which the basic function is carried out. Further detailing of the data of subblocks will naturally lead to a specification of the list of tasks realized by the relevant health care bodies and establishments.

Figure 2, besides the health care system proper, shows three new blocks:

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*See D.D. Venedictov (1976).

- "Health of the population", which includes demographic indices, physical development, morbidity, distribution of diseases and disability;

- "Socio-economic conditions", which reflects the number and composition of the population, the level of development of industry, transport networks, agriculture, science and technology, national income, the nature and level of nutrition, the standard of living, the sphere of services, education, culture, etc.;

- "Natural conditions", which includes climate, landscape, environmental pollution (air, water, soil), flora and fauna, existing natural foci of diseases, etc.

These last two blocks are far less detailed than the others, and are described in a preliminary way.

Health care activities take place in conditions characterized by the mutual influence of these blocks; the system of mutual influences is illustrated in a matrix whose dimensions are 42 × 42 (Figure 2). Each line indicates the influence of an element with all the other elements in the block-diagram. The degree of influence, obtained by expert appraisal, was registered in each matrix cell by: significant, symbol 2; noticeable, symbol 1; doubtful, symbol -; none or significantly low, no symbol.

The features of some tasks depend on the type of the establishment and the hierarchical level of management. For example, if the tasks of district (urban) public health departments include direct organization of medical care for the population, ensuring the development of public health establishments and their material-technical equipment, then the Ministry of Health, the highest level of management, is given responsibility for the fulfilment of the organizational-methodological functions; the preparation of a policy and of the main trends in the development of health care and medical science. In other words, the health care bodies--the management units of the system--have the task of ensuring an optimal combination of health care functions and establishments.

The sequence of events (algorithm) for realizing an envisaged medical program is shown in Figure 3. The preparation of such a program follows general principles and takes into account the specific features of the health care system. In this process health care bodies can actively influence the formation of tasks and the organization of scientific medical research, as well as the training and distribution of personnel and the provision of material-technical resources. Each influence has a protracted time lag (5-10 years), which fits in with the time expected for major changes to take place in world living conditions (20-40 years). Thus long-term planning of health care

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 the interrelation of different functions.

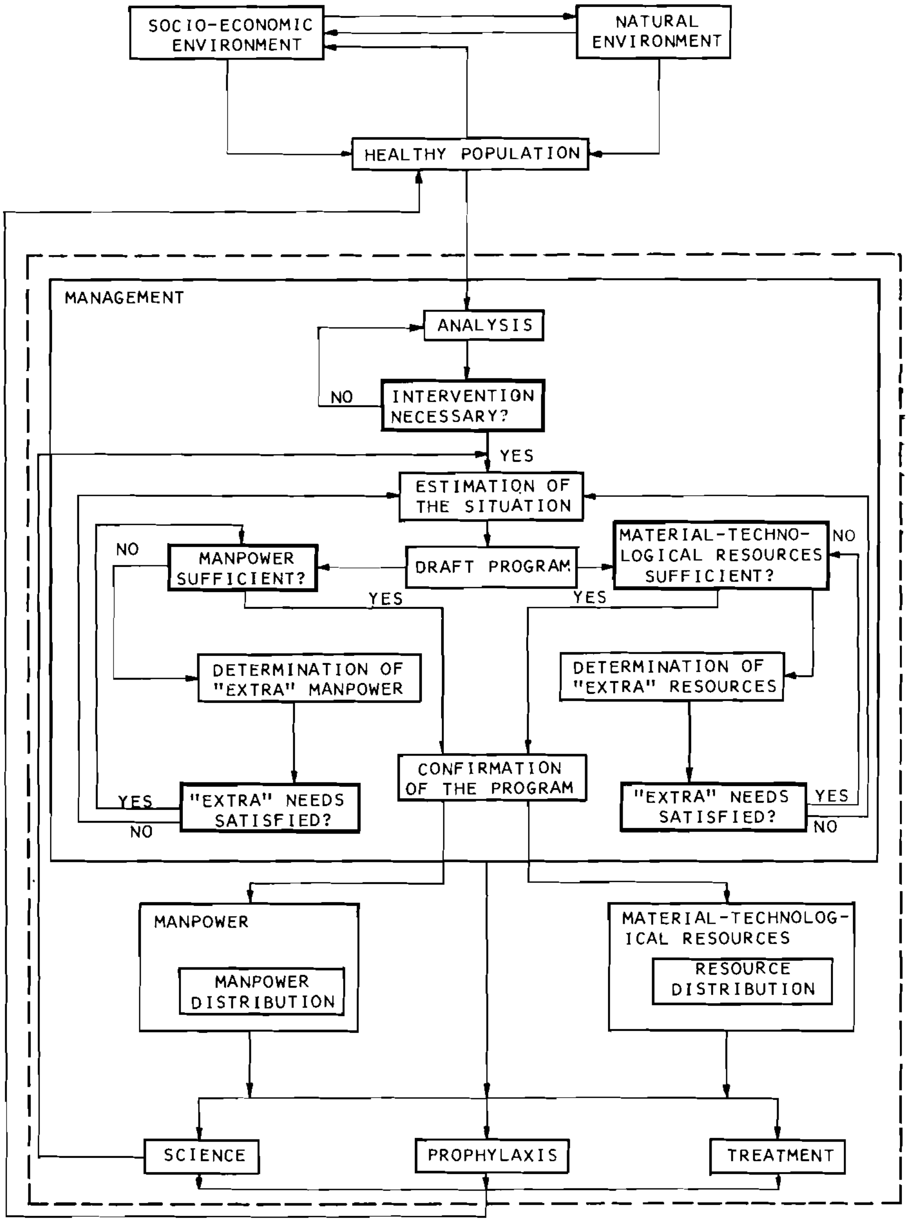

Figure 3. Layout of the implementation of a medical program.

services by a systems approach and maximum utilization of imitational dynamic models of a branch is possible.

An important condition for activating the model is the evaluation of the status of blocks and subblocks and their interaction for which a list of 340 indices, including 19 for the health of the population and 167 for public health has been compiled. It is not complete, and moreover, includes a number of indices that are not complete. So the efficacy of the separate blocks and subblocks cannot be fully evaluated.

At the Eighteenth World Health Assembly in 1965 it was proposed that qualitative indices characterizing various aspects of public health and obtained by means of scientific investigations should be regarded as normatives, while the same indices obtained by empirical methods should be regarded as standards. By examining the alternative ways of obtaining normative values with models it is possible to select optimal ways for the development of the system.

For preparing submodels of the public health care system in the USSR, a group of experts evaluated the functions and subfunctions characteristic of all 113 types of bodies and establishments, and then classified them by special algorithms obtained by computer. As a result, they established the hierarchy, trends and levels of amalgamation in all types of establishments and could identify establishments with similar functions and work out local submodels for establishments of various types and capacities.

A unified administrative-territorial principle for deploying the network of establishments results, and the existing similarity of functions in different systems for health care in various countries enables the pooling of efforts on an international scale in respect of modeling so as to achieve the common goals.

MATHEMATICAL APPROACH TO DEVELOPING A SIMULATION MODEL OF A HEALTH CARE SYSTEM

The simulation model of a health care system (SMHCS) is based on the general block diagram of a health care system (Figure 2) as described above.

First, the cause-result relations of the block diagram are represented in the form of equations. Secondly, the simulation model reflects the development of a system in time so that it may be used to study probable behavior of the system in the future. In doing this account is taken of inherent time-lags in information and material flows. These have considerable influence on the behavior of the system as a whole and its separate subsystems. Thirdly, the health care system is represented as a set of interacting specific models each of which simulates an independent aspect of health care of subsystem activity.

The synthesis of the SMHCS presumes that account is taken of scientific activity, the provision of treatment, preventive measures and managerial activity in the real health care system. Each aspect is simulated in accordance with a specific model. Effective management requires knowledge of the present and future demand for medical care. To obtain this, a specific model is constructed in respect of the population's medical care requirements.

Structure of the Model--Certain Definitions

The SMHCS implies examining the overall picture of the health status of the population and the need arises to introduce the following new terms. The number of new cases, both detected and undetected per 1000 population for a given type of disease over a certain period of time, will be called "the true number of cases for a given period per 1000 population". The total number of patients per 1000 population (for a given type of disease) at a given time will be called "the true number of patients at a given time per 1000 population". Not all patients make use of medical services immediately after the onset of a disease and so we deal only with detected cases--the concept of *morbidity* and *sickness*. The remaining segment determines, correspondingly, "the number of latent cases for a given period per 1000 population" and "the number of latent patients at a given time per 1000 population".

When developing an SMHCS three different specific models of morbidity and sickness are constructed to deal with three essentially different types of disease.

The first type of disease (the degenerative diseases) are characterized by a slow onset frequently unnoticed by the patient, and a protracted development where the patient first temporarily or partially loses his working capacity. Treatment of patients at this stage can still lead to full clinical recovery. Then the patient becomes consistently incapable of working and irreversible pathological changes take place. Diabetes, mental diseases, alcoholism, certain malignant neoplasms, etc., are examples of these diseases.

Diseases of the second type are those acute (communicable) diseases against which effective vaccines or methods of treatment exist and are employed.

Diseases of the third type do not have means of effective early prevention and vaccination (examples: accidents, poisonings, etc.).

Let us now consider the basic aspects of a public health system taken into account in the SMHCS. Curative activity consists in delivering medical care to patients as a result of which resources are utilized and the health status of the population changes.

Preventive activity is represented in the SMHCS in two ways. First, *early case detection and referral* of patients for treatment. Secondly, preventive action against the disease, e.g. *vaccinations* of the healthy population and other preventive measures.

Administrative activities studied in an SMHCS are:

- Personnel policy--which means adopting management decisions concerning the number and proportions of personnel resources so that personnel and other material-technical requirements are coordinated.

- Preventive screening of the population results in an increase in detection of patients with the initial symptoms of a disease and since treatment of mild cases is more effective, expenditure is correspondingly reduced. But an increase in preventive screening leads to increased expenditure on the screening itself. So a balance has to be struck.

- Norms and standards for establishing the workloads of doctors, hospital bed requirements, etc. may become obsolete. The SMHCS make it possible to study this and to recommend changes.

The overall structural pattern for decision-making with the SMHCS was given earlier. Processes specific for public health are simulated in the SMHCS block. The dynamics of development of a health care system depends on the state of the environment and on the resources allocated for the development of a particular branch. Characteristics most important for a public health system, such as demographic structure, standard of living, education and the level of economic development are simulated in the corresponding block. The decision maker studies the probable behavior of a real health care system under the proposed management policy and the quality of alternative management decisions can be judged for various population requirements in respect of medical care, mortality in different sex-age groups, current expenditure in the public health system, overall number of doctors, and so on.

Let us now proceed to describe the first variant of the model (see Appendix) and the flow chart (Figure 4). Here, the entire population is represented in the form of three groups broken down into strata according to sex and age (index I) and according to phases of the disease (index J). The HP group represents the healthy population, the LD group latent patients, and the RP group registered patients, i.e. those consuming public health resources. The numbers in the strata are calculated for each month. The dynamics of the population in groups and between strata is represented by Equations (1) - (3).

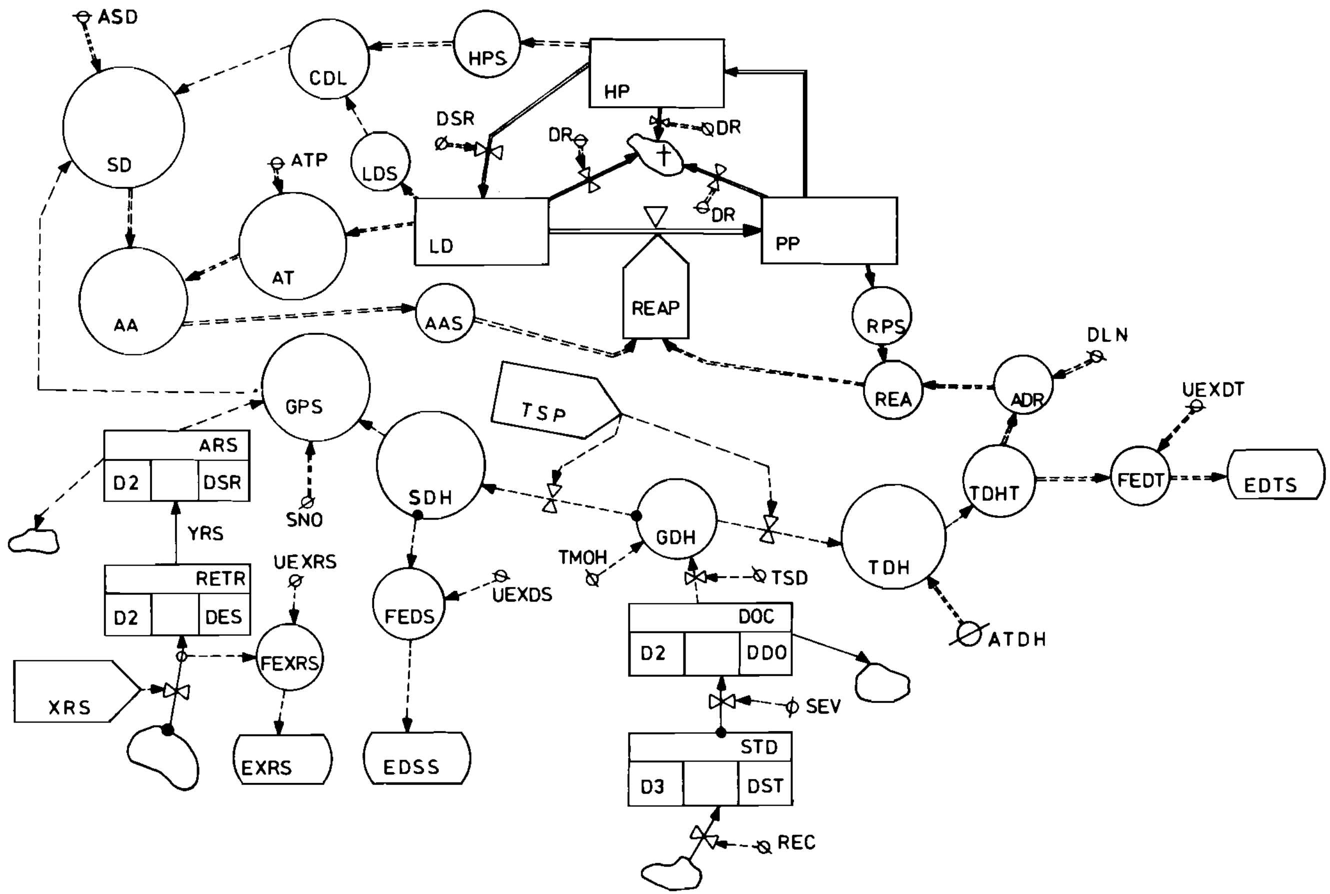

Figure 4. Flow diagram of the first version of the model.

Transfer from group LD to group RP is effected as the corresponding health care resources ADR (14) are released or increased, and it is determined by the variable REAP (16). That part of the population which has applied for medical care AAS (18) is formed from those unregistered patients who applied individually AT (7) and from the patients who were detected in preventive screening SD (9). The total number of the population from groups LD and HP who have undergone preventive screening for a unit of time, depends on the amount of technical resources allocated for these purposes ARS (24) and on the number of medical personnel SDH (11). The proportion of curative TDH (12) and preventive SDH (11) activity of medical personnel are set by the variable TSP. The proportion of medical personnel delivering inpatient and outpatient care are set by the variable ATDH. The potential of medical personnel engaged in curative activity, expressed in doctors' workloads, are set by the variable ADR (14). The possibility of additional workloads for medical personnel engaged in curative activity (based on the accepted norms and standards) REA is determined from (17). In the model, account is taken of time lags connected with the training of medical personnel STD, medical personnel DOC leaving the public health system, and delays in the delivery of technical resources for preventive screening RETR (23). Current and total expenditures of the health care system are represented by the following variables: FEXRS, REDS, REDT (current) and EXRS, EDSS, EDTS (total). The index T in the equations designates current time.

Purpose of Modeling

The decision maker who has to develop the health care system must consider an extremely large number of factors for any decision he takes. It is very difficult to find the best, or sometimes even an acceptable solution. The simulation of the development of the real health care system with a model makes it possible, in general terms, to establish trends in the development of this system and, in so doing, to improve the procedure for selecting the desired solution.

Development of a health care system means *first*, a change in the volume and proportions of the system's resources depending on the changes in the population's overall medical care requirements; *secondly*, as a change in the normative base depending on changes in the possibilities of satisfying the population's medical care requirements; and *thirdly*, as an increase in the proportion of preventive activity in the overall volume of work in a health care system. The SMHCS includes the three above-mentioned interrelated aspects of development, and also allows for interaction of the decision maker and the SMHCS.

Task-Setting

Instances of specific task-setting and the results obtained will be discussed in subsequent publications. Here we give an example.

Let the cost of treating one patient for a unit of time in phase A of a type 1 disease be represented as C_A, and phase B as C_B, and in phase C as C_C. Let us take [0,T] as the interval of time for which the behavior of the system is studied. In a unit of time $\nu \in (0,T)$ the public health system has A patients detected $P_A(\nu)$, B patients $P_B(\nu)$ and C patients $P_C(\nu)$. The cost of their servicing per unit time is shown in the following:

$$S_1(\nu) = (C_\nu, P_\nu) \quad ,$$

where

$$C_\nu = \left(C_A(\nu), C_B(\nu), C_C(\nu)\right) \quad ,$$

$$P_\nu = \left(P_A(\nu), P_B(\nu), P_C(\nu)\right) \quad ,$$

and $(\cdot,\cdot)$ denotes the scalar product of two vectors.

Total expenditures of the public health system on treatment during the period [0,T] will be as follows:

$$S_1^T = \sum_{\nu=1}^{T/\nu} (C_\nu, P_\nu) \quad .$$

With the increase in the volume of preventive screening, there is an increase in the related expenditures:

$$S_1^T = \sum_{\nu=1}^{T/\nu} C_\nu^S \cdot P_\nu^S \quad ,$$

where P_ν^S is the number of the population subject to preventive screening, and C_ν^S is the cost for a preventive screening in a unit of time.

However, with the increase in the volume of preventive screening, there must also be an increase in the ratio of detected patients to overall patients. If we are to determine $C_A < C_B < C_C$, it may happen that an increase in S_2^T in a certain interval of time leads to a decrease in S_1^T . Moreover, it may happen that with an increase of S_n^T there is a drop in the total expenditure on treatment and prevention $S^T = S_1^T + S_2^T$.

The task is to determine, if we take C_A, C_B, C_C, C as concrete values and presuppose certain tactics for preventive screening:

- At what value of $S_2^T = S_2^{T*}$ the overall expenditures S^T prove minimal;
- What is the influence of S_2^T on other indices of the efficacy of activity of a public health system, for example, on those relating to general mortality, the proportion of recoveries, general morbidity and morbidity in phases, etc.

This example also illustrates that the taking of decisions in selecting an acceptable policy for preventive screening is made not only on the basis of the cost criteria of preventive activity. Such a situation is typical for a public health system.

Working with the Model

The decision maker develops certain hypotheses about the future behavior of the environment, about limitations on management, and about certain parameters of the SMHCS. These may be hypotheses concerning trends in birth rates, changes in the dynamics of registered morbidity with the introduction of more effective drugs, trends in morbidity and so on. The initial hypotheses and the management variants studied are formalized and, together with other initial data, are put into the model. The results of calculations are visualized in the terminals (line-printer, CRT, etc.) in accordance with the requirements of the consumer. These results form the basis on which the decision maker adopts the decisions.

The Development Direction

At present, work on the development of the model is concentrated on a detailed mathematical description of the following sectors:

- Dynamics of population prevalence, with the diseases of the first type taken as an example;
- Consumption of HCS resources and its influence on prevalence dynamics. Special attention is paid to the consumption of HCS resources for preventive care;
- Effects of external subsystems on morbidity rate.

The description of prevalence dynamics is based on the following hypotheses:

Hypothesis 1: Generally, prevalence dynamics in the absence of HCS resource consumption is described by:

$$\Gamma_1: \quad H \rightarrow A \rightarrow B \rightarrow C \rightarrow D \quad ,$$

where H is the healthy condition; A,B, and C are phases of a disease; and D is death.

The time of a patient's stay in any condition,

$$J \in \{A,B,C\} \quad ,$$

is characterized by random time τ_J. The mean values and dispersions of τ_J are known and sufficiently describe the distribution of τ_J.

Hypothesis 2: The prevalence dynamics, when HCS resource consumption takes place, is described by:

$$\Gamma_2: \quad \begin{tikzcd} H \arrow[r] & A \arrow[r] \arrow[l, bend right] & B \arrow[r] \arrow[l, bend right] & C \arrow[r] & D \end{tikzcd} \quad ,$$

or by:

$$\Gamma_2^1: \quad \begin{tikzcd} H \arrow[r] & A \arrow[r] \arrow[l, bend right] \arrow[d, bend left] & B \arrow[r] \arrow[l, bend right] \arrow[d, bend left] & C \arrow[r] & D \\ & R_A \arrow[u, bend left] & R_B \arrow[u, bend left] & & \end{tikzcd} \quad ,$$

where R_A and R_B are the remission conditions in the phases A and B, respectively. The time a patient spends in each of the conditions

$$J' \in \{A,B,C,R_A,R_B\}$$

is determined by a random value τ_J^1. Means and dispersions of τ_J^1 values are also considered as known and sufficiently well describing the distribution.

Note 1: Γ_1, Γ_2, and Γ_2^1 do not reflect aging of population and require further detailing.

Note 2: Effects of resource consumption on prevalence dynamics could be understood as follows:

- Treatment of a patient (i.e. his consumption of HCS resources) allows for his transfer into an easier phase of a disease (for instance, the transfer $A \leftarrow B$). This is impossible if HCS resource consumption does not take place.

- Treatment of a patient allows for a change in the length of his stay in any possible phase of a disease.

Research into the dynamics of population prevalence requires knowledge of the dynamics of the age-sex structure of a population in a given region. A computer method for projecting the sex-age structure of a population has been devised (Klementiev, 1976) in which mortality and birth rate are considered as constants. In further development of the model, the effects of HCS activity on the parameters will be taken into account.

THE FUNDAMENTALS AND GOALS OF HEALTH CARE MODELING

Dynamic modeling of health care systems is still in its infancy, but even today it is obvious that this method may give specialists and public health organizers much valuable material for understanding and solving problems of organization of health care for the population. It has particular promise in eight fields:

1. Specifying the concept of health and the quantitative characteristics of a healthy status of individuals and entire populations. The difficulties of making an objective evaluation of the health status of individuals, families, and populations are well known and widely discussed, and use is still made of traditional demographic indices, as well as data on the causes of death, morbidity and the physical development of the population. To a considerable extent these indices still justify themselves, but, in the future their drawbacks will become more and more evident. That is why the elaboration of new comprehensive indices or a single unified index must be carried out.

2. Specification of the links between the health care sector and other spheres of social life. What forces and funds must human society optimally expend on the needs of health care and secondly, how are the resources allocated for health care to be spent most rationally and with maximum effect? The health care sector, although

not productive, nevertheless has a tremendous impact on all spheres of public life, preserving labor resources and affecting production, the social climate, etc. We feel that attention should be devoted to the theoretical aspects of the problem of health care economics since direct "practical" considerations (choice of methods of treatment depending on their cost, the economic justification of treatment of elderly people or terminal cases, etc.) could prove extremely dangerous. There are economists who claim that even for the economy as such one must not take a purely economic approach, and this is especially true for health care: human life and health cannot be directly expressed in monetary units. Nevertheless, one must take into consideration all the available resources and plan to make use of them most effectively.

3. Specification of the role of health care factors in determining the level of health of the population. Because of the important role socio-economic factors play in determining the level of the population's health, certain specialists go to the other extreme and consciously or unconsciously, belittle the role of public health factors. Although measures outside the sphere of public health are undoubtedly a necessary condition, and can play a decisive role in improving public health, the energetic and purposeful implementation of health care measures can have a favorable effect on the population's health when the socio-economic measures has yet to be felt.

4. Analysis of the existing criteria for effective management of public health services, and for the activity of health care bodies. It is unlikely that new comprehensive criteria for evaluating the efficacy of a public health system will appear in the immediate future, but a serious systems analysis of the indices being used now could bring us significantly closer to resolving this important task. It is promising to compare the indices used in different countries to describe the activities of health care services and establishments, and to single out those which can be used equally in any system as a first step towards formulating more general and universal criteria. Attempts should also be made to identify criteria which would not only describe an activity, but would also help us to arrive at a judgement of its efficacy, and to make optimal decisions about corrective measures.

5. The development of an improved "health information service"--an analysis of all the scientific, statistical, printed, reported, management and other information available in national and international public health systems. Many countries have succeeded in speeding up

the processing of traditional statistical and other data with the aid of computers but these have been local information processing systems covering individual medical establishments or types of activity, with the subsequent build-up and unification of local systems into regional or even national systems.

At present there are two trends in the application of computers in medicine: first, for analyzing and managing biological systems (modeling of biological systems, automation of clinical and laboratory investigations, automated diagnosis of diseases); and secondly, for the management of public health as a social system (processing of statistical data and primary carriers of medical information, management of hospitals and other establishments, scientific medical information, economic analysis and forecasting in public health and so on) (Figure 5). Moreover, besides building information and management systems according to function, a number of countries are developing comprehensive service according to territory, which undoubtedly is an important, but much more difficult task. Differences in methods of computer utilization in health care, the lack of comparability of initial and final data, the incompatibility of systems for the mechanical processing of medical information, etc. are being felt increasingly, and so the establishment of unified principles for processing the health information of different countries in order to facilitate exchange of information and cooperation is an important task for WHO and IIASA.

6. Appraisal of future health care development by modeling the basic tendencies in health development in different political and social conditions, and taking into consideration the development of human society and systems of national and international health care. At present, many countries are preparing forecasts for economy, science and technology up to 2000. Such work is also being conducted in the health field, but not taking into consideration all the complex interrelationships between the health care system, its subsystems and all spheres of social life. This too is, a task for WHO and IIASA. Evidently we need to draw up health forecasts for three main areas:

   - Development of medico-biological science;
   - The conditions of social life;
   - The development of national and international health care systems.

7. The construction of models of individual blocks and services of heath care ("micro-models") applicable to

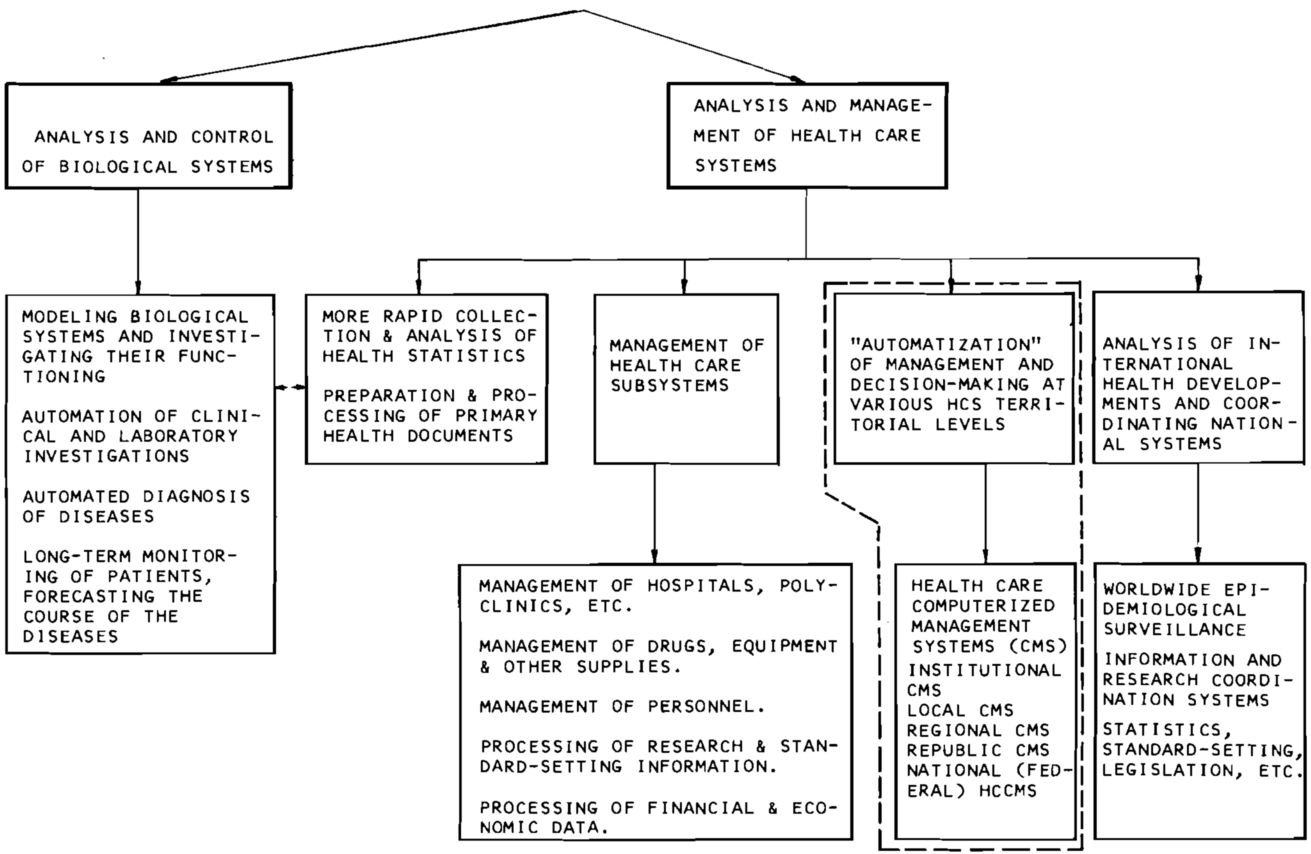

Figure 5. Use of computers in medicine.

conditions in different countries and to different requirements, so that they gradually become closer to each other and finally link up. The USSR and other socialist countries are already tackling a task of a higher level--the optimization at the present level of management of the existing State system of public health care. Since 1968, the USSR has been building a computerized health management system for the whole country consisting of a set of hierarchically interrelated subsystems at national, republican, oblast (regional) and settlement levels, as well as a computerized management system for medical establishments. Such a computerized branch management system should lead to the improvement of all levels of management of health care systems.

8. Finally, in our opinion, systems analysis and modeling of health care sector at various levels will not only bring out the common features and patterns of their development in different countries, but will promote the further development and increase the efficiency of international cooperation in this field.

CONCLUSIONS AND PROPOSALS FOR FURTHER RESEARCH

The present stage of health care development calls for the widespread use of promising methods of systems analysis and modeling in order to work out optimal variants for managing health care systems on a national scale and to promote international cooperation through WHO, IIASA and other international organizations.

Further studies of this problem are:

1. Analysis of the activities and formalized description of existing national health care systems--the aim being to determine how the interaction between the basic elements of the system and their functions is organized in different national health care systems, and to describe the influence of other social and natural factors on the health care system.

2. Identification of the most important problems common to all systems of health care. Specialists will have to examine problems related to the organization and management of public health on a national and regional scale. By using the systems approach, it will be possible to solve the following problems:

   - Planning the training and employment of personnel;

   - Planning the adjustment of the system of medical norms;

- Planning and distributing allocations;
- Planning the most important medico-biological studies;
- Evaluating the efficacy of different large-scale preventive and health-improving measures;
- Planning the development of international cooperation in the field of public health and medicine.

An important feature of the systems approach is the possibility of solving these problems in conjunction with each other.

3. Analysis of information services for work on systems studies in public health. The purpose is to compare the information requirements for solving the problems listed above with existing information. The need may arise for determining the volume, level and regularity of information input, and to improve methods of information collection, input and processing, and also the problem of establishing a definitive terminology. It will be expedient to publish appropriate glossaries and thesauri and to establish a list of measurement units, i.e. indices of reflection, and standards which will be of great significance in building a dynamic model. This stage is completed by the preparation of a technological scheme for processing information and the creation of information models and systems.

The above-mentioned stages should be the basis for developing a dynamic model of health care on a national scale. Mathematical equipment, methods of modeling, and systems analysis need to be selected and models created of separate elements and subsystems of public health which, as they become ready, are joined together to form an integrated model of health care systems. Much work will be necessary to prepare algorithms and program packages for the synthesis of a dynamic model which will then have to be checked experimentally in an interactive regime.

At this stage, the main effort will be directed towards devising methods for taking management decisions with the man-machine system, as well as for comparing variants in management policy and selecting the best solution.

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Appendix

EQUATIONS

(1) HP(I,T+DT) = HP(I,T) + DHD(I,T,T+DT) - HP(I,T)
*(DSR(I,T) + DR(I,T))*DT/1000 + TRHI(I,T,T+DT)
- TRHO(I,T,T+DT)

(2) LD(I,J,T+DT) = LD(I,J,T) - TRHL(I,J,T,T+DT)
+ TRLI(I,J,T,T+DT) - TRLO(I,J,T,T+DT) - LD(I,J,T)
*DSR(I,T)*DT/1000 - REAP(I,J,T,T+DT)

(3) RP(I,J,T+DT) = RP(I,J,T) + REAP(I,J,T,T+DT)
+ TRRI(I,J,T,T+DT) - TRRO(I,J,T,T+DT) - RP(I,J,T)
*DR(I,T)*DT/1000 - DHD(I,J,T,DT)

(4) HPS(T) = $\sum_{I}$ HP(I,T)

(5) LDS(T) = $\sum_{I,J}$ LD(I,J,T)

(6) CDL(T,T+DT) = LDS(T)/(LD,S(T)+HPS(T))

(7) AT(I,J,T,T+DT) = ATP(I,J)*LD(I,J,T)

(8) AA(I,J,T,T+DT) = AT(I,J,T,T+DT) + SD(I,J,T,T+DT)

(9) SD(I,J,T,T+DT) = GPS(T,T+DT)*CDL(T,T+DT)*ASD(I,J)

(10) GPS(T,T+DT) = SNOR(T)*DT*ARS(T)
+ SNOD(T)*DT*SDH(T)

(11) SDH(T) = GDH(T)*TSPS(T)

(12) TDH(T) = GDH(T)*TSPT(T)

(13) TDHT(J,T) = TDH(T)*ATDH(J,T)

(14) ADR(J,T) = TDHT(J,T)*DLN(J,T)

(15) RPS(J,T) = $\sum_{I}$ RP(I,J,T)

(16) REAP(I,J,T,T+DT) = CRP(I)*REAP(J,T,T+DT)

(17) REA(J,T) = ADR(J,T) - RPS(J,T)

(18) AAS(J,T,T+DT) = $\sum_{I}$ AA(I,J,T,T+DT)

$$(19)\quad \mathrm{REAP}(J,T,T+DT) = \begin{cases} \mathrm{AAS}(J,T,T+DT);\ \mathrm{REA}(J,T) \geq \mathrm{AAS}(J,T,T+DT); \\ \quad \mathrm{REA}(J,T) > 0 \\ \mathrm{REA}(J,T);\ \mathrm{REA}(J,T) < \mathrm{AAS}(J,T,T+DT); \\ \quad \mathrm{REA}(J,T) > 0 \\ 0, \mathrm{REA}(J,T) < 0 \end{cases}$$

$$(20)\quad \mathrm{EDH}(T) = \mathrm{DOC}(T)*\mathrm{TSD}(T)$$

$$(21)\quad \mathrm{DOC}(T+DT) = \mathrm{DOC}(T)+DT*(\mathrm{XDC}(T,T+DT) - \mathrm{YDC}(T,T+DT)$$

$$\mathrm{YDC}(T,T+DT) = \mathrm{DELAY}\ 3\ \ (\mathrm{XDC}(T-DT,T),\mathrm{DDO})$$

$$(22)\quad \begin{cases} \mathrm{STD}(T+DT) = \mathrm{STD}(T) + DT*(\mathrm{XST}(T,T+DT) - \mathrm{XDC}(T,T+DT) \\ \mathrm{XDC}(T,T+DT) = \mathrm{DELAY}\ \infty\ \ (\mathrm{XST}(T-DT,T),\mathrm{DST}) \end{cases}$$

$$(23)\quad \begin{cases} \mathrm{RETR}(T+DT) = \mathrm{RETR}(T) + DT*(\mathrm{XRS}(T,T+DT) - \mathrm{YRS}(T,T+DT) \\ \mathrm{YRS}(T,T+DT) = \mathrm{DELAY}\ 2\ \ (\mathrm{XRS}(T-DT,T),\mathrm{DES}) \end{cases}$$

$$(24)\quad \begin{cases} \mathrm{ARS}(T+DT) = \mathrm{ARS}(T)DT*(\mathrm{YRS}(T,T+DT)-\mathrm{ZRS}(T,T+DT)) \\ \mathrm{ZRS}(T,T+DT) = \mathrm{DELAY}\ 2\ \ (\mathrm{XRS}(T-DT,T),\mathrm{DSR}) \end{cases}$$

$$(25)\quad \begin{cases} \mathrm{FEDT}(T,T+DT) = \sum_{J} \mathrm{UEXDT}(J,T,T+DT)*DT/2 \\ \qquad *(\mathrm{RPS}(J,T)+\mathrm{RPS}(J,T+DT)) \\ \mathrm{EDTS}(T) = \sum_{T^1=0}^{T-DT} \mathrm{FEDT}(T^1,T^1+DT) \end{cases}$$

$$(26)\quad \begin{cases} \mathrm{FEDS}(T,T+DT) = \mathrm{UEXDS}(T)*\mathrm{SNOD}(T)*DT/2 \\ \qquad *(\mathrm{SDH}(T)+\mathrm{SDH}(T+DT)) \\ \mathrm{EDSS}(T) = \sum_{T^1=0}^{T-DT} \mathrm{FEDS}(T^1,T^1+DT) \end{cases}$$

$$\begin{cases} \mathrm{FEXRS}(T,T+DT) = \mathrm{UEXRS}(T)*\mathrm{SNOR}(T)*DT/2 \\ \qquad *(\mathrm{ARS}(T)+\mathrm{ARS}(T+DT)) \\ \mathrm{EXRS} = \sum_{T^1=0}^{T-DT} \mathrm{FEXRS}(T^1,T^1+DT) \end{cases}$$

SYMBOLS

HP(I,T)	the number in block "Healthy population" of sex-age group I (stratum) at moment T.
DHD(I,T,T+DT)	the number of the population in stratum I of block RP, transferred to block HP during time DT.
DSR(I,T)	$DPL(I,T)\frac{POPUL(I,T)}{HP(I,T)}$, where DPL(I,T) is the real number of sick persons per unit of time for 1000 population of stratum I, and POPUL(I,T) represents the total number of the population.
DR(I,T)	the mortality in sex-age group I, measured by the number of deaths per 1000 population of the given stratum in a unit of time.
DT	discrete count.
TRHI(I,T,T+DT), TRHO(I,T,T+DT)	the number of the population that have entered and left, respectively, by age from stratum I of block HP during DT.
LD(I,J,I)	the number of the population of stratum I in group LD from phase J of the development of the disease at moment T.
TRLI(I,J,T,T+DT), TRLO(I,J,T,T+DT)	the number of the population that have entered and left, respectively, by age from stratum I of block LD for DT.
TRHL(I,J,T,T+DT)	the difference between the number of the population transferred in DT from phase J to (J+1) and from phase (J-1) to J.
DHD(I,J,T,T+DT)	the difference between the number of the population that have entered and left for DT from phase J of block RP.
CDL(T,T+DT)	concentration of undetected patients for interval of time (T,T+DT) (latent morbidity).
ATP(I,J)	proportion of patients that have applied for care themselves.
AT(I,J,T,T+DT)	number of patients that have applied for care themselves during DT in stratum I with phase J of disease.

SD(I,J,T,T+DT)	number of patients (I,J) detected during preventive screening.
AA(I,J,T,T+DT)	total number of patients (I,J) detected during DT.
GPS(T,T+DT)	total number of preventive screenings conducted during DT.
ASD(I,J)	distribution of patients according to phases of disease J and age-groups I.
SNOR(T)	number of preventive screenings conducted per unit time by technical equipment of an automated system of preventive screenings of the population (ASPSP).
SNOD(T)	number of preventive screenings conducted in a unit of time by one doctor engaged in preventive work.
SDH(T)	given number of doctors conducting preventive screenings of the population.
GDH(T)	total number of doctors engaged in preventive and curative work.
TSPS(T), TSPT(T)	coefficients characterizing the ratio of time spent by doctors on preventive and curative work.
TDH(T)	given number of doctors engaged in curative work.
ATDH(J,T)	coefficient showing distribution of doctors providing treatment in J phases (inpatient, outpatient doctors).
DLN(J,T)	standard doctor workload (phase J).
REA(J,T)	difference between possible and actual number of patients.
DOC(T)	number of persons with higher medical education.
TSD(T)	proportion of doctors engaged in curative and preventive work in the overall number of persons with higher medical education.
STD(T)	number of students of higher medical institutes.
RETR(T)	unfulfilled volume of deliveries of technical equipment for ASPSP.

ARS(T)	quantitative evaluation of technical equipment for ASPSP.
UEXDS(T)	cost of conducting one preventive screening by a doctor.
FEDS(T), EDSS(T)	current and total expenditures connected with the conducting of preventive screenings by doctors.
UEXDT(J,T,T+DT)	expenditures for one patient during period DT (phase J of disease).
DT(T), EDTS(T)	current and total expenditures for treatment of patients.
UEXRS(T)	cost of conducting one preventive screening with the help of ASPSP.
FEXRS(T), EXRS(T)	current and total expenditures connected with preventive screenings with the help of ASPSP.

A Systems Approach to Japanese Medical Care Using a Simulation Model

Shigekoto Kaihara and Kazuhiko Atsumi

JAPANESE HEALTH CARE DELIVERY SYSTEM

Historically, Japanese medical care has been delivered by the private sector. Before World War II, the number of hospitals owned by the public sector, primarily university, charity or military hospitals, was limited. Neither central nor local government was regarded as being responsible for medical care delivery. Medical care was, so to speak, left to the personal relationship between physicians and patients. After the war, the situation changed rapidly. Now most of the people think that the delivery of medical care is, at least in part, the responsibility of the central or local government. Many new hospitals owned by the public sector have been built and local health centers now cover all parts of Japan. A health insurance system was introduced and every citizen of Japan is covered by this system. Nevertheless, most medical care is still in the hands of private physicians and the health insurance system deals only with the economic part of medical care delivery.

Accordingly, the delivery of medical care in Japan has become more and more complicated. Health centers, Government hospitals and clinics are now working independently. Some patients complain that there is no way of knowing which hospitals they should go to when they become ill; some say that even though they are covered by health insurance they cannot get any medical care in remote areas. Total medical expenditures are increasing year by year and absorb an increasing proportion of the gross national product. However, there has been little success in organizing medical care in Japan because of the complexity of the delivery system.

Recently, the concept has gained ground that we should regard medical care as a social system and should apply the results of systems sciences to seek solutions to the problems involved. With the help of the systems approach, the optimum relationship among various medical facilities such as clinics, hospitals and health centers might be found. The same might be true within hospitals where the interrelationship of the various sections needs reorganization.

Acting on this hope, the Japanese Government appointed a survey team in 1972 which investigated the application of the systems approach to analyzing and planning health care delivery in Japan. In 1973, as a result of this survey, a new section in the Medical Affairs Bureau of the Ministry of Health and Welfare was established, called The Office for Investigating the Development of Medical Systems. In 1974, as a subsidiary of this office and of the Ministry of International Trade and Industry, a new organization was formed which deals solely with the development of medical systems; its name is The Japanese Medical Information Systems Development Center.

PROJECTS SPONSORED BY THE JAPANESE MEDICAL INFORMATION SYSTEMS DEVELOPMENT CENTER

The Japanese Medical Information Systems Development Center is at present engaged on five projects. They are:

- Survey and evaluation of hospital systems;
- Survey and experiments on the reorganization and planning of health care delivery in a region;
- Compilation of a coding system and thesaurus of medical terms;
- Experiments on an information service system to physicians;
- Developments of new technologies in health care delivery.

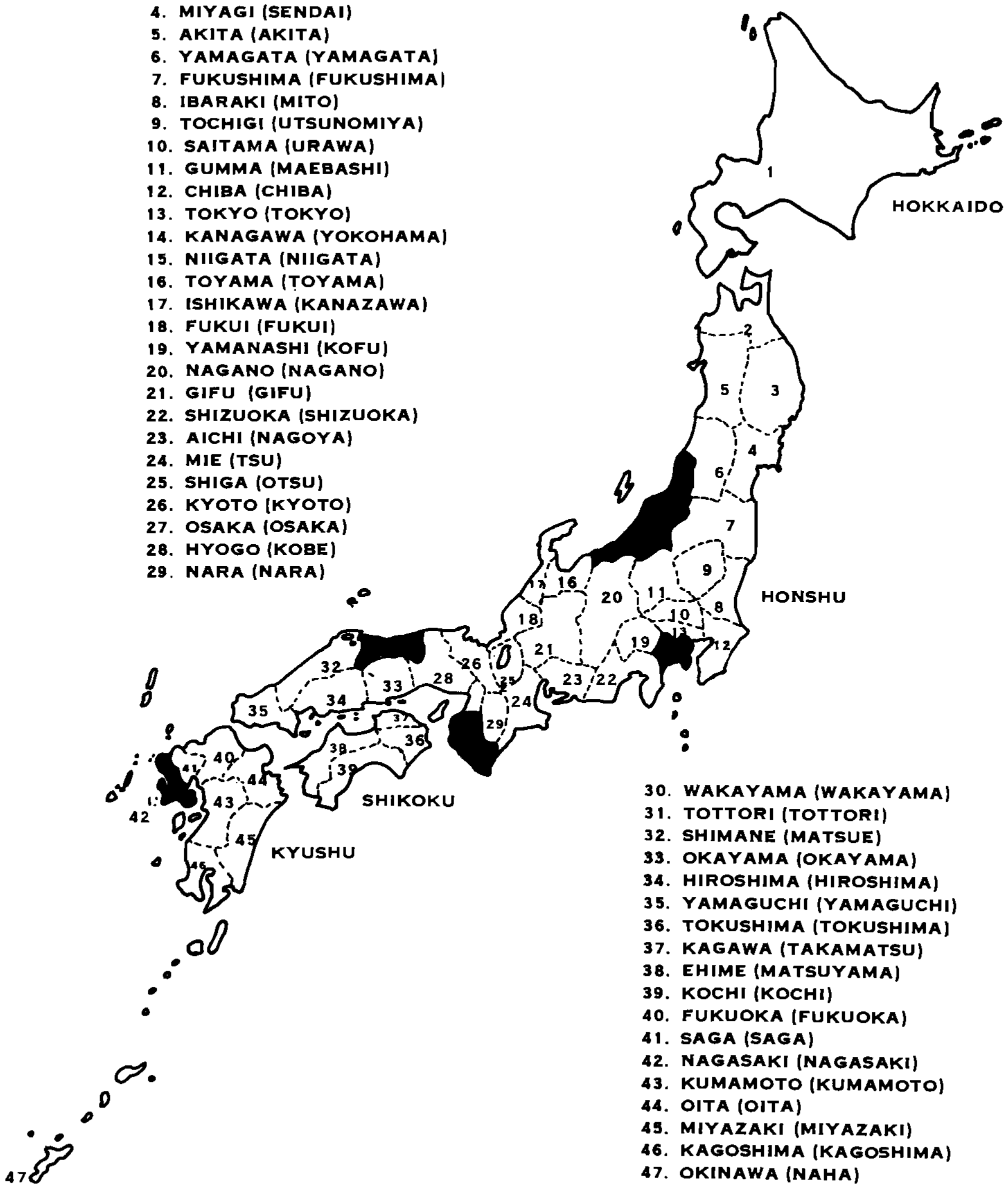
Among these projects, the second one is regarded as the most important, and at the moment four regions have been selected as model regions for various surveys and experiments. In the Nagasaki prefecture, which consists of thousands of islands, the project is mainly concerned with medical care delivery to these small islands. In Kanagawa prefecture, which is a heavily industrialized region, the emergency medical care system has been given priority in the reorganization of the health care delivery system. In Tottori prefecture, screening and early detection of disease are the main subject of investigation. In Wakayama and Niigata prefectures, experiments are being made with health care delivery in a region of mountains and heavy snowfalls. Since these are five year projects, it is too early to evaluate the results. It is reported, however, that the new technology and systems approach show great possibilities of improving medical care delivery if they are properly used (Figure 1).

In addition to these five projects, the organization also has a policy making committee, responsible for establishing guidelines for the projects and investigating methods of evaluating them.

Noting that there has been almost no standard method of evaluating the health care delivery systems, the committee agreed

NAMES OF PREFECTURES AND
PREFECTURAL CAPITAL CITIES

1. HOKKAIDO (SAPPORO)
2. AOMORI (AOMORI)
3. IWATE (MORIOKA)
4. MIYAGI (SENDAI)
5. AKITA (AKITA)
6. YAMAGATA (YAMAGATA)
7. FUKUSHIMA (FUKUSHIMA)
8. IBARAKI (MITO)
9. TOCHIGI (UTSUNOMIYA)
10. SAITAMA (URAWA)
11. GUMMA (MAEBASHI)
12. CHIBA (CHIBA)
13. TOKYO (TOKYO)
14. KANAGAWA (YOKOHAMA)
15. NIIGATA (NIIGATA)
16. TOYAMA (TOYAMA)
17. ISHIKAWA (KANAZAWA)
18. FUKUI (FUKUI)
19. YAMANASHI (KOFU)
20. NAGANO (NAGANO)
21. GIFU (GIFU)
22. SHIZUOKA (SHIZUOKA)
23. AICHI (NAGOYA)
24. MIE (TSU)
25. SHIGA (OTSU)
26. KYOTO (KYOTO)
27. OSAKA (OSAKA)
28. HYOGO (KOBE)
29. NARA (NARA)



30. WAKAYAMA (WAKAYAMA)
31. TOTTORI (TOTTORI)
32. SHIMANE (MATSUE)
33. OKAYAMA (OKAYAMA)
34. HIROSHIMA (HIROSHIMA)
35. YAMAGUCHI (YAMAGUCHI)
36. TOKUSHIMA (TOKUSHIMA)
37. KAGAWA (TAKAMATSU)
38. EHIME (MATSUYAMA)
39. KOCHI (KOCHI)
40. FUKUOKA (FUKUOKA)
41. SAGA (SAGA)
42. NAGASAKI (NAGASAKI)
43. KUMAMOTO (KUMAMOTO)
44. OITA (OITA)
45. MIYAZAKI (MIYAZAKI)
46. KAGOSHIMA (KAGOSHIMA)
47. OKINAWA (NAHA)

Figure 1. Map of Japan showing prefectures selected as model regions for projects.

that one of its most important tasks was to investigate methods of analyzing, planning and evaluating health care delivery systems. As its contribution, it started in 1974 the development of a simulation model of Japanese health care delivery. The first objective of the model was to provide a method of understanding the interrelationships of the various health statistics available at the moment in Japan, so that the prediction of future parameters might be possible. This project is still ongoing. The analysis of medical demands has been tested in the model and health care supply is now being studied. Preliminary results of this analysis will be described in the fourth section.

BASIC HEALTH STATISTICS OF JAPAN

Population

Figure 2 shows Japanese population trends, including the estimated future population as calculated by the Institute of Population Problems of the Ministry of Health and Welfare. The latest population census conducted on 1 October 1970 revealed that the population of Japan amounted to 103,720,060. One of the remarkable points about the Japanese population is the rapid change in the shape of the population pyramid over the past 20 years. Figure 3 shows the comparison of population pyramids for 1935 and 1972. The population pyramid in the future will show even more people in the higher age groups.

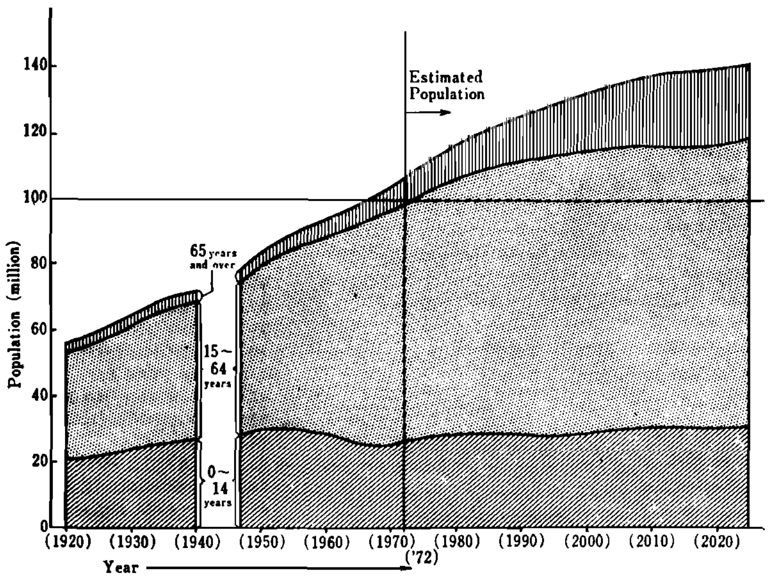


Figure 2. Japanese population trends.

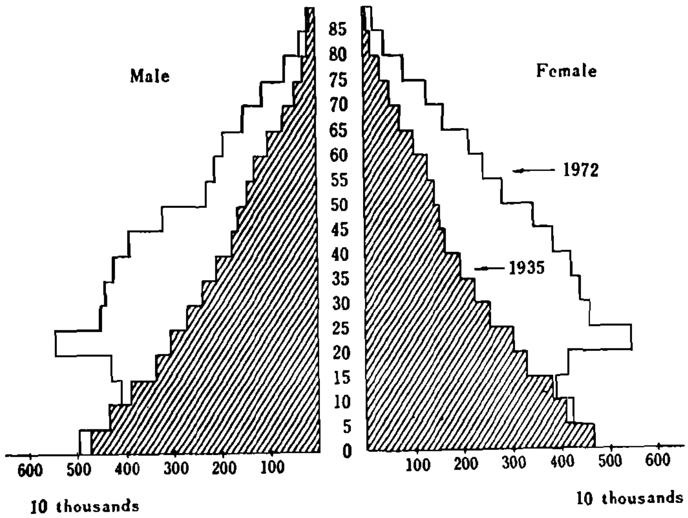


Figure 3. Population pyramids for 1935 and 1972.

Vital Statistics (Table 1)

Live Births

After its extraordinary rise in 1947, the birth rate started to decline rapidly and reached 17.2 in 1957. This rapid decrease seemed to be due to a decline in the number of marriages, the extensive use of contraceptive measures and the changing attitudes of people toward family size.

Deaths

The annual death rate has been decreasing since 1920. It reached 7.8 as early as 1955 and for the past ten years it has kept between 6.6. and 7.4.

Deaths by Leading Causes (Table 2)

It has been the recent tendency for deaths from degenerative diseases to constitute a growing proportion of the total; in particular, so-called adult diseases, such as lesions affecting the central nervous system, malignant neoplasms, heart diseases and some others, have increased, while deaths from infectious diseases have greatly decreased.

Table 1. Statistics (from *Health Services in Japan* published by Ministry of Health and Welfare), 1900-1972.

Year	Population	Live births	Deaths	Natural increase	Infant deaths (under 1 yr.)	Neo-natal deaths (under 28 days)	Maternal deaths	Still-births	Marriages	Divorces
1900	43 847 000	1 420 534	910 744	509 790	220 211	112 259	6 200	137 987	346 528	63 828
1910	49 184 000	1 712 857	1 064 234	648 623	276 136	126 910	6 228	157 392	441 222	59 432
1920	55 963 053	2 025 564	1 422 096	603 468	335 613	139 681	7 158	144 038	546 207	55 511
1930	64 450 005	2 085 101	1 170 867	914 234	258 703	104 101	5 681	111 730	506 674	51 259
1940	71 933 000	2 115 867	1 186 595	929 272	190 509	81 869	5 070	102 034	666 575	48 556
1941	71 680 200	2 277 283	1 149 559	1 127 724	191 420	77 829	4 929	103 400	791 625	49 424
1942	72 384 500	2 233 660	1 166 630	1 067 030	190 897	76 177	4 586	95 448	679 044	46 268
1943	72 883 100	2 253 535	1 219 073	1 034 462	195 219	76 588	4 542	92 889	743 842	49 705
1944	73 064 300	…	…	…	…	…	…	…	…	…
1945	71 998 100	…	…	…	…	…	…	…	…	…
1946	73 114 100	…	…	…	…	…	…	…	…	…
1947	78 101 473	2 678 792	1 138 238	1 540 554	205 360	83 047	4 488	123 837	934 170	79 551
1948	80 002 500	2 681 624	950 610	1 731 014	165 406	72 907	4 437	143 963	953 999	79 032
1949	81 772 600	2 696 638	945 444	1 751 194	168 467	71 485	4 601	192 677	842 170	82 575
1950	83 199 637	2 337 507	904 876	1 432 631	140 515	64 142	4 117	216 974	715 081	83 689
1951	84 573 000	2 137 689	838 998	1 298 691	122 869	58 686	3 691	217 231	671 905	82 331
1952	85 852 000	2 005 162	765 068	1 240 094	99 114	51 015	3 417	203 824	676 995	79 021
1953	87 033 000	1 868 040	772 547	1 095 493	91 424	47 580	3 373	193 274	682 077	75 255
1954	88 293 000	1 769 580	121 491	1 048 089	78 944	42 726	3 262	187 119	697 809	76 759
1955	89 275 529	1 730 692	693 523	1 037 169	68 801	38 646	3 095	183 265	714 861	75 267
1956	90 259 000	1 665 278	724 460	940 818	67 691	38 232	2 838	179 007	715 934	72 040
1957	91 088 000	1 566 713	752 445	814 268	62 678	33 847	2 677	176 353	773 362	71 651
1958	92 010 000	1 653 469	684 189	969 280	57 052	32 237	2 560	185 148	826 902	74 004
1959	92 971 000	1 626 088	689 959	936 129	54 768	30 235	2 381	181 893	847 135	72 455
1960	93 418 501	1 606 041	706 599	899 442	49 293	27 362	2 097	179 281	866 115	69 410
1961	94 285 000	1 589 372	695 644	893 728	45 465	26 255	1 914	179 895	890 158	69 323
1962	95 178 000	1 618 616	710 265	908 351	42 797	24 777	1 813	177 363	928 341	71 394
1963	96 156 000	1 659 521	670 770	988 751	38 442	22 965	1 701	175 424	937 516	69 996
1964	97 186 000	1 716 761	673 067	1 043 694	34 967	21 343	1 699	168 046	963 130	72 306
1965	98 274 961	1 823 697	700 438	1 123 259	33 742	21 260	1 597	161 617	954 852	77 195
1966	99 056 000	1 360 974	670 342	690 632	26 217	16 296	1 266	148 248	940 120	79 432
1967	99 637 000	1 935 647	675 006	1 260 641	28 928	19 248	1 365	149 389	953 096	83 478
1968	100 794 000	1 871 839	686 555	1 185 284	28 600	18 326	1 275	143 259	956 321	87 327
1969	102 022 000	1 889 815	693 787	1 196 028	26 874	17 116	1 094	139 211	984 142	91 280
1970	103 119 447	1 934 239	712 162	1 221 277	25 412	16 742	1 008	135 095	1029 405	95 937
1971	104 345 000	2 000 973	684 521	1 316 452	24 805	16 450	905	130 920	1091 229	103 595
1972	105 742 000	2 038 682	683 751	1 354 931	23 773	15 817	827	125 154	1099 984	108 382

Table 2. Percentage of selected causes of deaths to total deaths (from *Health Services in Japan* published by Ministry of Health and Welfare), 1950-1972.

International B list number	Cause of death	1950	1960	1965	1966	1967	1968	1969	1970	1971	1972
B5, B6	Tuberculosis (all forms)	13.5	4.5	3.2	3.0	2.6	2.5	2.4	2.2	2.0	1.8
B19	Malignant neoplasms	7.1	13.3	15.2	16.4	16.7	16.8	17.1	16.8	17.9	18.6
B26, B22, B29	Heart diseases	5.9	9.7	10.8	10.6	11.2	11.7	12.0	12.5	12.5	12.6
B27	Hypertensive diseases	...	2.1	2.7	2.7	2.7	2.6	2.5	2.6	2.5	2.5
B30	Cerebrovascular diseases	11.7	21.2	24.7	25.7	25.5	25.4	25.6	25.4	25.9	25.8
B32, B33.a, B46.d	Pneumonia and bronchitis	8.6	6.5	5.2	4.2	4.2	4.6	4.7	4.9	4.3	4.3
B37	Cirrhosis of liver	0.6	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.9	2.0
B38	Nephritis and nephrosis	3.0	2.2	1.6	1.5	1.5	1.5	1.4	1.3	1.3	1.1
B45.a	Senility without mention of psychosis	6.5	7.7	7.0	6.6	6.4	5.8	5.5	5.5	5.2	4.8
B4, B46.e	Gastritis, duodenitis, enteritis, and colitis	7.6	2.8	1.8	1.7	1.6	1.5	1.4	1.2	1.2	1.1
BE47, BE48	Accidents	3.6	5.5	5.7	6.3	6.2	5.8	6.2	6.1	6.2	6.2
BE49	Suicide	1.8	2.9	2.1	2.2	2.1	2.1	2.1	2.2	2.4	2.6
	Others	30.1	20.3	18.6	17.6	17.8	18.1	17.4	17.5	16.7	16.6

Medical Care

Hospitals and Clinics

The number of hospitals and beds has rapidly increased in recent years as far as the per-population ratio is concerned (Table 3). However, we are faced with the problem of scarcity of medical facilities in the rural and mountain areas as already mentioned.

Medical Care Personnel

Table 4 shows the number of various types of medical personnel. Although the number of physicians, dentists and pharmacists is statistically about the same as in European countries on a per-population basis, we are confronted with the problem of an excessive concentration in the urban areas and a lack of qualified personnel in public health work. There is currently a plan to increase the number of doctors to 150 per 100,000 of population by establishing new medical schools (Table 5).

Table 3. Number of hospitals by type and kind, 1971-1972.

	Total		Mental hospitals		Tuberculosis sanatoria		Leprosaria		Communicable disease hospitals		General hospitals	
	1971	1972	1971	1972	1971	1972	1971	1972	1971	1972	1971	1972
Grand total	8 026	8 143	900	925	139	126	14	16	30	29	6 943	7 047
National	437 (255)	439 (257)	3 (3)	4 (4)	30 (27)	24 (21)	11 (11)	13 (13)	—	—	393 (214)	398 (219)
Prefectural and municipal	1 067	1 067	44	47	23	22	—	—	30	29	970	969
Semi-public	179	178	—	—	2	2	—	—	—	—	177	176
Social insurance	280	274	2	1	6	5	—	—	—	—	272	268
Private	6 063	6 185	851	873	78	73	3	3	—	—	5 131	5 236

Note: 1) Those figures in the brackets are those directly under the jurisdiction of the Ministry of Health and Welfare.

2) Those semi-public facilities include hospitals operated by the Japanese Red Cross Society, etc.

Table 4. Number of medical care personnel, Japan, 1954-1972.

Year	Physician		Dentist		Pharmacist		Public health nurse		Midwife		Clinical nurse	
	Total No.	Per 10 000 pop.	Total No.	Per 10 000 pop.	Total No.	Per 10 000 pop.	Total No.	Per 10 000 pop.	Total No.	Per 10 000 pop.	Total No.	Per 10 000 pop.
	Thousand		Thousand		Thousand		Thousand		Thousand		Thousand	
1954	92	10.5	31	3.5	51	5.8	12	1.4	56	6.3	119	13.5
1956	96	10.7	32	3.5	53	5.9	12	1.4	54	6.0	137	15.2
1958	100	10.9	32	3.5	57	6.1	12	1.3	52	5.7	160	17.4
1959	101	10.9	33	3.5	58	6.3	13	1.3	52	5.6	170	18.3
1960	103	11.0	33	3.6	60	6.5	13	1.4	52	5.6	186	19.9
1961	104	11.0	33	3.6	62	6.5	13	1.4	51	5.4	195	20.7
1962	105	11.1	34	3.6	63	6.6	14	1.4	50	4.8	204	21.5
1963	107	11.1	34	3.6	65	6.8	14	1.5	46	4.8	216	22.5
1964	108	11.1	35	3.6	67	6.9	14	1.4	44	4.5	230	23.8
1965	109	11.1	35	3.6	69	7.0	14	1.4	42	4.3	245	24.9
1966	111	11.2	36	3.6	71	7.2	14	1.4	46	4.7	246	24.9
1967	112	11.1	37	3.6	72	7.2	14	1.4	35	3.4	253	25.2
1968	114	11.2	37	3.6	74	7.3	14	1.4	33	3.2	267	26.2
1969	116	11.3	37	3.6	76	7.4	14	1.3	32	3.1	283	28.3
1970	119	11.5	38	3.7	78	7.7	14	1.3	32	3.1	281	28.1
1971	123	11.7	39	3.7	83	7.9	14	1.3	28	2.7	291	27.6
1972	...	...	...	...	...	...	15	1.4	30	2.8	338	31.5

Note: Number of clinical nurses include assistant clinical nurses.

Table 5. Number of training schools for medical care personnel and students entering annually as of April.

	Number of training institutions		Number of students entering annually	
	1972	1973	1972	1973
Physician	59	60	5 600	5 900
Dentist	22	23	2 060	2 180
Pharmacist	38	39	5 560	5 820
Veterinarian	16	16	800	800
Public health nurse	53	56	1 610	1 770
University	4	5	140	200
Junior college	1	1	20	20
Others	48	50	1 450	1 550
Mid-wife	51	55	1 220	1 315
University	1	2	40	100
Junior college	1	2	20	35
Others	49	51	1 160	1 180
Clinical nurse	542	595	20 215	22 772
University	8	9	220	280
Junior college	15	18	810	990
Others	519	568	19 185	21 502
Assistant nurse	771	769	33 301	33 992
High school (nursing course)	109	116	5 675	6 305
Others	662	653	27 626	27 687
Radiology technician	24	26	980	1 000
X-ray technician	9	6	695	485
Health laboratory technician	23	20	835	770
Clinical laboratory technician	41	56	1 675	2 445
Dental hygienist	68	73	2 389	2 609
Dental technician	43	45	1 435	1 502
Physical therapist	8	10	140	180
Occupational therapist	3	4	60	80
Orthoptist	1	1	30	30

Medical Care Statistical Surveys

National health survey

Since 1948, the Government has been conducting 'National Health Surveys (Family Sickness Survey)' and 'Patient Surveys' on a nation-wide scale by using sampling methods. In the National Health survey, about 27,000 households containing 90,000 people in 420 areas are sampled, and the incidence of disease and injury among the population is classified by type of disease or injury, geographical area, occupation, economic status, sex, age, etc. and also by the mode of treatment of disease and injury and by the amount of payment for the treatment by patients.

Patient survey

In the patient survey, 773 hospitals (1/10 of the total number), 684 general clinics (1/1000 of the total number) and 297 dental clinics (1/100 of the total number) are sampled and the number of in- and out-patients who use these facilities, is enumerated by type of disease or injury, sex, and age, and by the method of paying the charge for treatment together with the length of hospitalization. Again, the consultation rate has been constantly increasing over the past 15 years.

A SIMULATION MODEL OF HEALTH CARE

As shown in the previous section, many statistics relative to health care are reported annually from various organizations. It is a characteristic of these statistics to show some changes every year; however, since the mechanism of the change is not always clear, the prediction of future trends has not been easy. This has also made it difficult to plan health care delivery in the country.

As a first step, therefore, an analysis of medical demands was made, and a simulation model of demands was constructed, in which it was endeavored to include the statistical changes described in the previous section. Since health care is related to various social factors, the model had to take these non-medical factors into consideration. It was also the aim of the preliminary study to identify these external factors.

Figure 4 shows the main concept of the model. In this model, the total population was divided into four groups, namely the healthy (X_1), the unaware sick (X_2), the sick without medical care (X_3), and patients (X_4). Between these four groups, flows of people were assumed. Some of the healthy become ill at a more or less constant rate; the unaware sick move into the group of "sick without medical care" and these move into the group of "patients". Some patients die and others recover and return to the healthy group at certain rates. The factors which are assumed to influence the flows are also shown in Figure 4. The flow between the healthy and unaware sick, is affected by the incidence of various illnesses. The advance of civilization and education will affect the flow between the unaware sick and the sick without medical care, for as people become more medically educated, they will pay more attention to their illnesses. More sick without medical care flow into the group of sick with medical care when they can get medical care more easily. This factor was designated in the model as "accessibility to physicians". Accessibility is made up of two factors; namely, the amount of medical care available and the economic status of the patients. Then advances in medical diagnosis and treatment will affect the return flow of patients to the healthy group. The intention in adopting the structure described above was to attribute changes in medical demands to changes in the flows between the groups.

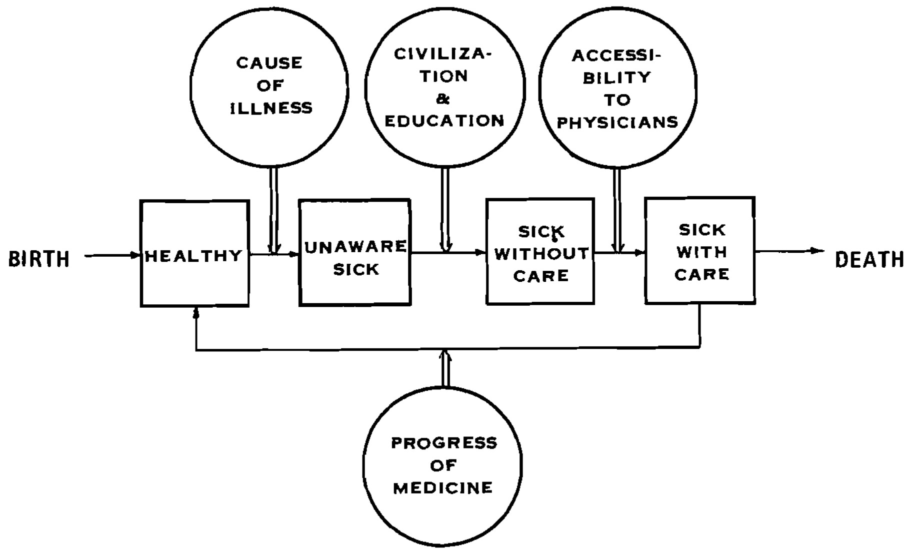


Figure 4. Main concept of demand model.

Figure 5 shows the structure of the demand part of the simulation model. The structure is the same as in Figure 4 except for R_7, R_8, R_9 and R_{10}. The inverse flow from X_2 to X_1

covers the sick who get well without seeing physicians. In this model, each group is divided into four levels by age; people under 14, and people aged 15 to 44, 45 to 64 and over 65 respectively. Each age group has the same structure as in Figure 5. R_7 and R_8 are the flows between these age groups. This means that the model is made up of 16 different groups with 29 flows between them. However, for simplicity of exposition, we use the model of one age level in the following discussion.

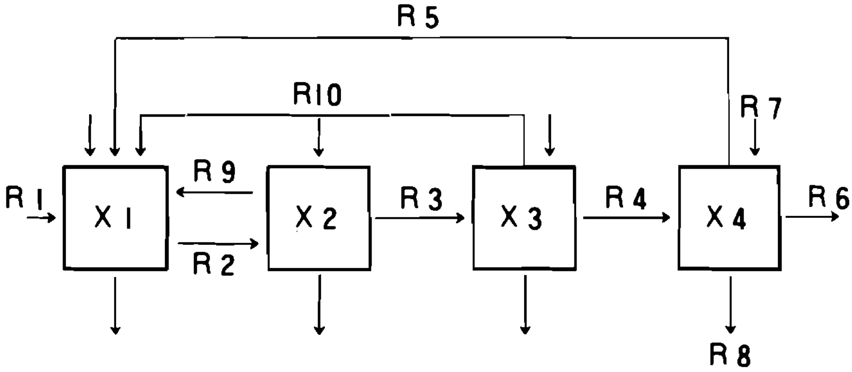


Figure 5. Structure of demand model.

The model is expressed by a set of differential equations. On the assumption that the rates are constant over the year and the system is in equilibrium in the sense that no large changes from external causes take place, these equations can be solved.

In building the model, the statistical values described in the third section were mainly used, namely the birth rate for R_1, the number of first visits to physicians from the Patient Survey for R_4, the duration of illnesses from the National Health Survey for the calculation of R_5, the death rate for R_6, the population census for R_7 and R_8, the rate of requests for medical care in the National Health Survey for the calculation of R_{10}, the Patient Survey for X_4 and prevalence rate shown in the National Health Survey for the calculation of X_3.

No statistical values are available at present for R_2, (ideal incidence rate of illness), R_3 (the rate at which the unaware sick become aware of their illnesses), R_9 (the rate at which the unaware sick recover), X_1 (number of healthy) and X_2 (number of the unaware sick). However, if one of these values is given, the other parameters can be calculated from the sets of equations. In this study, the rate R_2 was assumed to be constant over the past 15 years, and the other parameters were calculated. The calculation was performed for each year on the assumption that the system remained in equilibrium over the year. After all the parameters were obtained for each year, the total model was run for the past 15 years, using the program DYNAMO. The validity of the model was tested by comparing the calculated parameters with the original statistical values.

Figure 6 shows some of the results of the calculations. It represents the annual rates of change of parameters. Each number in the graph corresponds to the suffix of rate, except for rate 10, which is represented by T. It will be noticed from this graph that R_3 has gradually increased over the past 15 years. This seems to be the main cause of the increases in the prevalence rate and the total number of patients. The gradual decrease of R_5 may also contribute to the increase of patients. R_4 gradually increased until 7-8 years ago and then decreased again. This might have been caused by the relative shortage of supplies of medical care.

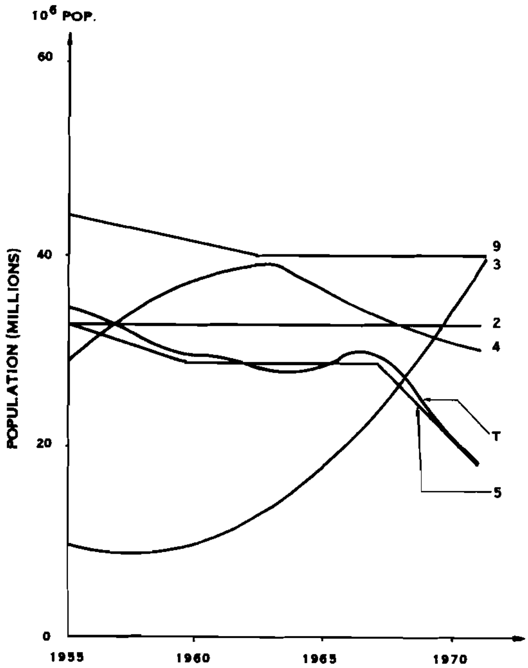


Figure 6. Calculated annual rates of change of parameters.

Figures 7 and 8 show the changes in population, with forecasts up to 1985 of the percentage of people over 65 years old and the numbers of healthy and sick respectively. This shows a gradual increase in the future numbers of the aged and sick.

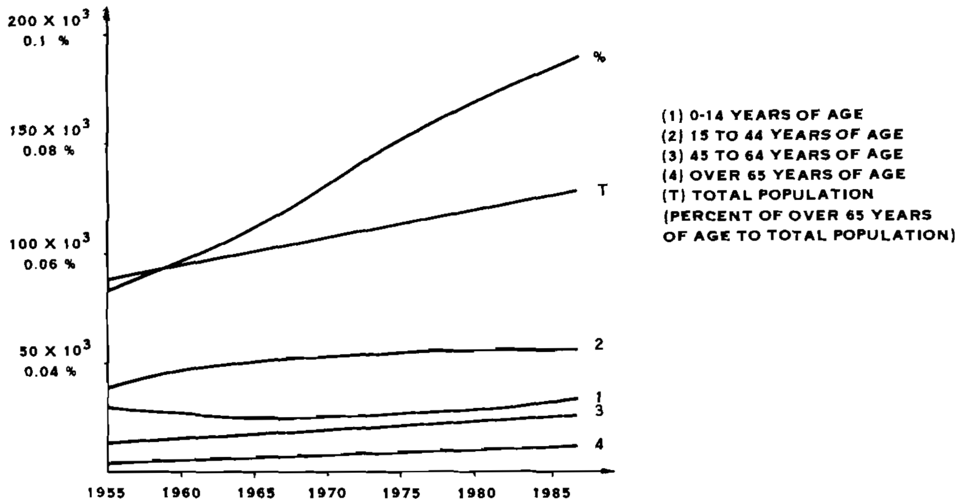


Figure 7. Forecasts of population showing percentage of the people over 65.

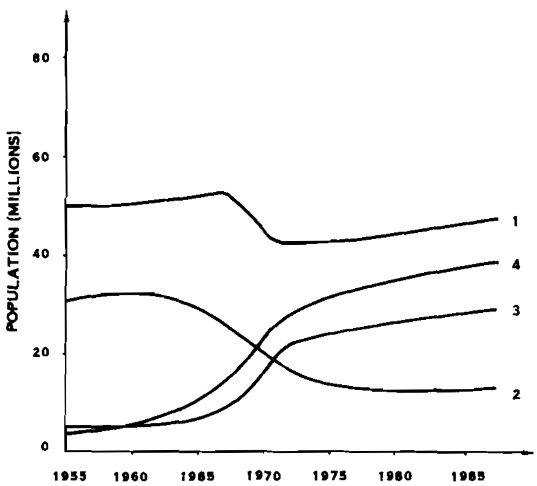


Figure 8. Estimated number of the healthy (1), unaware sick (2), the sick without medical care (3) and the sick (4).

These are preliminary results and do not represent any official view. However, we hope that the simulation method will be of great help in the future in planning national health delivery.

Technological and Social Assessment Of a Medical Information System

K. Atsumi

INTRODUCTION

The best solution to the problem of satisfying the increasing demand for medical care within limited medical resources, is to systematize the health care system by means of information technology and to increase efficiency in medical care.

A medical information system (MIS) at the regional level is already operative in the USA and European countries. However, MIS at the national level is still at the planning stage in USSR and Czechoslovakia; it is functioning partially only in Sweden.

In Japan, national projects on MIS have been started recently by the Ministry of Health and Welfare (MHW) in collaboration with Ministry of International Trade and Industries (MITI).

Although the impact of MIS has been held to be very great, very few surveys assessing the implications of the technology used in MIS have been reported, except the United Nations Seminar on "Human Rights Problem in Computerization" in May 1972 and the OECD Seminar on "Confidentiality Problem in Medical Data Bank" in June 1974.

The main purpose of technology assessment (T.A.) is to predict the negative effects arising from the use of information technology and to devise mens of countering them. It may also include a forecast of the technological problems to be solved.

In this report, T.A. is applied to the Japanese national project for a comprehensive medical information system. In this project, software such as philosophy and vision on MIS are to be planned by MHW and hardware such as computers, terminals and medical instruments are to be developed by MITI.

In MHW, four committees--on fundamental problems, regional medical care, hospital automation and coding and thesaurus--have been established.

In MITI's project, starting from the hardware to be utilized in remote area without medical doctors, many kinds of equipment have been surveyed and analyzed. Hardware, methods and instruments to be developed are classifed under the following heads: multiplex and modulation transmission; filing, access and privacy protection in medical information system; medical image storage; color image transmission; and medical electronic devices and their interfaces to computers.

THE MAIN PROBLEMS ASSOCIATED WITH MIS

The main problems relative to MIS occur in the following fields: biomedical engineering, systems engineering, cost of MIS; manpower, including systems engineers, and changes in social values.

Forecast on Biomedical Engineering

From the viewpoint of biomedical engineering, many forecasts about MIS have been published in the USA and in Japan.

The trends are summarized in Figure 1. In the case of most of the MIS subsystems shown in Figure 1, it is expected that, investigations and researches having started in the 1970s, they will begin functioing in the 1980s and that their use will be widespread in the 1990s.

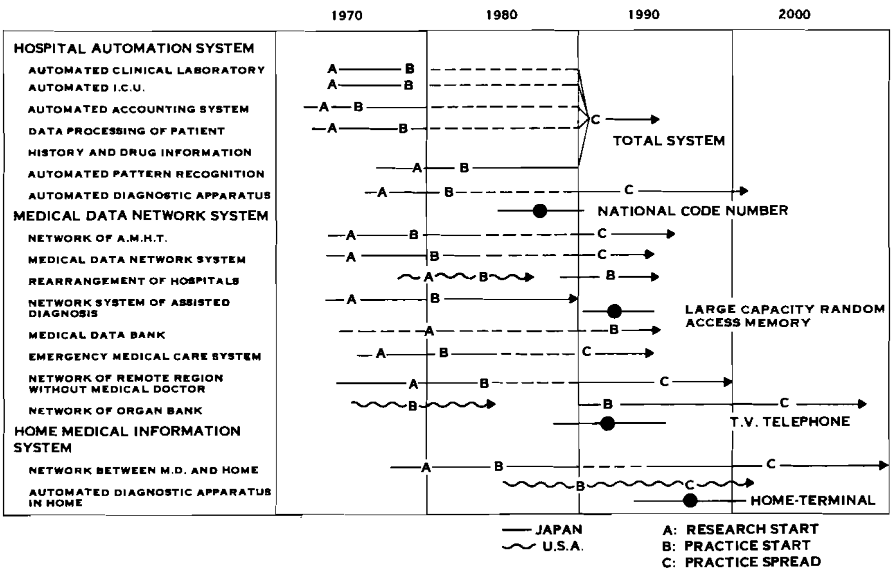


Figure 1. Forecast on application of medical information system.

Forecast on Systems Engineering

The Science and Technology Agency of Japan published a forecast of future trends in systems engineering and its applications in *Science and Technology Developments up to A.D. 2000.*

The principal problems for solution by the year 2000 were considered to be:

- Pattern recognition;
- Memory: random access in large capacity, molecular memory, holographic memory;
- Biological software: functions such as learning, self-modification and adaptive control.

In a report to an OECD meeting in December 1973, Dr. Anderla divided systems science and engineering into five fields--hardware, software, systems design, terminals and telecommunications. He quoted predictions that the computer problems in the field of systems engineering such as the leveling-up of adaptation and learning and optical memories would be solved by the 1980s.

Forecast on Cost of the Health Care Service

Macro- and micro-economic studies on the cost of computers and terminals were made by a working group from the national MIS project teams.

The macro-economic study provided the following information: the gross national product (GNP) for 1985 was estimated at 165 trillion to 220 trillion yen, the cost of installing computers at 4.3 to 5.7 trillion yen and total expenditures on national health care at 6.6 to 10.6 trillion yen which represented 2.6% and 4%-4.8% respectively of GNP (Table 1).

Out of the total expenditures on national health care, data processing would cost 320 to 550 billion yen which would be equivalent to 7% to 9% of the cost of computer installation.

On the other hand, the micro-economic study indicated that the total expenditures required for setting up computer terminals as well as installing computers in the central and regional medical information centers would amount to 377.5 billion yen, plus 100 billion yen for hospital computers, making a total of around 500 billion yen (Table 2). This amount agrees with the forecast of 500 billion yen arrived at in the macro-economic study.

Forecast on Manpower

Many trained personnel will be required to operate the medical information system, but the training of systems engineers is

Table 1. Forecast on costs of national health care and installation of computers. *(Unit: 10 Yen)

	Construction & Installation Cost			
	Unit Cost	Number of Units	Total Cost	
	Million Yen	Units	In Hundreds of Million Yen	
Medical Information Center	100	102	1020	National Center 2 Regional Center 100
Computer	–	–	135	
Terminal	2	130,000	2600	60,000 Units in Hospitals 70,000 Units in Clinics
Computer for Medical Care	–	500	1000	30% of 1500 General Hospitals
Others	–	–	265	
Total	–	–	5000	

Table 2. Construction and installation costs of MIS.

	1972	1975	1980	1985
Growth Ratio of GNP *			1.04 1.07	1.04 1.07
GNP (G)*	96	112	136 157	165 220
Computer Installation Cost (C)*	1.4	2.1	3.4 3.9	4.3 5.7
National Medical Care (M)*	3.2	4.2	5.4 7.0	6.6 10.6
C/G × 100	1.4%	1.8%	2.5% 2.5%	3.6% 2.6%
M/G × 100	3.4%	3.7%	4.0% 4.5%	4.0% 4.8%
Modified No. of Installed Computers	17,000	26,000	42,000 49,000	54,000 72,000

the most urgent problem because there will be a serious shortage of such personnel in the information-oriented society of the future.

The total number of computers in Japan was 24,183 in 1975. It is forecasted that this will rise to 42,313 in 1978 and 61,425 in 1980 and for these operations, many systems engineers will be required.

The gap between the supply and demand of systems engineers will increase year by year and the ratio of supply to demand will be 17.5% by 1980, as shown in Table 3.

Table 3. Forecast of ratio of supply and demand of systems engineers and programmers in Japan.

Demand & Supply / Year	Demand (A) (Number)	Supply (B) (Number)	Ratio of B to A (%)
1974	161,050	57,439	35.7
1975	197,470	62,323	31.6
1976	239,450	67,232	28.1
1977	288,190	72,120	25.0
1978	345,320	76,974	22.3
1979	412,880	81,788	19.8
1980	493,960	86,556	17.5

If 100 billion-130 billion yen per year is spent on education and training, there will still be 40,000 systems engineers short. To this figure must be added the demand for 40,000 systems engineers in the medical field. This shortage may be one of the most important problems in providing manpower to operate MIS.

Changes in Social Values

Present-day society is a flexible and ceaselessly changing information-oriented society in which multifarious and sometimes conflicting values co-exist. To achieve social welfare and greater equality, affluence is necessary, but from the viewpoint of ecology, there is a limit to supplies of resources and manpower.

At this point, improved efficiency by means of computerization becomes important.

THE IMPACT OF MIS ON INDIVIDUALS AND SOCIETY

In view of the problems foreseen, it is anticipated that the date at which MIS will be introduced in Japan will be 1980.

As MIS is a complicated social system, a wide range of people is concerned. However, in order to clarify problems of technological and social assessment, they may be classified as follows: healthy client, patient, medical doctor, administrator of medical institution, paramedical staff, (systems) engineer, medical officer, and people working in the medical industries.

Fields Affected

It is anticipated that the influence of MIS on society at large will be deep and far-ranging. As shown in Table 4, it will affect the following fields: individuals, medicine, economics and industry, science and technology, and society.

The details are summarized in Table 4.

Table 4. Fields affected by the operation of the medical information system.

1) Individuals

User 1) Healthy client
2) Patient

Supplier 1) Concerned with medical care
a) medical doctor
b) paramedical staff

2) Medicine

1) Medical policy
2) Medical institutes (Facility)
3) Medical practice

3) Economics & Industry

1) Cost of MIS
2) Financial system
3) Industry

4) Science & Technology

1) Medical technology
2) Medical electronics engineering
3) Systems engineering
4) Telecommunications technology

5) Society

1) Human right and privacy
2) Social security
3) Prolongation of life span (old people, employment)
4) Medical regime & structure
5) Social structure

Evaluation of Impact

Evaluation of health care activities has proved difficult, because a quantitative estimate of cost effectiveness is almost impossible.

We may be forced to make a qualitative evaluation.

The following approaches are being considered for evaluating MIS: technological, economic, medical, and social.

Effects of Impact

It is anticipated that the main effects of MIS will be positive, with negative side effects and some neutral effects. These effects are summarized in Table 5 for each of the fields mentioned above.

Measures to Counter the Negative Effects of MIS

In order to sound public opinion about the development of MIS, the MHW project team sent out questionnaires in 1973. Uneasiness was mainly expressed about its impact on society as detailed in Table 5.

It is therefore important to investigate measures to counter its negative effects as shown in Table 6.

Table 5. Main and side effects caused by MIS.

<table>
<tr><th colspan="3"></th><th>Positive main effects</th><th>Negative side effects</th></tr>
<tr><td rowspan="4">Field: Individuals</td><td colspan="2">Healthy Client</td><td>1) Health care administration will improve and early detection of diseases will be possible.
2) Prevention of diseases will improve.
3) Life expectancy will be prolonged.
4) Health status will improve.</td><td>1) Increased national expenditures on health and medical care.
2) Fear of invasion of privacy.
3) People will become uneasy at detection of diseases that would disappear without medical treatment.
4) Misdiagnosis and mistreatment due to error of computer or system.</td></tr>
<tr><td colspan="2">Patient</td><td>1) Rehabilitation will improve and the reintegration of the patient into society will be facilitated.
2) Greater equality in treatment and improved health care in remote areas.
3) Improvement in quality of medical services.
4) Waiting time in hospital will be reduced.
5) Wasteful medical costs will be reduced.
6) Consultations at medical institutes will become easy.</td><td>1) Patient's freedom to select medical doctors will be restricted.
2) Cost of medical care will increase.
3) Relationship with M.D. and patient will become less personal.
4) Fear of invasion of privacy through checks on patient's history.
5) Uncertainty regarding responsibility in the event of a breakdown in the system.
6) Misdiagnosis & mistreatment owing to breakdown in system.</td></tr>
<tr><td rowspan="2">Concerned with Medical Care</td><td>Medical Doctor</td><td>1) Improvement in efficiency of M.D.
2) Leveling-up of M.D.'s knowledge & technique.
3) M.D.'s extra-medical duties will be reduced.
4) Back-up for M.D. will be provided.
5) Good for medical education.</td><td>1) Pollution by flood of medical information.
2) Collapse of relationship between doctor and patient.
3) Increased regimentation of M.D.s.
4) Loss of M.D.'s job satisfaction.
5) Diminution of M.D.'s community role.
6) Occurrence of needless disputes about medical care.
7) Bureaucratization of M.D.</td></tr>
<tr><td>Paramedical Staff</td><td>1) Expansion of scope of work
2) Release from incidental jobs.</td><td>1) Shortage of manpower due to expansion of scope of work.</td></tr>
</table>

Neutral
• More rigorous training to achieve high medical technology. • Medical duties undertaken by paramedical staff.

Table 5. (continued)

Field		Positive main effects	Negative side effects	Neutral
Field: Medicine	Medical Policy	1) Answer to increasing demands for health care. 2) Optimum allocation of limited medical resources. 3) Leveling-up of quality of health care with minimum increase of medical resources. 4) Possibility of medical audit. 5) Compatibility with other social systems. 6) Data collection for medical planning.	1) Increased cost of health care. 2) Shortage of manpower.	• Revision of the health care structure. • Amendment of medical legislation. • Planning for new medical education.
	Medical Institutes (Facility)	1) Medical institutes linked in a network. 2) Integration of institutes into regional health care system 3) Quantitative planning in institutes. 4) Optimum allocation of institutes within a region. 5) Saving of wasteful costs.	1) Emergence of differential ranking between institutes. 2) Disorder in the event of a breakdown in the system. 3) Medical care outside the system held in slight esteem.	• Reorganization of institutes.
	Medical Practice	1) Accurate data on medical & health care collected. 2) Easy monitoring of patients. 3) Speed up, equalization and extension of medical service. 4) Greater accuracy in diagnosis & treatment. 5) Increased cure rate. 6) Achievement of comprehensive medicine.	1) Regimentation of medical practice. 2) Restriction of medical doctor's freedom in medical care. 3) Decline in medical fields not included in system.	

Table 5. (continued)

<table>
<tr><th colspan="2"></th><th>Positive main effects</th><th>Negative side effects</th></tr>
<tr><td rowspan="3">Field: Economics & Industry</td><td>MIS</td><td>1) Saving of wasteful medical costs.</td><td>1) Increased economic burden.</td></tr>
<tr><td>Financial System</td><td>1) Development of financial system for medical materials.</td><td>1) Decline of financial system which is not associated with MIS.</td></tr>
<tr><td>Industry</td><td>1) Development of medical electronics industry.
2) Development of health industry.
3) Development of systems industry.</td><td>1) Abnormal expansion of specific fields which are profitable for MIS.</td></tr>
<tr><td colspan="2"></td><td colspan="2">Neutral
Increased use of medical electronics equipment rather than pharmaceutical drugs.</td></tr>
<tr><td colspan="2">Field: Science and Technology</td><td>1) Modernization of medical technology.
2) Development of medical electronics technology.
3) Development of systems engineering.
4) Development of telecommunications engineering.
5) Development of technology of pattern recognition.</td><td>1) Neglect of technology not associated with the systems sciences.
2) Cost increased due to introduction of expensive medical electronic equipment.
3) Reduction of cost/performance ratio in favor of high safety & reliability.
4) Inadequate communication lines for medical use.</td></tr>
<tr><td colspan="2" rowspan="2">Field: Society</td><td>1) Improvement in social welfare due to good medical care.
2) More equal access to medical care.
3) Prolongation of life span.
4) Increased potential for important social activities.</td><td>1) Economical burden due to increased medical costs.
2) Fear of bringing about controlled society.
3) Fear of invasion of privacy.
4) Pollution by information.
5) Increased feeling of human alienation.
6) Structure of medical services will become precarious.
7) Disorder in the event of a breakdown in the system.
8) Imbalance between demand and supply due to increased demands for unnecessary health care.</td></tr>
<tr><td colspan="2">Neutral
Increased demand for health and welfare.
Problems of old people.
Employment problems (type and availability of jobs).</td></tr>
</table>

Table 6. Measures to counter the negative effects of introducing the MIS.

Result of Impact	Possibility of Occurrence	Possibility of Control	Counter Measures
Increased demands for health & welfare	considerable	difficult	Welfare planning, education in self-restraint
Increased problems about old people	medium	medium	Measures to deal with such problems
Employment problems (type and availability of jobs)	medium	medium	Vocational training, more equal chances of employment, change in retirement age
Increased cost of health & medical care	considerable	medium	Improvement of efficiency in medical system, medical planning, reduction of medical demands through education
Collapse of structure of medical services	medium	medium	Reorganization of structure, extension of social security
Imbalance between demand and supply due to increased demands for unnecessary medical care	considerable	medium	Regulation by medical care planning, policy of controls for medical industry
Disorder in event of breakdown of system	considerable	medium	Extension of safety system (Dual system, back up system, etc.)
Fear of bringing about a controlled society	medium	medium	Decentralization, participation by citizens in administrative organization
Fear of invasion of privacy	considerable	difficult	Control of education and qualifications of persons in charge of data processing; legislation; research and development of hardware and software for protection of privacy
Pollution by information	medium	difficult	Selection of essential information through education
Fear of loss of personal relationship between doctor and patient	small	medium	Patient's right to select doctor; doctor's right to professional freedom. Restoration of doctor's right to concentrate on his job, unburdened by extra-medical duties
Fear of producing a regimented society	small	medium	Medical services will be available outside the system. Respect will be paid to culture and technology outside the systems sciences

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Methodological Aspects of Modeling and Decision Making In the Health Care System

A.I. Yashin

The overall need for improved planning and management of the national economy leads to some specific problems with regard to the health care system (HCS), one of them being to ensure the most rational allocation of resources within it.

Since the health care system is not an industry, it is not always possible to formalize the concept of the "most rational" and this gives the decision maker or administration a certain freedom of action.

The decision maker, typically, has a responsibility to make use of his experience and ability in order to foresee the consequences of his decisions and calculations and to judge between alternative courses of action.

At present means are available not only to improve considerably the forecasting capacity by developing and using the appropriate computer model, but also to improve decision making to some extent with the help of man-machine dialogue.

In order to achieve a meaningful interaction between the decision maker (the DM) and the computer, the man must feel a certain degree of confidence in the model. In other words, the model should provide a simulation of the processes occurring in the system which is "satisfactory" in the eyes of the administration. The man-machine interaction procedure is determined by the characteristics of the health care system, the model and the computer used for simulation. These are reflected in the special algorithmic computer language developed for use by the man and the computer for their dialogue.

The development of an HCS model which can be put to practical use, may be divided into the following stages:

- As the first stage, the preliminary model is built;
- At the second stage, the satisfactoriness of the model is checked and the method for it is developed;
- At the third stage, the man-machine procedure for decision making is developed.

Each of these stages is discussed below in more detail.

DEVELOPMENT OF THE PRELIMINARY MODEL

To develop the preliminary model, we have first to analyze the problems facing the system. At this stage, systems analysis must be used. In the terminology of systems analysis, a problem is defined as the discrepancy between the current aims of the administration and the real situation. The model should not be just a simulation of the processes occurring in the system, it should be directed toward problem-solving.

A number of subsystems are identified and the links between them are described using the list of problems, typically compiled by the experts, and an analysis of the internal organization of the system [1,2].

Problem orientation should be taken into account when deciding upon the subsystems to be included, that is, the solution of each problem requires analysis of a particular group of subsystems.

Relationships between the subsystems are described by using statistical techniques in conjunction with the data provided by demographical, social and medical statistics.

When statistical data are inadequate, heuristic and evaluation techniques are used.

One of the subsystems involved in solving these problems is the population, which consists of interacting groups of people classified in a variety of ways. Interaction between the groups consists of an exchange of individuals between them. The interaction factors are determined from data on morbidity and mortality and other indicators taken from medical and demographical statistics.

Another subsystem involved is medical personnel, which may also be conveniently represented as a set of interacting groups, classified according to specialization, education, qualifications, etc. In this case, interaction also consists of an exchange of individuals between groups, by retraining, changes of educational level, etc.

Provision of an adequate number of medical personnel with the appropriate specialization constitutes one of the means of solving health care problems.

Various patterns of distribution of medical personnel over specializations will affect the structure of morbidity in differing ways.

The models of these subsystems are discussed below in greater detail.

The Population Model

We visualize the population block as being made up of a set of interacting subblocks consisting of the models of various population groups. The population may be classified into groups of people suffering from various diseases at different stages or groups classified according to sex, education, marital status, number of children, disability, income, occupation or particular living conditions, etc. Population groups may also be classified by various combinations of the above characteristics.

Let $u(j,t,x)\Delta x$ denote the number of people in group j at time t in the age range $(x,x+\Delta x)$. The exchange of individuals between groups is given by the factors $q_{ij}(t,x,V_t,y_t)$. By definition, $q_{ij}(t,x,V_t,y_t)\Delta t$ is, to an accuracy of $0(\Delta t)$, the proportion of people from group i at age x who transferred to group j during the time interval from t to t + Δt, provided that the indicators of health care development are at the level V_t and the environment is characterized by the parameters y_t. It follows that

$$\sum_{j\neq 1} q_{ij}(t,x,V_t,y_t)\Delta t \leq 1, \qquad i = 1,2,\ldots,L,$$

where L is the number of population groups.

The following equilibrium equations can be readily written to an accuracy of $0(\Delta t)$ for the population groups

$$\begin{aligned} u(j,t,x) = {} & u(j,t-\Delta x,x-\Delta x) \ (1-\sum_{i\neq j} q_{ij} \\ & (t-\Delta x,x-\Delta x,V_t,y_t,u)\Delta x) \\ & + \sum_{i\neq j} q_{ij}(t-\Delta x,x-\Delta x,V_t,y_t,u)u \\ & (i,t-\Delta x,x-\Delta x)\Delta x \quad . \end{aligned} \tag{1}$$

Let us denote

$$\sum_{i\neq j} q_{ji}(t,x,V_t,y_t,u) = q_{jj}(t,x,V_t,y_t,u) \quad .$$

Then we find

$$\begin{aligned} u(j,t,x) = {} & u(j,t-\Delta x,x-\Delta x) + u(j,t-\Delta x,x) - u(j,t-\Delta x,x) \\ & + \sum_{i} q_{ij}(t-\Delta x,x-\Delta x,V_t,y_t,u) \\ & u(i,t-\Delta x,x-\Delta x)\Delta x \quad . \end{aligned} \tag{2}$$

When we transfer the second term of the right-hand side to the left-hand side, divide both sides by Δx, and let Δx tend to zero, we obtain the following system of partial differential equations

$$\frac{\delta u}{\delta t} = (j,t,x) = - \frac{\delta u}{\delta x}(j,t,x) + \sum_i q_{ij}(t,x,V_t,y_t,u)u(i,t,x) \quad , \tag{3}$$

where $j = 1,2,\ldots,L$.

(It should be noted that this equation can be derived using the probabilistic approach to the complicated problem of reproduction and death.) The initial conditions for these equations have the form

$$u(j,0,x) = f(j,x) \quad ,$$

where $f(j,x)$ are the given functions which determine the age structure of the groups at the moment 0.

The boundary condition for $X = 0$ has the form

$$u(j,t,0) = \int_0^X \sum_i u(i,t,x)F(i,j,t,x)dx \quad ,$$

where $F(i,j,t,x)$ is the number of the newborn babies entering the group j who have parents in group i of the age range $(x,x+\Delta x)$ during the time interval from t to $t + \Delta x$, X being the limiting age.

If the system has an immigration flow $M(j,t,x)$ and an emigration flow $N(j,t,x)$ the equations are modified into

$$\frac{\partial u(j,t,x)}{\partial t} = \frac{\partial u(j,t,x)}{\partial x} + \sum_i q_{ij}(t,x,V_t,y_t,u)u(i,t,x) + M(j,t,x) - N(j,t,x) \quad , \tag{4}$$

the boundary conditions for these equations remaining the same.

By making use of the delta function concept, the boundary conditions may be incorporated into the right-hand side of the equation (see [1])

$$\frac{\partial u(j,t,x)}{\partial t} = - \frac{\partial u(j,t,x)}{\partial x} + \sum_i q_{ij}(t,x,V_t,y_t,u)u(i,t,x) + M(j,t,x) - N(j,t,x) + \delta(x)\int_0^X \sum_i u(i,t,x) F(i,j,t,x)dx + \delta(x)F(j,x);$$

$$j = 1,\ldots,L \quad . \tag{5}$$

The Medical Personnel Model

To complete the system of equations, we have to provide a description of changes in the health care and environment indicators.

Let us denote by V_t the number of the medical personnel divided into M groups

$$V_t = (V_{1t}, V_{2t}, \ldots, V_{Mt}) \quad ,$$

where V_{it} is the number of the medical personnel in group i at the time t. The groups may be classified by medical specializations, qualifications, sex, etc.

Let us denote by $K_{ij}(t,x)$ the factors which determine the exchange of individuals between the medical personnel groups, similar to the factors $q_{ij}(t,x,V_t,y_t u)$ for the population groups. Then we can derive the equilibrium equations for personnel in the groups to an accuracy of $0(\Delta x)$

$$\begin{aligned} V(j,t,x) = {} & V(j,t-\Delta x,x-\Delta x)(1-\sum_{i\neq j} K_{ij}(t-\Delta x,x-\Delta x)) \\ & + \sum_{i\neq j} K_{ij}(t-\Delta x,x-\Delta x)u(i,t-\Delta x)\Delta x \\ & + Q(j,t-\Delta x,x-\Delta x)\Delta x - P(j,t-\Delta x,x-\Delta x)\Delta x \quad , (6) \end{aligned}$$

where $V(i,t,x)\Delta x$ is the number of medical personnel in group i at time t in the age range $(x,x+\Delta x)$; $Q(j,t-\Delta x,x-\Delta x)\Delta x$ is the number of personnel transferred to group j during the time interval from $t - \Delta x$ to t in the age range $x - \Delta x$ and $P(j,t-\Delta x, x-\Delta x)\Delta x$ is the number of personnel who left group j during the time interval from $t - \Delta x$ to t in the age range $x - \Delta x$.

Let us denote $K_{jj}(t,x) = - \sum_{i\neq j} K_{ji}(t,x)$. As with the equation for $u(j,t,x)$, we obtain the equation for $u(j,t,x)$ by letting Δx tend to zero

$$\begin{aligned} \frac{\partial V(j,t,x)}{\partial t} = {} & - \frac{\partial V}{\partial x}(j,t,x) + \sum_i K_{ij}(t,x)V(j,t,x) \\ & + Q(j,t,x) - P(j,t,x) \quad . \qquad (7) \end{aligned}$$

At time $t = 0$, the distribution is known--it equals $F(j,x)$. Moreover, graduates from the various medical schools enter the medical personnel groups at time t_K in the numbers $\hat{V}(j,t_K,x)$. Taking into account this fact and the initial conditions, the equation may be rewritten as

$$\frac{\partial V(j,t,x)}{\partial t} = -\frac{\partial V}{\partial x}(i,t,x) + \sum_i K_{ij}(t,x)V(j,t,x) + Q(j,t,x)$$

$$- P(j,t,x) + \sum_{K=1}^{\infty} \delta(t-t_K)\hat{V}(j,t_K,x)$$

$$+ \delta(t)F(j,x) \quad . \tag{8}$$

The vector $V_t = (V_{1t}, V_{2t}, \ldots, V_{Mt})$, which is the argument of the function $q_{ij}(t,x,V_t,y_t,u_t)$, has the components

$$V_{1t} = \int_0^x V(j,t,x)dx \quad , \qquad i = 1,\ldots,M.$$

The Medical Education Model

Since the training of physicians, nurses and auxiliary medical personnel takes a certain amount of time, it may be easily seen that the function $\hat{V}(j,t_K,x)$ satisfies the system of equations with time delay

$$\hat{V}(j,t_K,x) = \bar{V}(j,t_K-\tau_j,x-\tau_j) + \sum_{n=1}^{R_j} \sum_{i=1}^{M} \beta_{ij}(t_K-\tau_j^n)$$

$$\bar{V}(i,t_K-\tau_j^n,x-\tau_j^n) \quad . \tag{9}$$

Here τ_j is the time required to train the medical personnel in group j; $\tau_j^1, \tau_j^2, \ldots, \tau_j^{R_i} = \tau_j$ are the periods required for the successive stages of training and R_j is the number of training stages for personnel in group j.

The factors $\beta_{ij}(t_K - \tau_j^n)$ equal the proportion of personnel in group i who were retrained at stage n^M of training as personnel for group j. Let us denote by $\bar{V}(j,t_K-\tau_j,x-\tau_j)\Delta x$ the number of first year students of specialization j in the year $t_K - \tau_j$, in the age range $(x-\tau_j, x-\tau_j+\Delta x)$.

The system may be regulated by defining $\bar{V}(j,t_K-\tau_j,x-\tau_j)$ for each value of t_K and the factors $\beta_{ij}(t_K-\tau_j^n)$ with restrictions

$$\sum_j V(j,t_K-\tau_j,x-\tau_j) = W(t_K-\tau_j,x-\tau_j) \quad . \tag{10}$$

Below it will be assumed that $q_{ij}(t,x,V_t,y_t,u) = q_{ij}(t,x,V_t)$.

CHECKING "ADEQUACY" AND TESTING THE MODEL

Let us assume that a preliminary model has been developed and built with a computer. However, it can be used only when the administration for which it has been developed has checked it and found it to be satisfactory in relation to the real system.

The "adequacy" of models for many technological systems is checked by using the "adequacy" criterion which represents the model's capacity to simulate real processes.

The development of such a criterion for models of socio-economic systems involves some difficulties. The fact is that the administration cannot always provide a quantitative mathematical formulation for the "adequacy" criterion. At the same time, the decision maker (DM) experiences some psychological difficulties in accepting a formal criterion developed by an expert on mathematical simulation.

Fortunately, the DM has a wonderful ability to gauge the simulation capacities of various models, that is, to evaluate, which model is more adequate.

This ability of the DM, which stems from his accumulated experience in managing the system, makes it possible to utilize the man-machine procedure of testing the model with the purpose of giving the DM some confidence in it.

The system which the DM reveals in the preferences that determine his verdict on the model's "adequacy" is equivalent, under certain conditions, to the existence of a certain function which gives rise to this preference system.

For instance, let us assume that there are models which differ in the value of a parameter C and the results obtained with these models are checked by the DM. (Let us assume that it is the parameter which determines the different values of the factor q_{ij} in the equations describing population dynamics.) The DM makes a judgment about which of the two models with parameters C_1 and C_2 respectively is the more "adequate"; this judgment is equivalent to the existence of a certain function f(C) which has the following property: if the DM believes that the model with parameter C_1 is preferable to the model with parameter C_2 then we have $f(C_1) > f(C_2)$; if, for parameters C_3 and C_4, we have

$f(C_3) > f(C_4)$, then the model with parameter C_3 is more adequate than the model with parameter C_4. Thus, the problem of finding the adequate model is reduced to the problem of finding the value of C for which the function f(C) has a maximum, though the explicit expression for the function f(C) is not known.

Is it possible to find the value of C from the DM's preference system without knowing the form of f(C)? It turns out that it is. Indeed, let f(C) have only one maximum. Then for each value C_1 and C_2 we know the sign of the difference $f(C_1) - f(C_2)$ and hence we know the direction in which the function increases.

The next model to be checked by the DM has parameter C_3 which can be chosen by the computer itself by "stepping" in the parameter space towards increased values of the function f(C) from whichever of the points C_1 and C_2 has been preferred. Thus, the DM has to determine which of the two models compared by the computer is preferable. In its turn, the computer has to select the "step" in the parameter space given convergence to the point of the highest preference.

If the DM does not find the model adequate after this procedure, the structure of the model and the parameter vector should be changed and the procedure should be repeated. When the DM is satisfied with the simulation capacity of the model, the decision-making stage may be initiated.

THE MAN-MACHINE DECISION-MAKING PROCEDURE

Let us assume that we have a model which is considered to be of practical use. How can the model contribute to selecting the most effective solution from the DM's viewpoint? Socioeconomic systems, such as health care are difficult to manage because there is not standardized formal criterion of the optimum. The classical optimization theory cannot provide a solution when there is no criterion of the optimum. However, the situation is not hopeless. The administration can compare the results obtained, for instance, with two different management approaches and prefer one of them. Thus, a preference system is developed using the set of alternatives identified at the first stage of the model development. Under certain conditions, this preference system is equivalent to a certain function similar to that discussed in connection with the problem of adequacy.

Let us denote a management approach (or one of the alternative decisions of the administration) by V. The properties of the DM's preference system are equivalent to those of the function $\phi(V)$ whose explicit form is unknown. The procedure for finding the point of highest preference, V*, is identical to the procedure for checking the model described in the previous section.

Note 1. The system of equations for population groups is a generalization of the well-known demographical equation for population size with allowance for age structure [3]. Similar equations are frequently used in physics to describe the transfer and exchange of matter (using other boundary conditions).

In health care problems, the factors of these equations depend significantly not only on the time t and the age x but also on the other parameters of the model, for instance, on the indicators of system development V_t and on those describing the environment. Dynamics of these indicators are described, in their turn, by other systems of equations.

Note 2. It would be more convenient to have the procedures to improve management defined in the form of functions, rather than vectors. It is clear, however, that calculations carried out by the DM (in this case relating to the function of usefulness) will then involve a comparison of an infinite number of such functions and this is impracticable within the framework of the method discussed.

Note 3. The simulation approach used in this report involves knowledge of the "fine structure" of the interaction between various groups of population, namely, the factors q_{ij}. Unfortunately, the available statistical data do not always yield sufficiently accurate values for these factors. Even though heuristic and evaluation procedures can contribute to solving this problem, it is rather difficult to establish the adequacy of such a model.

It appears that use of the model will make it necessary to introduce new techniques for the collection of data in the health care system. In the absence of appropriate information, the methods of multidimensional statistical analysis should be used.

Note 4. The simulation approach discussed above has certain advantages, including the use of the powerful methods of numerical integration of partial differential equations. It may be readily shown that the different approaches to simulation of the health care system may be treated as specific examples of the algorithms for numerical solution of the above general equations given in the preceeding sections.

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Can Systems Modeling Aid Both Rationalization And Humanization of Health Care?

John H. Milsum

INTRODUCTION

The ideals to be followed in a systems approach are admirable. They include the ability to "stand back" sufficiently far to determine important interactions with other systems and in consequence the ability to establish the original system and its objectives from a sufficiently broad viewpoint.

This broad viewpoint is implied by the World Health Organization definition of health which comprises *physiological* (physical), *mental* and *social* well-being, rather than merely the absence of disease or infirmity. However until recently, and correlated with the advances of scientific medicine, the role of medicine has been seen largely in terms of physical disease and its treatment (Figure 1). More recently, the rapid rise of psychological science and its several health-related professions

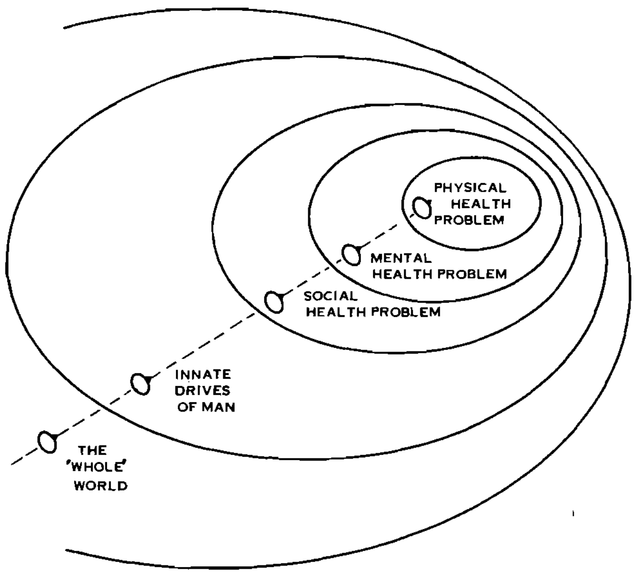

Figure 1. Viewpoints for the health care system.

has seen increasing emphasis upon the mental health aspect, as included in the WHO definition. Specifically, there has been increasing recognition of a tight mind-body coupling, which has given rise to the expression "psychosomatic illness", implying that physical illness has a mental component. We observe from the old expression "mens sana in corpore sano" that this new recognition largely signals a return to long-held beliefs about the indivisible duality of man. Most recently, as the many interacting subsystems of our civilizations become evermore tightly coupled, particularly through industrialization and urbanization, it has become imperative to recognize the major effects of the social environment upon individual health, as embodied in the word social in the WHO definition.

Beyond all this, the mythology of all countries has been concerned more with the life and destiny of the individual person than with the civilizations that social man has generated. Thus, while there may be much controversy about the extent to which man's characteristics are acquired or hereditary, it seems unarguable that the long history of his evolution has provided him with an important historical component in his overall view of life. This has been translated into deeply held philosophical, moral, and spiritual beliefs about the "purpose of life". In any dynamically evolving society, the result will be considerable tension between the rights and responsibilities of the individual and those of the society of which he is part. In any case, such beliefs have important connotations for personal health.

A hierarchical view of organizations may also be helpful here. The cells of which mankind are comprised are certainly ordered into a hierarchy as illustrated in Figure 2. In view of the increasing complexity and length of the "time constant" as one moves up this hierarchy from the individually viable element, the cell, through man himself to his societies, it seems natural to postulate that the lower levels successively constitute subsystems for the levels above, and therefore, in a meaningful sense, exist for the purpose of sustaining the more complex higher levels of systems. Certainly there is much evidence of systems optimization in terms of constraints being applied at many levels in the hierarchy upon the levels immediately below. On the other hand, it has been remarked that from an evolutionary point of view "an egg may regard a chicken as just a way of reproducing another egg". In this context the human organism could be postulated to represent only a more effective way for individual cells to organize so as to optimize the conditions for their own existense, as, for example, in such cell colonies as sponges.

All of these apparently peripheral subjects are in fact highly pertinent to a systems approach to health care. Further, in the health care system now being considered there are present, almost for the first time, a number of factors which have crucial long-term significance. Some of these are:

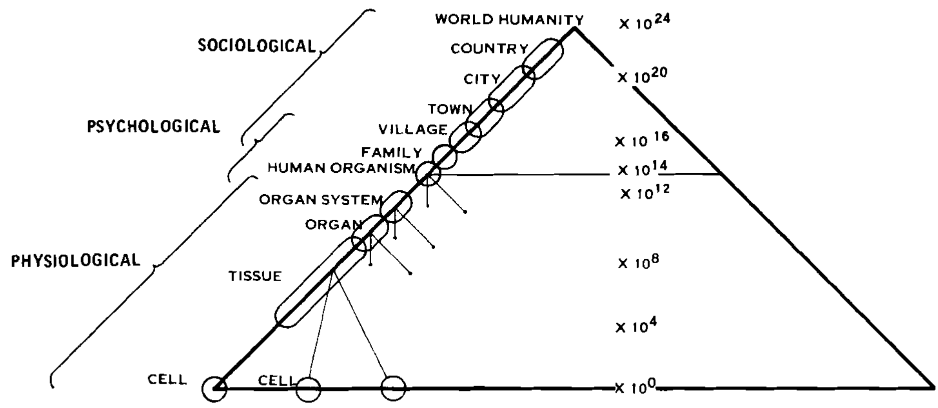

Figure 2. The human hierarchy.
The multiple subsystems at any level are suggested by the several radiating lines. The variation in size at any level is suggested by the length of the link.

- Meaningful medical control over the birth and death process;
- Ability to (inability not to?) alter, significantly or quickly, the physical environment in which the human race has evolved so slowly in previously relatively unchanging conditions;
- The stressors of a civilized and especially an urbanized society;
- The changing age structure of the population and its implications, especially in relation to geriatric health care.

In evolving a good design for the health care system, it is well to bear in mind how these various factors relate to the fundamental life cycle of every individual, namely, conception, birth, growth, maturity, senescence and death, as shown in Figure 3. The feedback from maturity to conception indicates the regeneration process due to reproduction, while the feedback path from death indicates the cycling of successive generations and the implications of the relevant birth and death rates on the demography of the population.

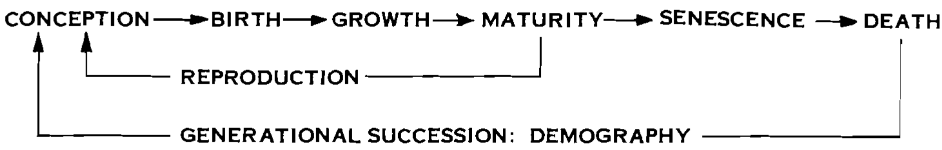

Figure 3. The life cycle.

The relationship between the "humaneness" and "rationality" mentioned in the title of this paper is explored in Figure 4. This suggests that the rationality is based on an empirical science of medicine, itself based on empirical science generally, and does not inherently provide any basis for the many value judgements which are needed in the health care system. In its broadest sense, humaneness, based originally upon the society's concepts of the purpose of life, must be the basis for such decisions. Humaneness then becomes incorporated in medicine more through the "art" than the "science". In particular the "tender loving care (TLC)" which seems such an important component in illness dynamics, derives mostly from the humaneness aspect, since rationality concerns itself more directly with efficiency and optimization aspects. The two are not of course necessarily incompatible, and ultimately all ethically based decisions will be founded upon some combination of the factors perceived through these two streams. While such decisions can occur at all the stages of Figure 3, those which are most controversial in our societies today relate to the "control" aspects at birth and death.

A systems approach to health care demands that many questions be answered before such decisions can be made. The questions relate directly of course to the value, in the broadest sense, of individual life and hence to the concepts of purpose in both individual and social life. It is worth repeating that these difficult ethical problems have now become inescapable, particularly because of the very efficiency of our modern high-technology health care systems through which it is now possible to exercise significant effect upon the span and quality of human life.

Actually, if a sufficiently thoughtful systems view is taken, it may be important to question this last claim. For example, an analyst needs much more definite answers than now available, in regard to the role of psycho-social factors. Thus, it seems increasingly clear that many accidents and illnesses are essentially contracted by the individual as "diseases of choice", but for reasons not well understood. In pursuing this

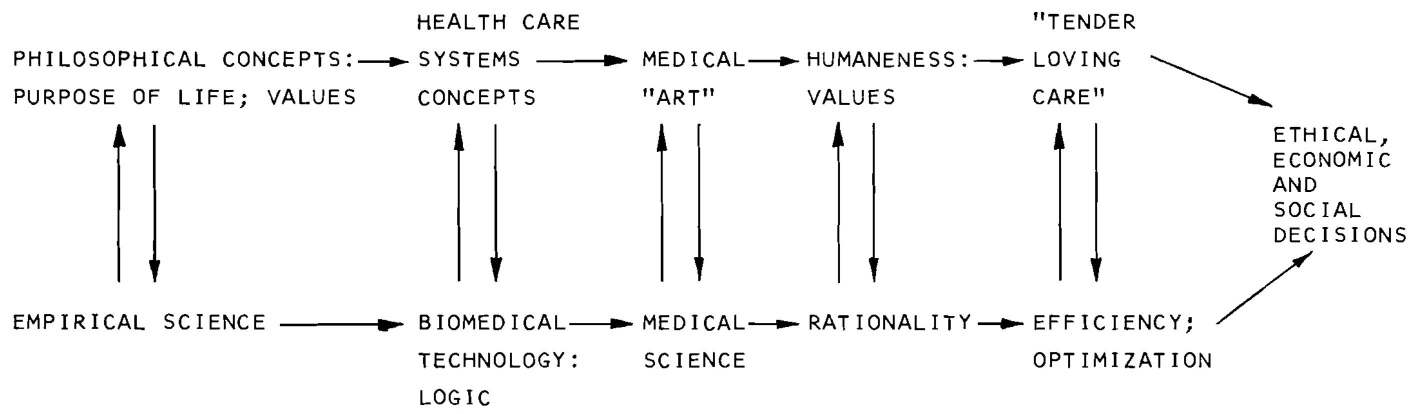

Figure 4. Humaneness and rationality in the health care system.

thought, we add the concept that all individuals behave purposefully in a (closed-loop) control system context. In this context, over a sufficiently long period of time and at a sufficiently deep subconscious level, an individual may therefore choose to become sick as his desired "output of performance". In order to intervene in this closed-loop system, it may obviously be more effective in the long run to learn why the parameters of the system have been changed so as to concentrate on sickness rather than on the more natural and beneficial state of health. Otherwise well-intentioned interventions may not necessarily have the desired effect, especially if undertaken in the "technological fix" context of addressing a symptom rather than the cause. This is one more example of where simple and apparently "good" interventions in a closed-loop complex system may have "counter intuitive" effects. Specifically the efficient "curing" of one illness by medical science may not absolve the patient of his need to be sick, which may thus result in the subsequent appearance of another illness to "replace" the first. Clearly, a systems approach to health care design must take account of such complexities in its attempt to optimize effects.

More generally, the averaged illness record of an individual may be a significant measure of his perception of the quality of his life. For example, during periods of high motivation, morbidity usually declines and vice versa. Indeed it may well be that a country's morbidity statistics can serve as a readily available measure of the quality of life as perceived by the population at large.

HEALTH-ILLNESS DYNAMICS AND HEALTH STATUS INDICATORS

It is becoming widely accepted that overt illness and disability or death, are only the final stages in a process of "disease" in the body that begins many years earlier. Indeed the particular form of disease, accident or illness to which the patient succumbs may be relatively unimportant compared to the body's overall prevailing disposition toward non-health. The general form of such a progression in six stages, with a particular example of arteriosclerotic heart disease (heart attack) is shown in Figure 5. As will be discussed, this progression has important implications for the desirable balance between preventive medicine and acute sick care.

From the viewpoint of an ideal Health Status Indicator (HSI), it can therefore be expected that a "static" indicator will be inadequate unless it can be subtle and comprehensive enough to incorporate the biochemical, enzymatic, hormonal and physiological deteriorations from optimal that presumably occur, as subthreshold precursors, long before the disease actually breaks out on the surface. Thus a satisfactory HSI needs to be "dynamic" in order to incorporate the long time lags between causal factors and the onset of illness.

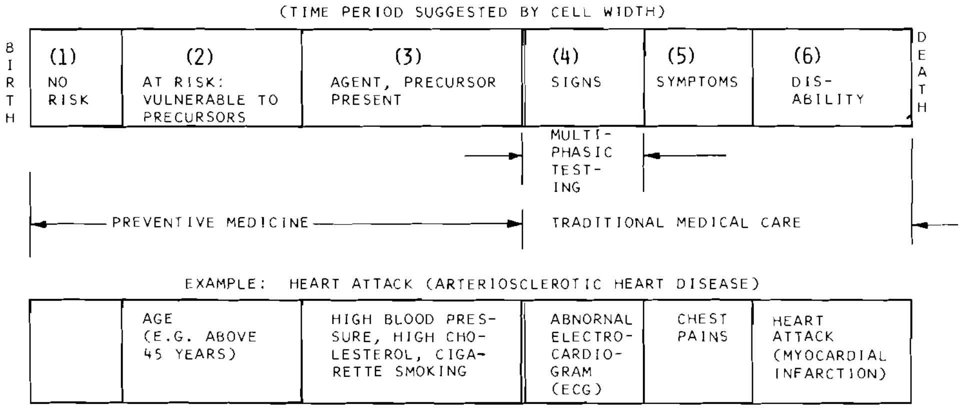

Figure 5. Natural history of disease.

Medical science seems typically to have been unduly concerned to discover the "single cause" for each given disease in our recent research-oriented age. This concern derives in part from the "germ-theory" of disease etiology and perhaps in particular from the hope that if a major cause can be isolated, then biomedical "technology" can develop a cure. However, recent history has shown that such cures usually turn out to be either partial or to have significant side effects or to be effective only until resistance develops. Indeed a "technological fix" cannot represent a systems approach since it is now evident that the major set of interactions in a complex system must be understood before cure or control interventions are attempted.

In this regard, a significant number of pertinent risk factors have been established as common features for many diseases. For arteriosclerotic heart disease the following are known: tobacco smoking habits increased, blood cholesterol elevated, blood pressure elevated, diabetes present, diabetes in family history, overweight, lack of exercise, and ischemic heart disease in family history.

More generally, lifestyle is emerging as a generic source of risk factors for all major killing diseases in our highly developed societies. These "killers" range in their order of importance from a preponderant set of "violence" deaths (motor vehicle accidents, suicide, homicide, drowning, etc.) for the young, (admittedly, with lower overall death rates), to "indulgence" deaths due to degenerative diseases from middle age on (heart attack, stroke, pneumonia, cancer, etc.).

As an overall concept, it seems useful to hypothesize illness as the result of a dynamic process involving deviation from the conditions prevailing in the homeostatically-maintained healthy organism, due to a multi-factorial set of precursors or risks. Stress levels may be the underlying function representing this deviation. As indicated in Figure 6, the major risks arise from genetic inheritance, environmental physical stressors, environmental psychological stressors, and lifestyle (e.g. malnutrition and inadequate exercise).

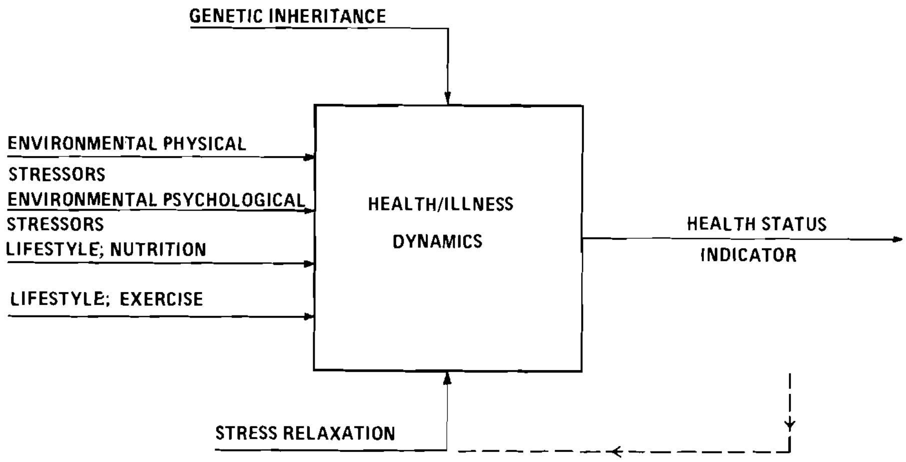

Figure 6. Multi-factoriality in health illness.

A major problem in the scientists' epidemiological approach to verifying such a hypothesis is that the controlled experiments necessary for formal proof are complicated, expensive and time-consuming, to say the least. There may also be ethical questions about their acceptability. In this context, the systems approach would indicate that those paths should be chosen which, it is generally agreed, probably contribute toward health and do not have significant, known ill-effects. Some examples are [1]:

- It is better to be slim than fat.
- It is better not to smoke cigarettes.
- Exercise and fitness are better than sedentary living and lack of fitness.
- Alcohol is a danger to health, particularly when driving a car.

- Tranquillity is better than excess stress.

- The less polluted the air is, the healthier it is.

In short, a systems approach would seem to indicate, on almost any criterion, that preventive medicine and the promotion of health must become the primary effort of the health care system, if the population's health is the true goal. In one simple schema, this involves concentrating on the following major modifiable aspects for all people: nutrition, exercise, stress reduction, and environmental quality and ecological balance (internally and societally).

Of course, the health care system thus defined embraces most governmental functions and also much of the individual person's private concerns. Indeed, as remarked earlier, the health state becomes a proxy for the quality of life as perceived by society at large. However, in dealing with such a large system, the problem of how to apply the trade-offs and comprises necessary for optimization obviously becomes difficult, since many deeply-ingrained social beliefs and customs, as well as professional and political territorialities, are involved.

A further very real problem may well be that urban civilized man has adapted to many habits which are contra-indicated for health, but which nevertheless have been embraced as representing desirable features in the quality-of-life equation, given the constraints of present society. In simple words, advice on how to become healthy and enjoy it is not always immediately welcomed. Perhaps man's major problem is not whether he can adapt to a deteriorating environment, but rather that he will do so, and happily!

The systems approach again seems to indicate the need to presevere with strategies which have the goal of long-term personal and societal change toward better health. This involves the problem of discounting for future health benefits. This is also the problem that the economist faces in assessing the cost-benefit aspects of any long-term health programs and especially those aimed at producing a healthy population by prevention of illness.

An appropriate Health Status Indicator is now obviously much more than a weighted set of mortality indices, even combined with a set of morbidity indicators. As a minimum, it should be able to indicate the desired or ideal form of an individual life, including its relation to age. An attractive candidate is the linear scale between 0 and 1 where 1 indicates full health in the WHO concept and 0 indicates death [2]. Figure 7 shows first of all the ideal rectangular HSI trajectory in which full health is retained until death occurs quite suddenly from natural causes after a full life. The dotted lines suggest more typical trajectories seen today. The particular dilemma resulting from the advances in biomedical technology would seem to be that larger numbers of people can now be sustained for extended periods and at high cost, at low HSI levels.

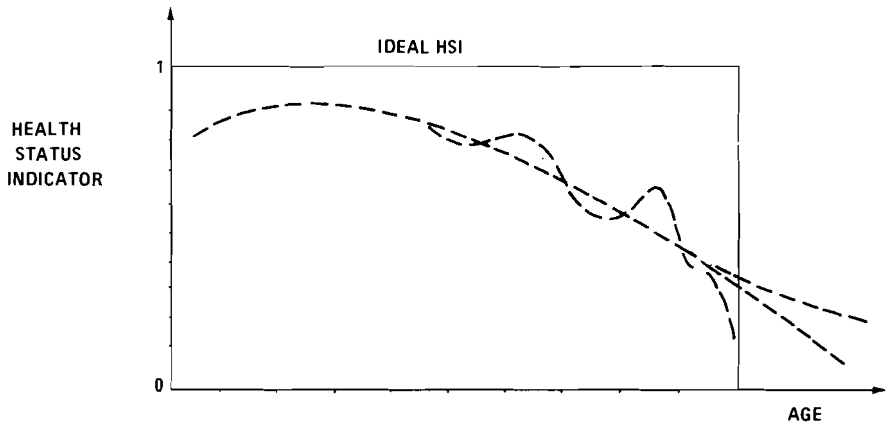

Figure 7. Health state indicators and age.

In principle, this HSI enables systems optimization techniques to be applied since the integrated effect of various health care programs can be compared. The integration is, first, over time for the individual, and then over all individuals affected in order to obtain population averages. The present difficulty lies in establishing HSI values for various health care programs, including their changes over time. Basically, they cannot be worked out by logic but must be obtained by sampling the population adequately as to their perceptions.

ELEMENTS OF AN EVOLVING HEALTH CARE SYSTEM

We have stated that biomedical technology has presented the health care system with many difficult ethical problems, so that the "humaneness" channel of Figure 3 must be used in deciding how societal values should govern the outcomes. Yet this same biomedical technology also offers many new tools which are of direct assistance in evolving goals of the health care system.

In North America, the rapidly developing areas of preventive, predictive or prospective medicine depend heavily upon establishing correlations with precursors or risk factors for disease. The epidemiological studies and their resultant statistical analyses depend equally heavily upon computers. Various operational programs have resulted with the primary aim of maintaining health, but also of screening for various diseases and incipient states of ill health. Automated Multiphasic Health Testing (AMHT) procedures typically apply a battery of tests and measurements, often with some computer processing of results. Health Hazard Appraisal (HHA) is another relatively new technique, which however largely concentrates upon measuring precursors or risk factors at the earliest possible moment [3], comprising some thirty questions, mostly in the lifestyle area (smoking habits, etc.), but with a few questions on clinical measures and family history. HHA is then computer-processed to compare the individual's health risks with those of the national averages. These risks are specified for different age and sex groups and also for different racial groups where the statistics indicate significant differences. We should note that the multifactorial relationships between individual risk factors (Figure 6), and combined risk are typically combinations of additive and multiplicative terms. The program then names a few "perscriptions" for lowering the person's health risks, and indicates how much the risks will have been reduced in each major disease category. This and other similar programs have not been applied long enough yet to generate scientific proof that they are effective in stimulating behavioral change. However, the constant emphasis upon health and hazards to it are felt to be significant in encouraging a changing view of health care in professional and patient alike.

HHA-type programs fit neatly into the objectives of Community Health Centres, which are also growing rapidly in various forms in North America. These are staffed by persons qualified in a variety of health disciplines and provide a primary entry point to the health care system. Such Centres can provide or stimulate the educational programs so necessary to bring about long-term behavioral change. Further, they can readily promote the objective of achieving the "activated patient". In this latter view, the primary responsibility for individual health must be willingly assumed by the individual. Of course, this has always been so in principle, but the recent dramatic changes in biomedical science and technology have tended to place the patient in a "patient" role indeed--that of a helpless bystander awaiting and enduring the seemingly interminable tests and procedures for impersonal scientific diagnosis and therapy of diseases. Under such circumstances, the disease and its cure may be perceived by the patient as only rather distantly related to himself and his lifestyle.

In order to establish the cost-benefit status of preventive medicine programs, especially in relation to sick care programs, data bases must be obtained by analyzing large numbers of individual (but anonymous) medical records over long periods of time. Such data bases are increasingly necessary in any case in many areas of the health care system.

It has long been clear that the conventional manually-maintained medical record is inadequate. Two steps are needed to bring it up to date, first, designing a logical format and secondly, computerizing. The Problem-Oriented Medical Record (POMR) provides a basic step forward in systematizing the medical record on logical lines and in a multi-disciplinary format [4]. It is not inherently intended for preventive medical practice, where specific problems are less frequent than in acute care and where the emphasis is on the risk of future problems. However, the POMR concepts seem broad enough to allow the modifications of detail necessary for its application to primary or ambulatory health care using a multi-disciplinary health care team. Since in a multi-disciplinary environment the record is often the main means of communication between members of the team, it must be easy to read and understand.

Computerization of information systems in health care has had a very mixed history. After many trials, with frequent failures, the future pattern is becoming reasonably clear. Highly interactive systems are needed with easily accessible video-display terminals at suitable locations throughout the health care facility. The health care professionals must come to depend upon the system, if it is to be successful. If they do not depend on it, they will not choose to input their information in a way satisfactory to the other team members and the usefulness of the whole system will rapidly deteriorate.

It is crucial in institutional care, as in preventive medicine, that the patient become as "activated" as possible, and recognized as a very real member of his health care team. This raises the question of his access to his medical (or health) record. Of course there may be some sensitive areas, where neither patient nor staff would benefit from the patient having access. On balance, however, it seems to be more advantageous therapeutically to the patient to have formal right of access. This feature will become especially important as the computerized data bases are built up on integrated health records for each person. The right of access also underlines the need for the patient to take the responsibility for giving "informed consent" to the procedures to which he is subjected.

The "consumer protection" aspect just discussed is associated with another aspect, that of "quality assurance", or quality control, in health care. Computerized health information systems can easily provide the requisite information, but the actual mechanism must be developed since no fully satisfactory one exists at present. "Protocols" show much promise here. In a protocol system, the health care professional is guided where necessary to the most appropriate steps to be taken in diagnostic tests, diagnostic decision making, prescriptions and therapy. Information can be provided at all these stages on the efficacy, probability of success, risks, etc., of the procedures. Further, the system can provide educational material to enable personnel to refresh their knowledge about infrequently-encountered situations or to update it. Indeed education can be built into almost all aspects of a computerized health information system and this feature may turn out to be the most important aspect of computerization.

These considerations entail building-up of centralized statistical data bases on health, health risks, diseases, drug interactions, normal (healthy) and deviant ranges for all the many laboratroy test variables and so on.

Quality assurance (quality control) in its broadest context requires the same audit of health care as of financial and other matters. This is especially true in the case of medicine involving sophisticated biomedical technology with its rapid escalation of costs and uncertain combination of potential hazard and benefit to the patient. The traditional type of audit is clearly inadequate and all the systems analysis tools for cost-benefit studies and all the information available from large data bases will be needed.

ALLOCATION AND PRIORITIES

In the systems approach, it is expected that, in almost all practical systems, there will be a competition, whether hidden or overt, for finite resources which demands will generally exceed. In consequence, analysis is needed to establish priorities before an optimal allocation of the available resources can be made. Further, such analysis may suggest the desirability of allocating more resources.

The establishment of priorities inevitably requires judgements about the relative values of the various "humaneness" aspects of the system. After this, the procedures for optimal allocation can be based on rationality.

In order to allocate resources in the health care system, one of the major tasks is to establish the real costs of its various aspects. The usual result is a matrix of coefficients relating the particular class of illness episode with the different amounts of resources needed for its treatment (treatment matrix, production matrix, hospital activity matrix, etc.). However this is applicable to conventional acute medical care of various epidodes such as surgical operations. A first level of optimization in allocation can be achieved if various rules for substitutability are available: for example, in using different types of health professionals to different extents for a given treatment. A higher level of optimization will be concerned with the choice between alternative paradigms of health care, in particular between acute medical care and preventive medicine. This level essentially requires that a set of treatment matrices be available. However, a simple listing of the direct costs will not be sufficient, since these must also be compared with corresponding benefits in order to assess equitably the merits of different programs. Then, as noted earlier, "accounting" problems arise since the benefits especially, and costs also to some extent, of preventive medicine will be spread over many years. Further, since an important benefit in this case may be a long-term increase in the quality of life, (in addition to any economic benefits attributable to reduction of treatment costs and "lost opportunity costs"), an attempt at optimal allocation must take into account the "humaneness" aspects.

SUMMARY AND CONCLUSION

The systems approach provides a useful framework for examining the health care system. Within this framework, many value judgements about individual and public health must be made before recommendations for an optimal system can be made. Ignorance and controversy are especially prevalent about the long-term costs and benefits of preventive medicine as compared with conventional acute medical care. These areas relate to man's perceived purpose in life, and hence are important to the underlying humaneness of the system. Initial analysis would suggest that many preventive programs should be implemented even before positive cost-benefit results can be rigorously established. An optimal combination of humaneness and rationality in the health care system will be difficult to achieve and maintain, but it is essential to the health of every nation.

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The Macro-Model: How It Works and How It Can Contribute to Planning in the United Kingdom Department of Health and Social Services (DHSS)

A.G. McDonald

The Department's planning process aims to produce a statement of the future resources to be provided for each client group and to describe the strengths and weaknesses of the pattern of care which would result from these resources. This paper explains how the macro-model might assist the Department in arriving at such statements and compares the model's potential contribution with that of other techniques. In the course of doing this, the paper attempts to explain in plain language how the model works.

The following terminology will be used to define a pattern of care:

- cover: the number of clients in a category receiving care;
- modes: the qualitative descriptions of the types of care received (for example, special housing + home nurse + meals);
- standards: the average quantities of different resources received by an individual of a particular category in a particular mode (for example, 3 meals/week).

It will be assumed, for the sake of illustration, that the Department is planning for a specific future year, 1978/79, and that in doing so, it is taking as a reference point the 1974/75 situation. This paper presents examples of how the model might contribute, in order of increasing sophistication. It starts with the user specifying cover modes and standards in detail and using the model to calculate resource consequences. It then considers applications in which the user specifies successively less information and gives the model successively more freedom.

CASE A

The most simple case is when the planners specify a proposed pattern of care, i.e., a statement of cover, modes and standards for 1978/79, and use the model to calculate the resources needed. In this application, the model is given no freedom to alter allocations of patients or resources; it is simply performing a lengthy piece of arithmetic, adding up the resources consumed by each category of patient. In this application, and in some of the others which follow, it is not imagined that planners would be able to specify all the data on cover modes and standards in absolute terms. Rather it is envisaged that most of the data would be specified in terms relative to the current situation. The specification would consist of statements of the kind: "cover for the categories in the Elderly client group in 1978/79 will remain the same as in 1974/75 except for a 2 percent increase in certain specified categories to take account of the aging of the population"; "the proportionate use of modes by the categories in the Mental Illness client group in 1978/79 will be the same as in 1974/75 except for a shift of 20 percent of chronic schizophrenics from hospital to care in hostels with community support"; "all standards of community care will remain at 1974/75 levels". The output would then show the change in the balance of resources that would be needed to deliver the specified pattern of care.

CASE B

The next step presupposes that the planners have stated desired levels of cover and standards for 1978/79 but wish to explore alternative ways of changing the balance of modes. For this run, the model would be given some freedom in allocating patients to modes, for example, up to 50 percent of hernia patients can be treated by day surgery with home nurse support. Thus the user of the model has to specify a criterion of choice. Up till now, in runs of this type, the criterion of minimum cost has been adopted; i.e., for every patient the model selects the cheapest allowable mode. However, any other relevant criterion could be used, for example, to minimize the use of hospital beds. The output of this type of run consists of statements of the modes selected by the model for each category and of the amounts of resources required (by client group and in total) along with the consequent expenditures. The results of such a run are optimum in the sense that they identify the pattern of care which best fulfills the selected criterion.

Discussion

Before we proceed to more sophisticated applications, it is worth considering how even these simple applications might provide contributions to the planning process which could not be obtained by more aggregate approaches. First, the specification of cover in terms of categories of individuals requiring similar types of care means that the model can reveal in quantitative terms the consequences of a changing balance of categories within a client group; for example, the aging of the population will tend to produce increasing numbers of clients in the severely disabled categories of the elderly section and thus lead to a greater demand for either institutional care or high intensity community care.

Secondly, the representation of alternative modes of care allows the model to predict the consequences of shifts in the balance of care, say from hospital to community care; in cases where such shifts are significant, a more aggregate approach may produce erroneous answers.

CASE C

Let us now suppose the model has been run as described in Case B but that some of the resource levels for 1978/79 suggested by the model are considered impracticable, for example, a doubling of the supply of home nurses. The model could now be rerun in exactly the same way except that constraints could be inserted on the rates of growth or decline of each individual resource, for example, no more than 10 percent of acute beds can be closed, no more than 5000 home nurses can be added to the current supply. Alternatively, or in addition, a budget constraint could be set, for example, zero growth in revenue expenditures. The model would still be seeking to optimize, under the given criterion, but this time the selection of modes is not simply a matter of always choosing the cheapest. For example, the imposed scarcity of home nurses may prevent the model from selecting the day surgery mode for every allowable surgery category *and* the community care mode for every allowable elderly category. Faced with competition for a scarce resource, the model will select those modes which produce the minimum cost. In a situation where there is competition for more than one or two scarce resources, it becomes impossible to perform this calculation on paper, though it can readily be done by computer.

The output of this run will list the modes selected by patient category and the resources and expenditures needed to meet the cover and standards specified by the planner. The output will also state for each constraint what might be gained by relaxing the constraint. Thus, in the example of a limit of 5000 on the increase of home nurses, the model would show what financial saving could be achieved if this limit could be stretched: extra home nurses would allow an increased use of day surgery or community care modes with the consequent net saving achieved by reducing institutional resources. Similarly, the output would state the cost (or saving) associated with increasing (or decreasing) each element of cover and each element of standards. This information can assist the planners to use the model in an interactive fashion, which Operational Research Service (ORS) consider to be by far its most profitable use. The planners can examine the output of a run, modify the starting assumptions (input data), rerun and so on. In this way, not only will the model's activity be directed into the most relevant areas but also the planners can gain an understanding of the model's assumptions and strengths and weaknesses and call for modifications or further work where they are most needed.

CASE D

The next step allows the model to vary standards. This presupposes that planners state the cover they wish to achieve in 1978/79 along with constraints on some resources and/or expenditures and that they are seeking to identify that set of resources which achieves the highest levels of standards within these constraints. The model can contribute to this task by use of a recent development: the concept of inferred worth [1]. In this type of run, the model is doing what it does in Case C except that:

- It has freedom not merely to choose modes but also to vary standards for each model;
- The criterion for selecting modes is not merely to minimize total cost but at the same time, to maximize standards. Now this criterion contains within itself an obvious conflict.

Thus, in the model, it is specified in terms of numbers which represent trade-offs between increases in the various standards and between their increases and their associated costs. The situation can be represented graphically. Figure 1 shows the net inferred worth associated with increasing the standard of home nurse visiting to a client in a category of the Elderly client group, whilst Figure 2 shows the same for a category from the Mental Illness client group.

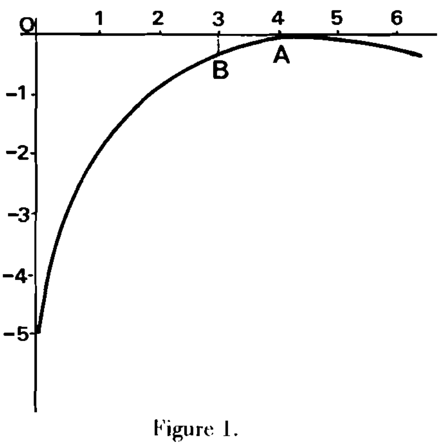

Figure 1.

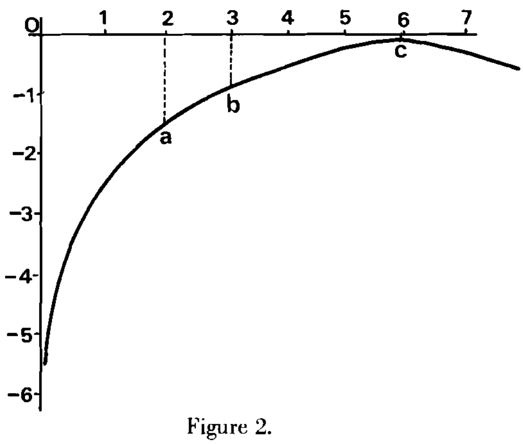

Figure 2.

In this type of run, the model will be concerned with rationing a limited number of home nurses between those categories of patient where it is "considering" selecting modes containing a requirement for home nursing. In selecting modes and their associated standards, it uses the criterion of maximizing inferred worth net of cost. Thus in Figures 1 and 2 it would reject an allocation represented by the points A,a (inferred worth 0 + -1.6 = -1.6) in favor of an allocation represented by the points B,b (inferred worth -.5 + -.1 = -1.4) since the latter represents a greater total net inferred worth for the same number, 6, of home nurses. It can be seen that the criterion incorporates the principle of diminishing returns.

The numbers representing the highest standards, i.e., those which the model is "striving" to reach, (4 and 6 home nurse visits in Figures 1 and 2 respectively), have been derived from the values of standards obtained, largely via professional judgements, in early work on the model. These numbers are referred to below as "ideal" standards. The trade-offs between standards (i.e., the relative gradients of the curves) are specified by other numbers. Both sets of numbers taken together are fed into the model to specify its criterion of choice. The original intention behind the concept of net inferred worth was that the numbers should be selected so as to accord with the preferences that one would expect decision makers in the field to adopt. In the absence of any other evidence, one could use numbers representing the preferences that it may be inferred have been operating in the field to date and that have produced the allocations of resources observable today, and assume that these preferences will continue to operate in the future. Alternatively, if planners have grounds for believing that preferences will change, perhaps as a consequence of DHSS intervention, the numbers could be modified. The current position is that ORS are using numbers which appear to give plausible results and which do not conflict with information about actual allocations in the field. However, ORS are concerned to gain empirical evidence on these quantities and have embarked on a program of collaboration with field researchers, such as Professor Holland, Dr. Kuchlick and teams at Exeter University and at certain psychiatric care registers. Although ORS cannot claim that the current data is fully tested for *predictive* purposes, they do claim that the current data is sufficient to assist the Department significantly in exploratory runs. This argument can best be illustrated by a further example.

Suppose planners state that they wish to explore options for 1978/79 in which cover remains at the 1974/75 level for all categories, apart from increases consequent upon demographic changes; that there is to be zero growth in expenditures and that there are constraints on the supply of certain resources. Their question is: "what is the allocation of resources which gives the highest standards within the given constraints?". In such a run, the model is, in effect, striving to find that balance of modes whereby it can most increase standards above their current levels towards the "ideal" standards. Ceteris paribus, it will increase a standard which is currently far from ideal, in preference to increasing one which is currently close to ideal (as shown in Figures 1 and 2). The output of such a run shows the "optimum" mix of resources, along with statements of the modes used and the levels of standards; the information on standards can be presented in absolute terms, (for example, one nurse visit per week to a bedfast client living in his own home), or in terms relative to current standards (for example, 20 percent less nurse visiting to the Elderly client group) or relative to ideal standards.

Given the current state of the data, ORS do not claim that this type of result is predictive in the sense of forecasting exactly how home nurses will be rationed in the field between each client category. The result is in the same logical predicament as the statements in the planning submission on how resources planned for the future will be shared between client groups; they are statements of how the Department would like the resources to be allocated, but it is not clear that the field decision makers would take the same view. Thus the result described above is best regarded as an exploratory result. It describes feasible and internally consistent allocations of resources and thus is perfectly valid as an aid to the Department in formulating a plan. The implementation of the plan is a separate issue.

CASE E

Given the problems of translating.central plans into decisions in the field, a more useful way of employing the model is a variant of Case D in which the planners interact with the model, altering the priorities in the choice criterion until a state is reached where the priorities are a reasonable compromise between what planners are aiming at and what they feel can actually be achieved in the field. In this type of application, the planners would study the results of Case D and call for modifications. For example, suppose that the initial run suggests low standards of community care for the mentally ill; if the Department considers that in practice the mentally ill would attract a larger share of the available resources, as a consequence of intervention by the Department or in the light of recent trends, then the priority of standards for the mental illness categories can be increased in the model. (This is achieved by increasing the numbers in the input data which describe the gradients of the standard curves for mental illness categories, i.e., the gradients of the function illustrated in Figures 1 and 2.) The model can now be rerun and will produce a new set of results. These results will probably suggest a different balance of resources. They will show increased standards for mental illness but only at the expense of some or all of the other client groups. The planners could examine these results, suggest modifications and initiate a further run. So the process could go on until an allocation of resources was obtained which satisfied the planner and which he felt could be implemented in practice.

Discussion

Cases C and E exemplify possible applications of the model in which planners use the model interactively to explore rapidly a number of strategic options. ORS claim that this type of exercise is likely to generate efficient and/or desirable options which would be missed by more aggregate approaches. It is not claimed that the model can produce, or ever will produce, the "right" answer. Rather it is a device which planners can use to gain insights which they might not gain in any other way. Nor is it true that the model fails if it cannot produce an option that is 100 percent acceptable to planners. It will have been useful even if it only provides insights that planners can incorporate into the option *they* put forward.

Another noteworthy feature is that the model preserves the accounting of all resources in the Health and Personal Social Services (HPSS). There are some client groups, such as children, dentistry, for which data on categories, modes and standards, are not yet incorporated into the data base of the model. However the expenditure and resources associated with these client groups is handled in the model in the same way as in the Programme Budget. Thus, particularly under conditions of tight expenditure constraints, the model demonstrates clearly that improvements in services for one client group can usually only be achieved at the expense of others; indeed it provides detailed information about the cost involved.

OTHER APPLICATIONS

There are many other ways in which the model might be applied to the planning process. Two will be mentioned here, very briefly, because they illustrate two further features of the model.

In all the examples mentioned so far, the information on cover for 1978/79 has been supplied by the user and incorporated into the input data. However, the model possesses the ability to vary cover in the same way as standards. Thus the user could merely specify some information on resource constraints and expenditures and use the model to find the "best" allocation in terms of cover and standards. The input data would include numbers describing the trade-offs between cover of the various categories and between these and standards. Thus, the model would be facing choices of the kind "treat 100 further mental illness patients or raise the standards of those already in care". In practice, it is not envisaged that the user would give the model complete freedom to vary cover. It is expected that he would specify lower and, possibly, upper limits for at least some categories: for example, at least 10,000 but no more than 20,000 hysterics must be treated. The model has not yet been applied in practice in this way although it has been applied, using Planning Statement information, in all the other ways mentioned in this paper.

In all the applications described so far, the model is provided with information, in varying degrees of detail, on the desired pattern of care and the results of the model show, inter alia, the resource consequences. It is possible to use the model the other way round--to supply it with a proposed set of resources and to get the model to calculate what the consequences might be in terms of cover, modes and standards. In this way, planners could try out proposed allocations. In practice, it is envisaged that planners would not merely have proposals on quantities of resources but also expectations about how some of these resources might be rationed between client groups and what cover or standards might be achieved; for example, "75 percent of home nurses will be allocated to the Elderly"; "cover and standards will not fall below 1974/75 levels". The model would then show whether or not all these expectations were compatible with the proposed resources; if they were not all compatible, the model would suggest alternative ways in which the expectations would need to contract, such as "cover for the physically handicapped would drop by three percent".

Discussion

This last possible application provides a further example of how the model could contribute in areas beyond the reach of aggregate approaches. In providing these examples, ORS are not suggesting that the macro-model could replace appropriate techniques, but rather that such activities are complementary and that the Department needs them all for a full examination of its strategic options.

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Some Requirements for Strategic Models of Health Services Illustrated by Examples from the United Kingdom†

A.G. McDonald and R.J. Gibbs

Three themes are presented in this paper. First, the form of strategic models should relate to the form of the organization taking the strategic decisions and to the form of the management hierarchy responsible for implementing them. Second, the models should take a very long-sighted view of the options open to the service and incorporate an understanding of what the ideal types of service would be; this is in contrast to descriptive models, which tend to perpetuate the status quo. Third, strategic models should represent the behavioral conflicts arising in the service as a result of the availability of resources being less than that needed to attain ideal levels of service. These three themes will be illustrated by reference to the modeling program in the United Kingdom Department of Health and Social Security (DHSS) and in particular to one model in the program, which explores resource allocation problems--the Inferred Worth Model.

The first theme is that in order for strategic models to be useful their form must relate to the form of the "customer" organization. Controllable variables in the model should be such that they can be mapped onto the decision variables of the organization. Otherwise, a model may have considerable academic interest but it cannot be harnessed by the executive.

Let us now examine how this principle has guided the modeling work of Operational Research Service (ORS) in the DHSS. A simplified version of the organization of the part of DHSS which deals with Health and Personal Social Services (HPSS) is shown in Figure 1. One group is concerned with the development of services for the various categories of clients; for example, one subdivision within this group deals with the development of services for the mentally handicapped, another with services for the elderly and so on. A second group is concerned with manpower policies (e.g., training, conditions of service); it is subdivided according to the different types of staff (medical, nursing, etc.). A third group deals with regional matters--the allocation of resources between regions, planning and management in the field authorities--and with health service buildings.

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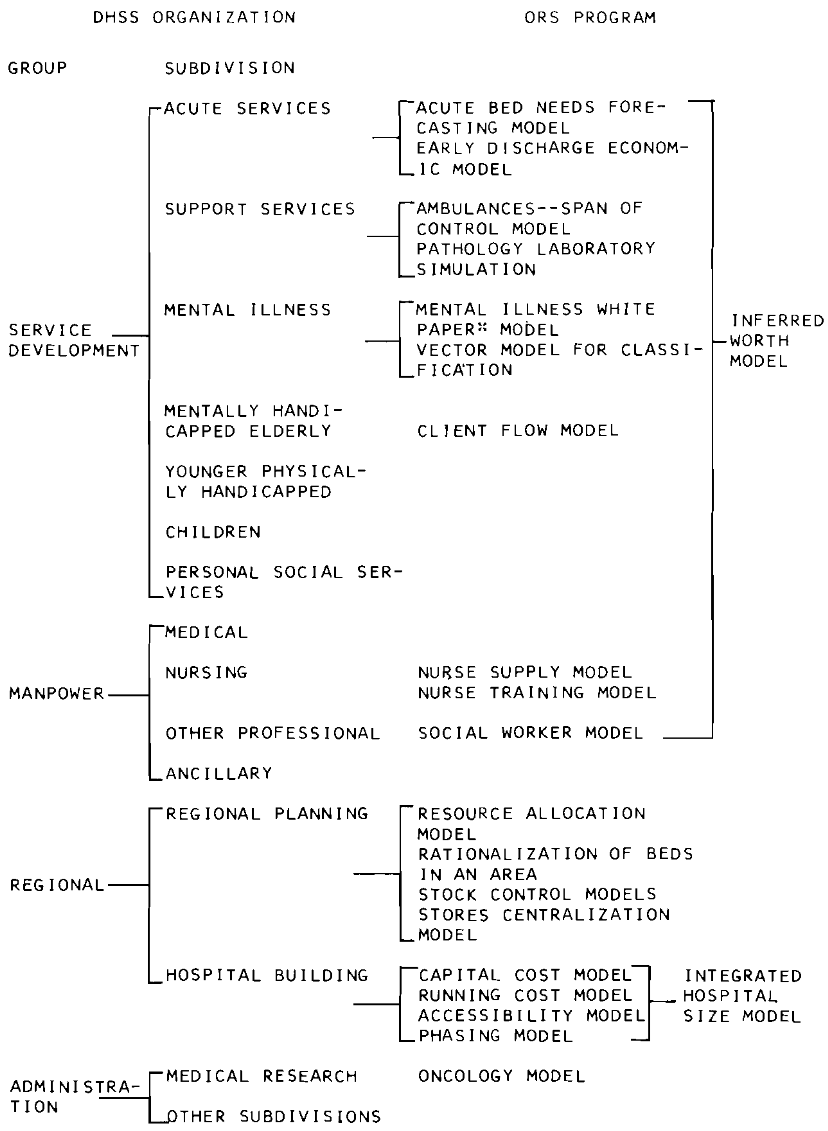
†This paper expresses the personal views of the authors; it is not a statement of official policy of the Department of Health and Social Security, UK.



* A White Paper is a document which explains government policy on a particular topic.

Figure 1. A simplified plan of part of the organization of the DHSS and its relation to the ORS modeling program.

A fourth group, administration, handles a number of subjects, one of which is medical research. (This description of the DHSS organization is incomplete and simplified but is adequate for the purposes of this paper.)

This pattern of organization at DHSS was designed to match the organization of planning and management in the field authorities of the National Health Service (NHS) and the Personal Social Services (PSS). There is not space here to give an adequate account of the current organization of the field authorities which dates from the reorganization of both NHS and Local Government in April 1974. Suffice it to say that at district level service planning is intended to be carried out by health care planning teams, one team for each client category; this parallels some of the functions of the Services Development Group at DHSS. Other branches of the organization at Area* level are responsible for some of the personnel functions, for ambulance services and for supplies, whilst Regions* have responsibility, inter alia, for the planning of hospital building and for the allocation of resources to areas; this parallels the functions of the Manpower and the Regional Groups at DHSS.

Although models should be designed to relate to the organization of the executive, it does not follow that the scope of a model should be delimited by the compartments in the executive's organization. Indeed one of the most valuable attributes of a model is that in exploring possible solutions to a problem in one part of the organization, it can illuminate consequences of concern for some other part of the organization that might otherwise be overlooked.

The Inferred Worth Model [1] is specifically concerned with the way in which the development of services for one client category may interact and compete with the development of services for another client category because of constraints on the overall availability of resources. It started in concept [2] as an attempt to survey the Department's interdependent activities in HPSS in order to facilitate a rapid enumeration of the principal consequences of different policies and thus allow the exploration of a large number of possible policy options. The model is designed to relate the care given to some of the different types of patient to the overall level of resources used by the HPSS. It does not attempt to set policy decisions but to illustrate their consequences. The model has been formulated, is being tested and its possible uses are currently being explored.

The model represents the pattern of care given to different types of patient in terms of:

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*The NHS in England has a three-tier hierarchy consisting of 14 Regions, 90 Areas and 205 Districts. A District serves a population of roughly 250,000.

- Cover: the number of patients receiving care (e.g., 60,000 hernia patients);
- Modes: the types of care available (e.g., day surgery followed by domiciliary care by home nurse);
- Standards: the levels at which care is given to individual patients in quantitative terms (e.g., six home nurse visits);

and explores alternative patterns within constraints on the availability of resources and finance. A mathematical description of the model is given in the Appendix to this paper.

Within the model, there is a representation of alternative modes of care for a number of types of patients within each main category (elderly, mentally ill, etc.). ORS had to work closely with each subdivision at DHSS to achieve this representation. However, the main value of the model lies in showing the conflicts and interactions between the proposed developments for the different client categories and this has required that results from the model be reported at a level above the subdivisions.

The second theme of this paper is that models need to take some account of "ideal" patterns of service in order to avoid becoming descriptive models perpetuating the status quo. This theme can be illustrated by reference to the Inferred Worth Model.

In the model, alternative modes of care are defined for each patient category. Consider, for example, the hernia category. One mode of care for such a patient would be surgery and a number of days in an acute ward of a hospital. An alternative mode is day surgery followed by a number of nurse visits to the patient's home. There is considerable evidence that the day surgery mode is cheaper for the service and frequently preferable for the patient and his family. From the economic point of view, the ideal pattern of service would be for most hernia patients to be treated by the day surgery mode. However, the current position in the United Kingdom is that day surgery is employed for only a small proportion of hernia patients although the trend is for this proportion to increase. Nevertheless, the model allows for the possibility that an ideal pattern of service could come about in the future by representing day surgery as a permissible mode of care for every patient in the hernia category. In practice, this ideal pattern may not come about because of (a) the scarcity of home nurses (b) the disapproval by some clinicians of day surgery and (c) the unsuitability of some patients for clinical reasons. These factors are represented in the model (see Appendix)--(a) by constraints on resources and by elasticities; (b) and (c) by constraints on the use of specific modes; the constraints can be relaxed if appropriate. In this way, the service is seen as developing, when permitted, from its current state towards an ideal one.

The modes of care for many other patient categories are represented in a similar way--one or more modes representing popular current practice and other modes that are thought to be possible or even desirable alternatives but may not be commonly employed today. For example, for the mentally ill, a long spell of hospitalization has been the normal mode of care for many of the more severe conditions. However, recent clinical and social developments have opened up the possibility of modes of care based less on hospital and more on community services (e.g., day hospital care, domiciliary care by nurses and social workers). Accordingly, for mentally ill patients, the following modes are defined: long stay hospitalization, short stay hospitalization followed by day care or domiciliary care, day care, out-patient treatment, etc. For the elderly, the traditional modes of care are geriatric hospitals and residential homes, but there is increasing awareness of the possibility and desirability of community care based either on the client's own home or on special housing with, sometimes, a warden in attendance. (Community care for an elderly client might involve some of the following types of service: home nurse, home helps (for help with cleaning, washing, shopping and/or cooking), "meals on wheels", day centers, geriatric day hospitals, physiotherapy, chiropody). Once again the community care modes are built into the model even though, for many categories of client, they are not extensively employed today.

From what has been said above, it can be seen that the model is capable of exploring patterns of service that are radically different from those that obtain today. Such a capability could not be shown by a model which started from a description of the current pattern of service and merely "tinkered" with the system by considering marginal changes--an approach which Lindblom [3] has described as "disjointed incrementalism" (or more graphically, "muddling through") and whose shortcomings for health service planning applications have been discussed by Himatsingani [4]. An exploratory model is to be preferred to the descriptive model even in situations where the restrictions on the system permit only marginal changes within the time period under consideration. For only by taking into account ideal possibilities can one select the best direction in which to move. Decision makers in a subsequent period will not thank their predecessors for having looked no further than the prevailing limits to change.

There is another aspect of the Inferred Worth Model in which ideals have been considered. This concerns the standards of care, as defined above. Thus for the day surgery mode of care for hernia patients, the UK literature [5] suggests that on average an ideal or desired standard might be about six postoperative home nurse visits. Similar ideal standards of care are defined for the other modes in the model. In practice, the service employs modes of care at considerably less than these ideal standards because of resource scarcities. This behavior is represented in the model by a function, "inferred worth". It is hypothesized that the service attempts to maximize inferred worth net of cost.

The contribution to total inferred worth from treating a patient at ideal standards is arbitrarily fixed at zero. There is a negative contribution for less than ideal standards described by a monotonically increasing function whose gradient equals the direct resource unit cost at the point corresponding to the ideal standard. This is illustrated for the day surgery mode for hernia patients in Figure 2. Even if the availability of home nurses permitted, the model would not allocate more than the ideal standard, six, to this mode since the extra contribution to inferred worth would be outweighed by negative contribution of resource cost. However, in all the applications of the model to date, the overall resource limits have been such that standards of care considerably less than ideal have been inevitable for nearly all modes. The model represents the present reality of the service accepting less than ideal standards by means of the functions described above, but it also represents the way the service might move in the direction of the ideal if resource availability increases; it does not freeze the service at the standards of today or any other moment of time.

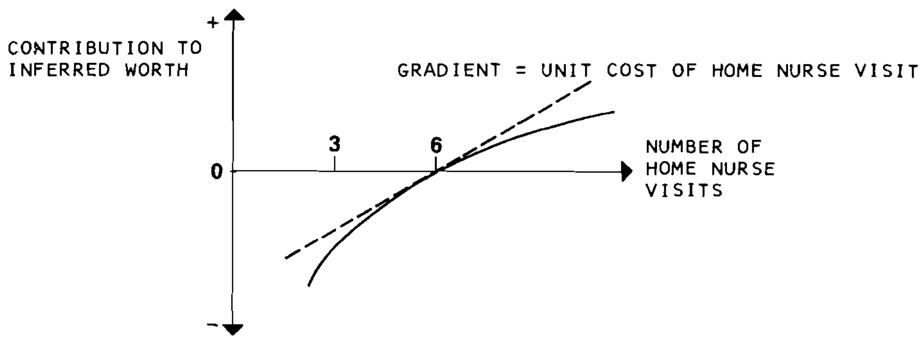


Figure 2. The contribution to inferred worth of varying standards of home nurse visiting to a hernia patient in the day surgery mode.

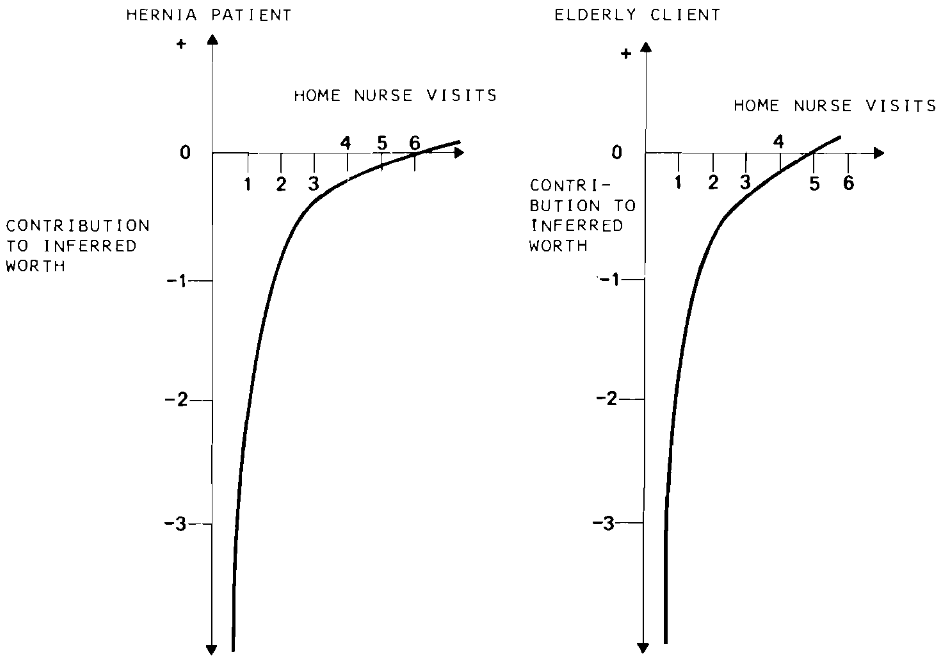
The third and final theme of this paper is the desirability for strategic models to represent the balance of forces and conflicts of interest that arise in the real world. A model which fails to do this and which merely calculates the consequences of alternative combinations of choice would be wholly adequate only for a system in which there is a single all-powerful decision maker with complete ability to implement his decisions. Modeling the preferences and priorities of the real-life system presents the analyst with a set of problems quite different from those he encounters when he models the resource consequences of a pattern of treatment or the prognosis of a clinical procedure. Here we are attempting to model the behavior of the professional staff in the service. But if our models fail to take the behavioral aspect into account, their solutions may be of only academic interest.

In the Inferred Worth Model, functions are defined which represent the inferred worth to the service of (a) treating more or fewer patients and (b) treating them at higher or lower standards. Given a set of limited resources, these functions will represent the competing demands for the resources. The solution provided by the model constitutes a prediction of how the service would in practice ration these resources if they were actually made available. The model represents simultaneously the choices concerning cover (the numbers of patients to be treated in each category), the modes of care for each category, and the standards for each mode. The mechansim of the model can be illustrated by a very much simplified example concerning the last of the three areas of choice: standards.

Take the situation where the model is considering one hernia patient in the day surgery mode and one elderly client of a domiciliary care mode. Let us further imagine that only five home nurse visits are available for the two of them. We have already seen (Figure 2) that the ideal standard for the hernia patient is six visits. Let us suppose that the ideal standard for the domiciliary mode of care for the elderly client is four home nurse visits (neglecting for the present the other services that might also be required for this mode of care). Let us further assume that elasticities for these two modes of care are identical, in which case the relevant curves of inferred worth contribution will be as shown in Figure 3.

Figure 3 also lists the possible integer solutions to the rationing problem. The extreme solutions of allocating all five units to one patient and none to the other attract a total inferred worth of $-\infty$. Intermediate solutions attract smaller penalties, and the optimum (since the two curves are of identical shape and differ only in scale) is the allocation of three visits to the hernia patient and two to the elderly client. This is the prediction which the model offers on how the service would actually ration the five nurse visits in this situation.

In practice, of course, the choices dealt with in the model are not as simple as this. The elasticities differ for different patient categories and different modes and so the solution would not be as symmetrical as in the example given. Also the model would consider, as would the service, whether an alternative mode of care might be employed for one of the two; if the elderly client could be assigned to a residential home mode, then extra home nurse visits would be released for, among others, the hernia patient. The model will select that combination of modes, standards and cover which maximizes inferred worth overall.



HERNIA PATIENT		ELDERLY CLIENT		TOTAL INFERRED WORTH
NUMBER OF VISITS	CONTRIBUTION TO INFERRED WORTH	NUMBER OF VISITS	CONTRIBUTION TO INFERRED WORTH	
5	-0.04	0	$-\infty$	$-\infty$
4	-0.13	1	-1.00	-1.13
3	-0.30	2	-0.20	-0.50
2	-0.80	3	-0.05	-0.85
1	-3.50	4	0	-3.50
0	$-\infty$	5	+0.02	$-\infty$

Figure 3. The rationing of a scarce resource between two competing clients as represented in the inferred worth model. (The curves depict the function $h_{ilk}(u_{ilk})$, as defined in the parameter values $F_{ik} = 1/3$ and $C_k = 1/30$.)

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Appendix: The Inferred Worth Model†

DEFINITIONS

i is a category of patient;

l is a mode of care;

k is a resource;

x_{il} is the number of patients in category i allocated to mode l;

d_i is the number of patients in category i to receive treatment;

D_i is the total population of potential patients in category i;

E_i is the elasticity of demand of patients in category i with respect to opportunity cost;

π_i is a constant (to be determined);

C_k is the unit cost of resource k;

u_{ilk} is the standard (amount of resource allocated) for resource k used in mode l for category i;

U_{ilk} is the corresponding ideal standard;

F_{ik} is the elasticity of the actual allocation of resource k to each patient in category i with respect to the opportunity cost of the resource;

B_k is the availability of resource k.

HYPOTHESIS

The service will choose the d_i, x_{il} and u_{ilk} so as to maximize the following function (total net inferred worth)

$$\sum_i g_i(d_i) + \sum_i \sum_l \sum_k h_{ilk}(U_{ilk})x_{il} - \sum_i \sum_l \sum_k C_k u_{ilk} x_{il} \quad ,$$

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†A full account is given in A.G. McDonald, et al., Balance of Care: Some Mathematical Models of the National Health Service, *British Medical Bulletin*, 30, 3 (1974).

where

$$g_i(d_i) = \frac{\pi_i D_i^{1/E_i}}{1 - 1/E_i} \; d_i^{(1-1/E_i)} \qquad \text{for } E_i \neq 1$$

or

$$\pi_i D_i^{1/E_i} \ln d_i \qquad \text{for } E_i = 1$$

and

$$h_{ilk}(U_{ilk}) = \frac{C_k U_{ilk}}{1 - 1/F_{ik}} \left\{ \left(\frac{u_{ilk}}{U_{ilk}} \right)^{(1-1/F_{ik})} - 1 \right\} \quad \text{for } F_{ik} \neq 1$$

or

$$C_k U_{ilk} \ln \left(\frac{u_{ilk}}{U_{ilk}} \right) \qquad \text{for } F_{ik} = 1 \quad ,$$

subject to the constraints

$$\sum_{l} x_{il} - d_i = 0 \text{ for all } i \quad ,$$

$$\sum_{i} \sum_{l} u_{ilk} x_{il} \leq B_k \text{ for all } k$$

and to any bounds that are specified on the value of d_i, x_{il} and u_{ilk}.

A Macroeconometric Model of the Production and Distribution of Physician, Hospital, and Other Health Care Services†

Donald E. Yett, et al.

INTRODUCTION

Almost a decade ago, as part of the Partnership for Health Act (P.L. 89-749), the U.S. Congress called for the establishment of national, regional, state, and local Comprehensive Health Planning (CHP) Agencies. Unlike those set up to administer the Regional Medical Care Program for projects relating to heart disease, stroke and cancer, the CHP agencies were charged with the responsibility to study and plan methods of providing for all aspects of health care--including preventive, diagnostic, therapeutic, and rehabilitative services--for the entire population of each local area.

The essence of the CHP program was its emphasis on state, and more particularly, on local agencies, with broad-based participation by consumers, providers, and representatives of other voluntary and governmental agencies in the process of setting goals and selecting projects to meet specific areawide needs. Although state and areawide CHP agencies (commonly referred to as "a" and "b" agencies, respectively) received federal grants for training, demonstration, and research projects, for the most part they had to rely upon voluntary cooperation to improve coordination among the various planning and service agencies in each area.

Not surprisingly, the results were mixed. Some CHP agencies served as little more than forums for debating the issues that divided the participants and for allocating federal grant funds among projects backed by various constituencies. Others took much more seriously their duties to certify the need and feasibility of capital expenditures on health facilities in excess of US $100,000, developing plans or guidelines under which such expenditures would or would not be approved. Some states even gave to their CHP agencies the responsibilities of approving all major changes in hospital services and review of rate increases. Nonetheless, even in those states where they were most active and had the greatest responsibilities, CHP agencies lacked the authority to initiate large-scale programs to implement

†The model reported on in this paper, the HRRC Macroeconometric Health Planning Model, was developed under a contract (HSM 110-69-1) with the U.S. Department of Health, Education, and Welfare, Health Services Administration.

their own plans. They had to rely primarily on the power to deny permission for changes that were inconsistent with the areawide plan.

In 1974, Congress passed the National Health Resources Planning and Development Act (P.L. 93-641) which will replace both the previous CHP and Regional Medical Care programs. Under this program, a system of Health Services Agencies will be established with both expanded regulatory authority, and, at least potentially, greater power to bring about the structural changes necessary to implement areawide plans for the cost-effective provision of comprehensive health care services. It is, of course, much too soon to judge what the effects of this new legislation will be when it has been fully implemented.

THE HRRC MACROECONOMETRIC HEALTH PLANNING MODEL

The Human Resources Research Center (HRRC) of the University of Southern California has undertaken the specification, estimation and simulation of a macroeconometric model of the health care system.* The major purpose of this model is to provide state and local health planning agencies with a means of forecasting the likely effects of pursuing alternative policies, as well as the course of trends that are beyond their control. It is our hope that it will gain wide acceptance by planners faced with the increased responsibilities given by Congress to the new Health Services Agencies. Indeed, it was specifically designed with that end in mind.

The macro approach was chosen as the proper framework for our state and substate econometric health planning model for several reasons.** First, it is relatively uncomplicated, and hence accessible to planners not trained in econometrics.

*See [1,2]. For the specification of another econometric model of the health care system see [3,4]. Econometric models that deal with certain portions of the health care system are the Feldstein model of hospitals [5,6], and of the Medicare system [7], and the Fuchs and Kramer model of physician services [8].

**The HRRC Health Planning Model is described as a macro-model because its equations predict the values of aggregate variables (e.g., the aggregate number of bed-days in short-term voluntary and proprietary hospitals, of beds in such hospitals, of medical specialists in private practice, etc.). This model should not be confused with the HRRC Prototype Microeconometric Model of the total U.S. Health Care Sector which, even though its present version is only a preliminary prototype, is considerably larger and more complex than the macro-model descirbed in this paper. This is because it deals explicitly with the behavior of finely-partitioned classes of individuals and institutions. For discussions of the micro-model see [9,10]. For another microsimulation model of the U.S. health care system, see [11].

Secondly, it is sufficiently detailed to be useful to health policy makers, without inundating them with more output than could be digested in the period available for decision making. Thirdly, it can be implemented, at both the state and local levels, using available data. Fourthly, it can be readily simulated and, as needed, altered to fit local circumstances.

It should be noted, however, that the first two advantages of our macro-model are, paradoxically, also its weaknesses. Because it forecasts aggregate magnitudes directly, it sacrifices the distributional effects of policy actions on constituent subpopulations (e.g., the poor and elderly). Similarly, because it focuses on a limited number of key relationships, it is too crude to use to forecast the details of complex programmatic changes. Nevertheless, despite these limitations, we feel that this model represents a reasonable compromise between intricate detail and relatively uncomplicated analysis that should be highly useful to health planners, including those who will be charged with the responsibility of implementing P.L. 93-641 at the state and local levels.

AN OVERVIEW OF THE MODEL

The scope of the HRRC macroeconometric health planning model is the entire personal health care system, excluding mental health services, drugs, and dental care. More specifically, it treats the following categories of health care institutions and manpower.

Inpatient services from:

1. Voluntary and proprietary short-term hospitals;

2. State and local governmental short-term hospitals;

3. Skilled nursing homes.

The endogenous variables for each of these inpatient institutions are the number of patient days utilized and the number of beds available. In addition, the model includes, as endogenous variables, the daily service charge for the above 1 and 3 and occupancy rates for the above 1,2, and 3.

The outpatient institutions treated in the model are:

4. Outpatient clinics of short-term voluntary and proprietary hospitals;

5. Outpatient clinics of short-term state and local governmental hospitals;

6. Offices of medical specialists (including general practitioners) in private practice;

7. Offices of surgical specialists in private practice.

In addition to the number of patient visits to each type of outpatient institution, the model also includes as endogenous variables the price per visit for the above 4, 6, and 7.

The categories of health manpower treated in the model are:

8. MD general practitioners in private practice;
9. MD medical specialists in private practice;
10. MD surgical specialists in private practice;
11. MDs in other specialities in private practice;
12. Physicians employed by hospitals;
13. Hospital interns and residents;
14. Registered nurses;
15. Practical nurses;
16. Allied health professionals and technicians;
17. Non-medical labor (e.g., housekeeping, maintenance, and clerical).

In addition to the number of such personnel "active" or employed, the model includes, as endogenous variables, the annual wage for the above 14, 15, and 16.

Demand and supply equations yield forecasts of the number of patient days and daily service charges for the inpatient institutions, the number of patient visits and prices per visit for the outpatient institutions, and the number employed and the corresponding wage rates in the various categories of health manpower. The health service institutions and the health manpower categories are linked through the fact that the sum of the quantities of health services produced is used in determining the demands for each type of health manpower.

DETAILED DESCRIPTION OF THE MODEL

Table 1 lists the 47 endogenous variables in the model. The exogenous variables are listed in Tables 2 and 3. Table 3 presents separately those variables that are included in the model primarily to reflect geographic-specific differences when it is applied to a particular state or substate area.

Most macroeconometric models are estimated using longitudinal data sets for the particular geographic area of interest (e.g., the nation, a specific state, etc.). In this case, however, sufficient data were not available to make that possible, and in any case, it would have been too large an undertaking to estimate separate models for each state and county or Standard Metropolitan Statistical Area (SMSA) in the US. Therefore, the following strategy was adopted:

- Estimate a "generalized" model using primarily 1970 cross sectional state data;

- Set the initial values of the endogenous variables equal to their 1967 levels for the State of California and, using reported historical figures on the corresponding exogenous variables, test the ability of the model to "forecast" actual experience over the 1968-1972 period;

- Substitute alternative specifications of the equations for any of the endogenous variables whose historical values could not be "forecast" within acceptable limits;

- Experiment with adjustments ("add-factors") to improve the model's ability to "track" the Californian historical experience;

- Conduct similar simulation experiments, but without any respecifications of equations or add factors, for two additional states (Pennsylvania and Louisiana) and three SMSAs (San Francisco, Pittsburgh and New Orleans) to determine how much "fine-tuning" is likely to be needed in order to use the generalized model to make forecasts and perform policy simulations for specific states and substate areas.

Table 4 (Sections A through J) presents the final estimated equations of the model. Space does not permit us to examine each of these equations and the reasoning behind the selection of their explanatory variables. But, for purposes of illustration, consider Equations (1) and (2) depicting the demand and supply for inpatient short-term hospital care.

In Equation (1), the number of patient days demanded from voluntary and proprietary short-term hospitals is negatively related to the price of hospital care relative to the price of outpatient care, positively related to the percent of the population aged 65 and over, positively related to per capita hospitalization benefits relative to the price of hospital care and negatively related to the per capita utilization of short-term governmental hospitals.

The supply of voluntary and proprietary hospital care (2) is solved for the price of hospital care, rather than the number of days provided. This is strictly a matter of convenience. It does not mean that the price of hospital care is determined solely by the solution of Equation (2). Indeed, it will be noted that the price of hospital care and the number of patient days appear in both equations (patient days appear via the occupancy term in Equation (2)). This means that estimation of the quantity and the price of hospital care depends upon the joint solution of both equations.

Another point illustrated by Equation (2) is that the model does not assume each sector will always be in equilibrium (that is, that supply will always equal demand). The fact that the price of hospital care in the current period is dependent upon the price in the previous period indicates there is a lag in the adjustment processes following changes in either supply or demand.

The remaining explanatory variables in Equation (2) show that there is a negative relationship between hospital prices and occupancy rates, and positive relations between hospital price and the average hospital wage, number of personnel per bed, and the value of assets per bed. The influence of bed capacity on hospital prices is introduced via the negative relation of prices to the occupancy rate. Hospital capacity itself is determined by the current number of patient days in relation to the number of beds in the previous period and the amount of federal hospital construction (Hill-Burton) funds awarded two periods earlier--indicating, not very surprisingly, a substantial lag in the completion of the adjustment process leading to a new level of hospital capacity.

The equations resulting from the estimation step of our methodology satisfied such criteria as having theoretically "correct" signs, significant t-values, high R squares, and reasonably small standard errors of regression--indicating that the model provides a good "explanation" of the variation among states in its endogenous variables for 1970. It remained to be seen whether the model would do well when it was used to "predict" historical experience for a specific state over time. That is, an important step in the model-building process was "tracking" its performance for California over the period 1968-1972. The final equations shown in Table 4 are those which passed both tests--that is, they gave good fits in the 1970 cross-sectional analysis and they exhibited good forecasting capability when scaled and simulated for a particular state over time.

Tables 5 and 6 give the final results of this process of testing the simulation properties of alternative cross-sectional specifications of the model. Table 5 shows the results obtained when each equation is solved in isolation from the rest of the model. In the case of the identities (sums and ratios of other endogenous variables) the relationships hold exactly so there is no difference between the "historical" and "simulated" values shown on the table. Also, it is likely that some of the "historical" data are subject to definitional differences and measurement errors, but it is impossible to say to what extent--if any--the results would appear to be better if this were not the case. (Parenthetically, the lack of comparability of the nursing home data over time was so great that "historical" values are given for only one year.)

It is apparent from Table 5 that most of the equations in the model track the California experience quite closely. Moreover, the simulated values do not diverge from the "historical" data over time. But, although the fit of the individual equations by themselves is of interest, the ability of the entire model to replicate historical data is of greater importance.

Table 6 presents a dynamic simulation of the complete model over the same period. Since the equations are solved simultaneously, these results include the effects of all interactions and linkages. Furthermore, the solution values are used for the lagged endogenous variables in subsequent years. While the simulation results in Table 6 differ from those presented in Table 5, the fit of the equations to the historical data is roughly similar. In some instances the correspondence is not as close (e.g., the price of hospital care), but in others the fit is improved (e.g., the number of hospital inpatient days).

For five of the endogenous variables (the price of hospital care, the number of "other" medical specialists and the wages of nurses, allied health professionals, and practical nurses), we experimented with the introduction of add factors to compensate for the trend which would have been observed if time-series data had been available for direct estimation. In each case, the difference between the historical and simulated values was narrowed, with very little adverse feedback on the solutions of the other equations of the model.

Exactly the same process--minus the trend adjustment step--was performed for two additional states and three SMSAs (Pennsylvania, Louisiana, San Francisco, Pittsburgh and New Orleans). The model did not perform as well in these tests as it did for California, but that was to be expected since an important step in selecting the final set of estimated equations had been checking their ability to track the historical data for California. However, the most important point is that the model performed well for the overwhelming majority of the equations tested; given the success attained by fine-tuning it for California, it is quite likely that in the future acceptable levels of performance can be obtained in most (if not all) states and substate areas without respecifying and reestimating the model for each one separately.

EXPERIMENTS PERFORMED USING THE ESTIMATED MODEL

Tables 7 and 8 illustrate some of the ways in which the model can be used to forecast both the direct and indirect effects of policy decisions. In both cases, the baseline simulation was performed on the assumption that recent trends for each of the exogenous variables would continue to 1980. The "experiment" reported in Table 7 involved assuming that through certificate-of-need regulations the ratio of total hospital beds per capita in California would be held constant at the 1972 level (that is, would grow in direct proportion to population). For the "experiment" reported in Table 8, it was assumed that various programs to redistribute physicians to "shortage" areas of the country (e.g., medical student loan remission, etc.) would cause the number of medical, surgical and other specialists to fall one percent below the baseline simulation for California (GPs were left unchanged). The net effect was to reduce the projected number of physician in-migrants by between 200 and 300 per year--or somewhat less than one-quarter of the projected in-migration.

In the first experiment (Table 7), since hospital beds increase less rapidly than utilization, the average occupancy rate rises in comparison with the baseline projection. This, in turn, leads to some differences in the forecast prices of health services and wage rates for the various categories of health manpower. There is also a modest increase in outpatient visits, since the model permits some substitutability of outpatient for inpatient care. The effect on the projected values of the other endogenous variables in the model is very minor.

In the second experiment (Table 8), the main impacts of reducing the flow of newly trained physicians to California is forecast to be a slight decline in the number of visits to surgical specialists and a corresponding increase in the number of visits to GPs. The smaller projected number of surgical specialists is associated with a somewhat smaller forecast number of interns and residents (especially domestic graduates). There are virtually no effects on the other endogenous variables of the model.

Two points should be emphasized with regard to these experiments. First, the assumed changes were rather small and of limited duration, leading to correspondingly small changes in the values of the endogenous variables. Larger and more long-lasting changes would certainly have shown more sizeable consequences. Second, the direct effects of both experiments were, to some extent, partially offset by secondary effects elsewhere in the model (e.g., the increased occupancy rates in the first experiment and the increased utilization of general practitioners in the second experiment). The existence of such offsetting secondary effects reinforces the importance of forecasting the secondary as well as the primary effects of policy changes.

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TABLE 1

ENDOGENOUS VARIABLES OF THE MODEL

A. Hospital Inpatient Care

PD-P	annual number of inpatient days provided by short-term voluntary and proprietary (STVP) hospitals (millions)
P-HP	average daily service charge in STVP hospitals (dollars)
OCCP	average occupancy rate in STVP hospitals (percent)
BEDP	number of beds in STVP hospitals (thousands)
PD-G	annual number of inpatient days provided by short-term state and local governmental (STSLG) hospitals (millions)
OCCG	average occupancy rate in STSLG hospitals (percent)
BEDG	number of beds in STSLG hospitals (thousands)
PDSH	annual number of inpatient days provided by federal and non-federal short-term general hospitals (millions)
BEDH	number of beds in federal and non-federal short-term general hospitals (thousands)

B. Skilled Nursing Homes

PDNH	annual number of patient days provided by skilled nursing homes (millions)
P-NH	average charges per patient day in skilled nursing homes (dollars)
OCCN	occupancy rate of skilled nursing homes (percent)
BEDN	number of beds in skilled nursing homes (thousands)

TABLE 1 Continued

C. Hospital Outpatient Clinics

OPVP	annual number of outpatient visits to STVP hospitals (millions)
OPVG	annual number of outpatient visits to STSLG hospitals (millions)
OPVN	annual number of total visits to hospital outpatient clinics at non-federal hospitals (millions)
P-OP	average revenue per outpatient visit at STVP hospitals (dollars)
OVSH	annual number of outpatient visits at federal and non-federal short-term general hospitals (millions)

D. Offices of Private Practice MDs

PVGM	annual number of patient visits to general practitioners and medical specialists in private practice (millions)
P-GM	price per visit to general practitioners and medical specialists (routine followup visit) (dollars)
PVSS	annual number of patient visits to surgical specialists in private practice (thousands)
P-SS	price per visit to surgical specialist (appendectomy for general surgeons) (dollars)

E. Physicians in Private Practice

#GPP	number of general practitioners in private practice (thousands)
#MSP	number of medical specialists in private practice (thousands)
#GPMS	number of general practitioners and medical specialists in private practice (thousands)
#SSP	number of surgical specialists in private practice (thousands)
#OSP	number of other specialists in private practice (thousands)
#MDP	total private practice physicians (thousands)

TABLE 1 Continued

F. Physicians Employed by Hospitals

OHMD	number of physicians (non-student) employed by hospitals (thousands)
IR-O	number of internships and residencies offered by hospitals (thousands)
IRDG	number of interns and residents (U.S. medical school graduates) employed by hospitals (thousands)
IRFG	number of interns and residents (foreign medical school graduates) employed by hospitals (thousands)
INRE	total interns and residents employed (thousands)
MDHP	total physicians employed by hospitals (thousands)

G. Registered Nurses

E-RN	number of full-time equivalent RNs employed by health service institutions (thousands)
W-RN	annual wage paid to general duty hospital RNs (thousands of dollars)
RNFT	number of RNs employed full time (thousands)
RNPT	number of RNs employed part time (thousands)

H. Practical Nurses

E-PN	number of full-time equivalent practical nurses employed by health service institutions (thousands)
PNFT	number of practical nurses employed full time (thousands)
PNPT	number of practical nurses employed part time (thousands)
W-PN	annual wage paid to practical nurses (thousands of dollars)

TABLE 1 Continued

I. Allied Health Professionals

E-AH	number of full-time equivalent allied health professionals employed by health service institutions (thousands)
W-AH	annual wage paid to allied health professionals (thousands of dollars)
AHFT	number of allied health professionals employed full time (thousands)
AHPT	number of allied health professionals employed part time (thousands)

J. Non-Medical Personnel

E-NM	number of non-medical personnel employed by health service institutions (thousands)

TABLE 2

EXOGENOUS VARIABLES OF THE MODEL

POP	total population (millions)
Y	annual per capita income (thousands of dollars)
ENRH	proportion of the population enrolled in private hospital insurance plans (percent)
ENRP	proportion of the population enrolled in private health insurance plans with coverage for regular medical insurance (percent)
ENRS	proportion of the population enrolled in private health insurance with surgical expense coverage (percent)
IBEP	annual insurance benefits paid by private health insurance plans per capita (dollars)
MCDH	Medicaid expenditures for hospital services per capita (dollars)
MCDN	Medicaid expenditures for nursing home services per person aged 65 and over (dollars)
MCDP	Medicaid expenditures for physicians services per capita (dollars)
%OLD	proportion of the population age 65 and over (percent)
MCRH	annual amount reimbursed per Medicare enrollee for hospital services (dollars)
MCRN	annual amount reimbursed per Medicare enrollee for services in extended care or skilled nursing facilities (dollars)
HCRP	annual amount reimbursed for physician's services per Medicare enrollee (dollars)
PD-F	annual number of patient-days provided by short-term federal hospitals (millions)
BEDF	number of beds in short-term federal hospitals (thousands)
EMBD	number of personnel per bed in voluntary and proprietary hospitals

TABLE 2 Continued

KPBD	value of plant assets per bed in short-term voluntary and proprietary hospitals (thousands of dollars)
OPVF	annual number of outpatient visits provided by federal hospitals (millions)
W-NM	average annual wage per non-medical hospital employee (thousands of dollars)
ADBD	annual admissions per bed in short-term voluntary and proprietary hospitals
HBFF	Hill-Burton funds for hospital construction (millions of dollars)
GRAD	annual number of medical school graduates (thousands)
SKRN	stock of registered nurses (thousands)
SKAH	stock of allied health professionals (thousands)
SKPN	stock of practical nurses (thousands)
TBEN	total benefits paid by private and public insurance programs per capita (dollars)
HBEN	benefits per capita for hospital care paid by private and public insurance programs (dollars)
DBEN	benefits per capita for physicians services paid by private and public insurance programs (dollars)
CPI	Consumer Price Index for all goods and services (1967 = 1.0)
TIME	time trend (1960 = 1.0)

TABLE 3

STANDARDIZING VARIABLES OF THE MODEL

PDGA	weighted average of inpatient days provided by short-term state and local governmental hospitals (days per thousand population)
PDPA	weighted average of inpatient days provided by short-term voluntary and proprietary hospitals (days per thousand population)
%CDH	proportion of long-term care beds in chronic disease hospitals (percent)
AGED	proportion of population age 65 and over who are at least age 75 (percent)
EBNH	full-time equivalent employees per bed in skilled nursing homes
HRGM	average hours per week devoted to medical practice by general practitioners and medical specialists (hours per doctor)
LVSS	average length of visit to surgical specialists, computed as the ratio of weekly hours to weekly visits (minutes)
RHOS	proportion of employed RNs who work in hospitals (fraction)
THRT	proportion of allied health professionals who are therapists (fraction)
RAG1	proportion of RNs who are age 25-29 (fraction)
RAG2	proportion of RNs who are at least age 39 (fraction)
%FEM	proportion of allied health professionals who are female (fraction)
DIET	proportion of allied health professionals who are dietitians (fraction)
'AG1	proportion of practical nurses who are age 25-29 (fraction)
'AG2	proportion of practical nurses who are age 55-59 (fraction)
'NBK	proportion of practical nurses who are black (fraction)
'NSP	proportion of practical nurses who are Spanish surname (fraction)

TABLE 4

ESTIMATED EQUATIONS OF THE MODEL

A. Hospital Inpatient Care

(1) $$\text{PD-P}^{*} = -\underset{(-2.38)}{36.2394}\ \text{P-HP/P-OP} + \underset{(5.67)}{61.1378}\ \text{\%OLD} + \underset{(4.91)}{656.3433}\ \text{HBEN/P-HP} - \underset{(-9.32)}{0.9308}\ \text{PDGA} + 317.8782\ .$$

$\bar{R}^2 = .81$

S.E. = 119.4853

(2) $$\text{P-HP} = \underset{(22.40)}{0.8971}\ \text{P-HP}_{t-1} - \underset{(2.04)}{0.1418}\ \text{OCCP} + \underset{(3.48)}{2.1657}\ (.25\ \text{W-RN} + .07\ \text{W-AH} + .13\ \text{W-PN} + .55\ \text{W-NM}) + \underset{(4.05)}{7.0271}\ \text{EMBD} + \underset{(0.56)}{0.0525}\ \text{KPBD} - 0.8362\ .$$

$\bar{R}^2 = .96$

S.E. = 3.4737

(3) $$\text{OCCP} = \frac{\text{PD-P}}{0.00365\ \text{BEDP}}\ .$$

(4) $$\text{BEDP}^{*} = \underset{(15.25)}{0.7958}\ \text{BEDP}^{*}_{t-1} + \underset{(3.74)}{0.7645}\ \text{PD-P}^{*} + \underset{(1.26)}{0.0226}\ \text{HBFF}_{t-2} - 0.0554\ .$$

$\bar{R}^2 = .99$

S.E. = 0.1092

TABLE 4 Continued

Hospital Inpatient Care (Continued)

(5) $$PD\text{-}G^* = -\underset{(1.16)}{41.9839}\ Y + \underset{(2.62)}{35.7549}\ \%OLD$$

$$-\underset{(-7.06)}{0.0634}\ PDPA + 614.8633\ .$$

$\bar{R}^2$ = .56

S.E. = 128.6748

(6) $$OCCG = \frac{PD\text{-}G}{0.00365\ BEDG}\ .$$

(7) $$BEDG^* = \underset{(9.99)}{0.5555}\ BEDG^*_{t-1} + \underset{(8.61)}{1.8055}\ PD\text{-}G^*$$

$$-\ 0.0130\ .$$

$\bar{R}^2$ = .99

S.E. = 0.0605

(8) $$PDSH = PD\text{-}P + PD\text{-}G + PD\text{-}F\ .$$

(9) $$BEDH = BEDP + BEDG + BEDF\ .$$

TABLE 4 Continued

ESTIMATED EQUATIONS OF THE MODEL

B. Skilled Nursing Homes

(10) $$PDNH^* = -\underset{(-3.72)}{42.7757}\ P\text{-}NH/P\text{-}HP + \underset{(5.95)}{0.0465}\ (MCDN + MCRN) - \underset{(-3.73)}{0.1289}\ \%CDH$$
$$\underset{(4.68)}{0.6486}\ AGED - 8.0106\ .$$

$\bar{R}^2 = .69$

S.E. = 2.3235

(11) $$P\text{-}NH = -\underset{(-2.23)}{0.0969}\ OCCN + \underset{(3.28)}{6.8211}\ EBNH + \underset{(6.25)}{1.6901}\ (0.077\ W\text{-}RN + 0.105\ W\text{-}AH$$
$$+ 0.087\ W\text{-}PN + 0.731\ W\text{-}NM) + 6.8898\ .$$

$\bar{R}^2 = .53$

S.E. = 1.0686

(12) $$OCCN = \frac{PDNH}{0.00365\ BEDN}\ .$$

(13) $$BEDN^* = \underset{(1.76)}{0.0975}\ BEDN^*_{t-2} + \underset{(21.65)}{2.7232}\ PDNH^* + 1.1956\ .$$

$\bar{R}^2 = .99$

S.E. = 1.6694

TABLE 4 Continued

ESTIMATED EQUATIONS OF THE MODEL

C. Hospital Outpatient Clinics

(14)
$$OPVP^{*} = \underset{}{0.8164}\ OPVP^{*}_{t-1} - \underset{(-1.90)}{0.4893}\ P\text{-}OP/P\text{-}HP + \underset{(2.44)}{0.092}\ PD\text{-}P + 0.1095 .$$

$\bar{R}^2 = .92$

S.E. = 0.0597

(15)
$$OPVG^{*} = \underset{(32.76)}{(.0091}\ OPVG^{*}_{t-1} - \underset{(-3.24)}{0.0496}\ OPVP^{*}_{t-1} + 0.0323 .$$

$\bar{R}^2 = .97$

S.E. = 0.0190

(16)
$$OPVN = OPVP + OPVG$$

(17)
$$P\text{-}OP = \underset{(5.34)}{0.5126}\ P\text{-}OP_{t-1} + \underset{(3.99)}{0.0819}\ P\text{-}HP + 0.2589 .$$

$\bar{R}^2 = .57$

S.E. = 1.9667

(18)
$$OVSH = OPVN + OPVF$$

TABLE 4 Continued

ESTIMATED EQUATIONS OF THE MODEL

D. Offices of Private Practice MDs

(19) $$PVGM^* = \underset{(-2.30)}{-\,0.3420}\ P\text{-}GM + \underset{(3.57)}{0.0170}\ P\text{-}SS + \underset{(1.58)}{0.0199}\ DBEN + \underset{(3.34)}{3.2051}\ \frac{\#GPP}{\#GPMS} + 0.0023\,.$$

$\bar{R}^2 = .60$

S.E. = 0.2691

(20) $$P\text{-}GM = \underset{(-2.88)}{-\,0.0844}\ HRGM + \underset{(4.03)}{0.5456}\ (.17\ W\text{-}RN + .34\ W\text{-}AH + 0.9\ W\text{-}PN + .40\ W\text{-}NM) + 8.3331\,.$$

$\bar{R}^2 = .55$

S.E. = 0.3866

(21) $$PVSS^* = \underset{(-.58)}{-\,0.0011}\ P\text{-}SS + \underset{(3.32)}{0.1850}\ P\text{-}GM + \underset{(2.08)}{0.0156}\ DBEN - \underset{(-2.89)}{0.0266}\ LVSS + 1.2076\,.$$

$\bar{R}^2 = .29$

S.E. = 0.1718

TABLE 4 Continued

D. Offices of Private Practice MDs (Continued)

$$(22)\quad P\text{-}SS = \underset{(1.01)}{0.8477}\ LVSS + \underset{(2.76)}{16.2109}\ (.16\ W\text{-}RW + .35\ W\text{-}AH + .05\ W\text{-}PN + .31\ W\text{-}NM) + 90.0891\ .$$

$\bar{R}^2 = .36$

S.E. = 14.2498

TABLE 4 Continued

ESTIMATED EQUATIONS OF THE MODEL

E. Physicians in Private Practice

(23)
$$\#GPP^* = \underset{(56.82)}{1.0134}\ \#GPP^*_{t-1} - \underset{(-.07)}{0.0001}\ P\text{-}GM + \underset{(.40)}{0.0002}\ PVGM^* - \underset{(-2.47)}{0.0749}\ \#MSP^* + \underset{(3.17)}{0.0916}\ \#SSP^* - \underset{(-.06)}{0.0024}\ \#OSP^* - \underset{(-1.50)}{0.0178}\ IRDG^* - 0.0174\ .$$

$\bar{R}^2 = .99$

S.E. = 0.0044

(24)
$$\#MSP^* = \underset{(43.57)}{0.9954}\ \#MSP^*_{t-1} - \underset{(-.03)}{0.000014}\ P\text{-}GM + \underset{(1.61)}{0.0008}\ PVGM^* - \underset{(-1.40)}{0.0180}\ \#GPP^* + \underset{(1.81)}{0.0391}\ \#SSP^* + \underset{(1.01)}{0.0304}\ \#OSP^* - \underset{(-1.62)}{0.0134}\ IRDG^* - 0.0058\ .$$

$\bar{R}^2 = .997$

S.E. = 0.0034

(25)
$$\#GPMS = \#GPP + \#MSP\ .$$

(26)
$$\#SSP^* = \underset{(29.90)}{1.0619}\ \#SSP^*_{t-1} + \underset{(1.90)}{0.0001}\ P\text{-}SS - \underset{(-.18)}{0.0001}\ PVSS^* - \underset{(-2.18)}{0.0402}\ \#GPP^*$$

TABLE 4 Continued

E. Physicians in Private Practice (Continued)

$$- \underset{(-2.22)}{0.0806}\ \#MSP^{*} + \underset{(.99)}{0.0398}\ \#OSP^{*}$$

$$- 0.0018\ .$$

$\bar{R}^2 = .99$

S.E. = 0.0052

$$(27)\quad \#OSP^{*} = \underset{(23.99)}{0.9346}\ \#OSP^{*}_{t-1} + \underset{(2.70)}{0.0430}\ \#GPP^{*}$$

$$+ \underset{(1.19)}{0.0373}\ \#MSP^{*} + \underset{(0.31)}{0.0099}\ \#SSP^{*}$$

$$- 0.0070\ .$$

$\bar{R}^2 = .995$

S.E. = 0.0029

(28) #MDP = #GPMS + #SSP + #OSP .

TABLE 4 Continued

ESTIMATED EQUATIONS OF THE MODEL

F. Physicians Employed by Hospitals

(29) $$OHMD^{*} = \underset{(0.73)}{0.00957}\ PDSH^{*} + \underset{(11.94)}{0.14399}\ OVSH^{*} - 0.02555 .$$

$\bar{R}^2 = .43$

S.E. = 0.03414

(30) $$IR\text{-}O^{*} = -\underset{(2.08)}{0.08511}\ PDSH^{*} + \underset{(9.27)}{0.34849}\ OVSH^{*} - 0.08354 .$$

$\bar{R}^2 = .32$

S.E. = 0.10644

(31) $$IRDG/IR\text{-}O = \underset{(3.96)}{.3350}\ \#MDP^{*} + \underset{(2.43)}{1.7627}\ GRAD^{*}_{t-1} - \underset{(-7.60)}{2.1594}\ IRFG^{*}_{t-1} + 0.3847 .$$

$\bar{R}^2 = .63$

S.E. = 0.0994

(32) $$IRFG^{*} = \underset{(2.99)}{0.1771}\ IR\text{-}O^{*} - \underset{(-2.65)}{0.1633}\ IRDG^{*}\ \underset{(12.54)}{0.8176}\ IRFG^{*}_{t-1} - 0.0074$$

$\bar{R}^2 = .99$

S.E. = 0.0069

(33) $$INRE = IRDG + IRFG .$$

(34) $$MDHP = OHMD + INRE .$$

TABLE 4 Continued

ESTIMATED EQUATIONS OF THE MODEL

G. Registered Nurses

(35) E-RN = RNFT + 0.5RNPT .

(36) W-RN = - 0.1800 E-RN/PDSH - 0.3051 PDNH/PDSH
(-1.55) (-3.35)

1.0525 #MDP/PDSH + 0.9287 W-NM
(2.29) (6.97)

+ 2.7559 RHOS + 1.1411 .
(1.73)

$\bar{R}^2$ = .81

S.E. = 0.2901

(37) RNFT/SKRN = 0.0479 W-RN/Y
(2.83)

- 0.8612 RNPT/SKRN + 0.9311 RAG1
(-7.02) (2.86)

+ 0.2203 RAG2 + 0.0323 .
(1.58)

$\bar{R}^2$ = .69

S.E. = 0.0180

(38) RNPT/SKRN = 0.0107 W-RN - 0.5187 RNFT/SKRN
(3.05) (-7.09)

+ 1.0588 RAG1 + 0.3008 RAG2 + 0.1098 .
(4.59) (2.95)

$\bar{R}^2$ = .74

S.E. = 0.0139

TABLE 4 Continued

ESTIMATED EQUATIONS OF THE MODEL

II. Practical Nurses

(39) E-PN = PNFT + 0.5 PNPT .

(40) $W\text{-}PN/W\text{-}NM = -\underset{(-.50)}{0.4437}\ E\text{-}PN/E\text{-}NM$

$+\underset{(2.05)}{0.2718}\ PDSH^{*} - \underset{(-4.06)}{0.5470}\ OVSH^{*}$

$-\underset{(-1.37)}{0.0536}\ PDNH^{*} + 1.8218$. $\bar{R}^2 = .27$

S.E. = 0.1644

(41) $PNFT/SKPN = \underset{(3.23)}{0.1217}\ W\text{-}PN/Y - \underset{(-2.62)}{0.4459}\ PNPT/SKPN$

$-\underset{(-1.99)}{0.7374}\ PAG1 - \underset{(-1.68)}{0.9054}\ PAG2$

$+\underset{(1.56)}{0.0725}\ PNBK + 0.5227$

$\bar{R}^2 = .51$

S.E. = 0.0282

(42) $PNPT/SKPN = \underset{(2.08)}{0.0165}\ W\text{-}PN - \underset{(-2.36)}{0.2700}\ PNFT/SKPN$

$-\underset{(-0.50)}{0.1373}\ PAG1 - \underset{(-.93)}{0.3689}\ PAG2$

$-\underset{(-2.12)}{0.1334}\ PNSP + 0.3621$.

$\bar{R}^2 = .37$

S.E. = 0.0236

TABLE 4 Continued

ESTIMATED EQUATIONS OF THE MODEL

I. Allied Health Professionals

(43) E-AH = AHFT + 0.5 AHPT .

(44) W-AH/W-NM = - 0.3913 E-AH/E-NM
(-0.26)

- 3.5722 THRT
(-4.38)

- 0.3818 OVSH/PDSH + 2.9700 .
(-2.22)

$\bar{R}^2 = .36$

S.E. = 0.1803

(45) AHFT/SKAH = 0.0593 W-AH/Y - 0.7215 AHPT/SKAH
(2.10) (-3.93)

- 0.1071 %FEM - 0.1762 DIET + 0.6731 .
(-1.10) (-1.19)

$\bar{R}^2 = .53$

S.E. = 0.0248

(46) AHPT/SKAH = 0.0099 W-AH - 0.4864 AHFT/SKAH
(1.65) (-4.55)

+ 0.0023 %FEM + 0.4266 .
(0.03)

$\bar{R}^2 = .44$

S.E. = 0.0209

TABLE 4 Continued

ESTIMATED EQUATION OF THE MODEL

J. Non-Medical Personnel

(47) $$\text{E-NM/E-RN} = -\underset{(-2.76)}{4.1826}\ \text{W-NM/W-RN} + \underset{(2.21)}{0.0192}\ \text{P-PH} - \underset{(-5.35)}{2.2749}\ \#\text{MDP/PDSH} + \underset{(3.78)}{0.3944}\ \text{PDNH/PDSH} + 4.4120 .$$

$\bar{R}^2 = .51$

S.E. = 0.3756

* The specifications of the endogenous variables given in Table 1 are used in simulation of the model. However, in order to facilitate estimation of some of the regression equations in Table 4, certain endogenous variables were expressed relative to the population base.

The numbers of hospital inpatient days (PD-P, PD-G, and PDSH) are per capita in equations (4), (7), (29), (30), and (40). The same endogenous variables are per thousand population in equations (1) and (5). The current and lagged numbers of hospital beds (BEDP, $BEDP_{t-1}$, BEDG and $BEDG_{t-1}$) are also per thousand population in equations (4) and (7).

PDNH is the number of nursing home inpatient days per person aged 65 or older in equations (10) and (13). In equation (40), PDNH is the number of nursing home inpatient days per capita.

The current and lagged numbers of nursing home beds (BEDN and BED_{t-2}) in equation (13) are per thousand persons aged 65 and older.

In equations (14), (15), (19), (21), (23), (24), (26), (29), (30) and (40), the current and lagged visit variables OPVP, OPVG, OVSH, PVGM and PVSS are each the number of patient visits per capita. In equations (23), (24), (26), (27) and (29) - (32), the current and lagged physician variables #GPP, #MSP, #SSP, #OSP, #MDP, OHMD, IR-O, IRFG, and IRDG are each defined as the number of physicians per thousand persons. The lagged exogenous variable GRAD is also defined on a per thousand persons basis in equation (31). To simulate the model, equations and terms in the deflated variables were re-inflated by the appropriate (exogenous) populations sizes.

TABLE 5

STATE OF CALIFORNIA --CHECK FIT OF INDIVIDUAL EQUATIONS TO HISTORICAL DATA

PD-P

	HISTORICAL	SIMULATED
1968	13.753	12.928
1969	14.381	13.441
1970	14.516	13.569
1971	14.459	12.683
1972	14.541	13.122

P-OP

	HISTORICAL	SIMULATED
1968	8.010	8.456
1969	9.110	9.720
1970	9.980	11.527
1971	12.230	13.076
1972	15.990	15.442

INRE

	HISTORICAL	SIMULATED
1968	4.580	4.580
1969	4.901	4.901
1970	5.221	5.221
1971	5.548	5.548
1972	5.997	5.997

P-HP

	HISTORICAL	SIMULATED
1968	80.000	80.262
1969	90.840	90.870
1970	105.900	102.086
1971	119.280	117.537
1972	133.840	131.456

DPV

	HISTORICAL	SIMULATED
1968	21.146	21.146
1969	21.734	21.734
1970	25.087	25.087
1971	25.254	25.254
1972	25.534	25.534

MDHP

	HISTORICAL	SIMULATED
1968	5.994	5.994
1969	6.487	6.487
1970	7.049	7.049
1971	7.409	7.409
1972	7.849	7.849

OCCP

	HISTORICAL	SIMULATED
1968	74.940	74.939
1969	76.209	76.209
1970	73.881	73.880
1971	71.162	71.163
1972	68.924	68.924

PVGM

	HISTORICAL	SIMULATED
1968	81.325	79.660
1969	82.702	81.796
1970	85.436	82.277
1971	86.702	83.245
1972	88.720	84.105

E-RN

	HISTORICAL	SIMULATED
1968	51.042	51.041
1969	51.852	51.852
1970	52.713	52.713
1971	53.714	53.714
1972	54.248	54.247

BEDP

	HISTORICAL	SIMULATED
1968	50.280	50.052
1969	51.700	52.803
1970	53.830	54.208
1971	55.666	55.668
1972	57.800	57.125

P-GM

	HISTORICAL	SIMULATED
1968	7.920	7.986
1969	8.467	8.485
1970	9.105	9.196
1971	9.735	9.820
1972	10.035	10.385

W-RN

	HISTORICAL	SIMULATED
1968	7.748	7.498
1969	8.554	7.906
1970	9.469	8.783
1971	10.384	9.535
1972	11.297	10.229

PD-G

	HISTORICAL	SIMULATED
1968	4.895	4.963
1969	4.968	4.834
1970	4.774	4.758
1971	4.840	4.725
1972	4.267	4.582

PVSS

	HISTORICAL	SIMULATED
1968	35.325	34.953
1969	36.258	38.019
1970	38.564	39.715
1971	39.795	40.849
1972	41.347	41.420

E-AH

	HISTORICAL	SIMULATED
1968	31.655	31.654
1969	33.061	33.061
1970	34.320	34.320
1971	35.690	35.689
1972	36.910	36.910

OCCG

	HISTORICAL	SIMULATED
1968	68.071	68.076
1969	66.553	66.557
1970	66.261	66.259
1971	65.380	65.376
1972	62.680	62.676

P-SS

	HISTORICAL	SIMULATED
1968	256.480	259.269
1969	269.683	275.167
1970	286.309	296.927
1971	306.114	315.807
1972	317.605	332.725

W-AH

	HISTORICAL	SIMULATED
1968	8.770	8.724
1969	9.412	9.121
1970	10.370	9.819
1971	11.327	10.651
1972	12.285	11.281

TABLE 5 Continued

STATE OF CALIFORNIA --CHECK FIT OF INDIVIDUAL EQUATIONS TO HISTORICAL DATA

	BEDG HISTORICAL	BEDG SIMULATED	#GPP HISTORICAL	#GPP SIMULATED	E-NM HISTORICAL	E-NM SIMULATED
1968	19.700	20.309	6.695	6.594	156.092	165.842
1969	20.450	19.818	6.568	6.609	165.737	187.679
1970	19.740	19.828	6.539	6.435	174.681	195.837
1971	20.283	19.574	6.388	6.413	184.214	214.392
1972	18.652	18.788	6.262	6.219	192.995	226.239

	PDSH HISTORICAL	PDSH SIMULATED	#MSP HISTORICAL	#MSP SIMULATED	E-PN HISTORICAL	E-PN SIMULATED
1968	22.787	22.788	5.577	5.520	16.703	16.704
1969	23.291	23.292	5.780	5.779	17.359	17.358
1970	22.810	22.810	6.078	5.969	17.940	17.940
1971	22.567	22.568	6.272	6.303	18.583	18.582
1972	21.780	21.781	6.433	6.485	19.152	19.151

	BEDH HISTORICAL	BEDH SIMULATED	GPMS HISTORICAL	GPMS SIMULATED	W-PN HISTORICAL	W-PN SIMULATED
1968	81.589	81.589	12.272	12.272	5.741	5.773
1969	83.495	83.495	12.348	12.348	6.240	6.165
1970	84.249	84.249	12.617	12.617	6.877	7.074
1971	85.139	85.139	12.660	12.660	7.514	7.999
1972	85.459	85.459	12.695	12.695	8.151	8.552

	PDNH HISTORICAL	PDNH SIMULATED	#SSP HISTORICAL	#SSP SIMULATED	RNFT HISTORICAL	RNFT SIMULATED
1968	0.0	26.533	7.194	7.174	39.837	39.147
1969	0.0	30.511	7.384	7.464	39.689	39.577
1970	0.0	30.451	7.770	7.613	39.944	39.269
1971	32.286	32.287	8.018	8.056	40.286	39.660
1972	0.0	33.690	8.243	8.289	39.827	39.496

	P-NH HISTORICAL	P-NH SIMULATED	#OSP HISTORICAL	#OSP SIMULATED	RNPT HISTORICAL	RNPT SIMULATED
1968	12.930	12.930	4.813	4.756	22.409	22.941
1969	0.0	13.889	5.313	5.003	24.326	24.424
1970	0.0	15.452	5.463	5.463	25.538	26.247
1971	0.0	16.769	5.788	5.620	26.857	27.819
1972	0.0	17.796	6.100	5.903	28.841	29.315

	OCCN HISTORICAL	OCCN SIMULATED	#MDP HISTORICAL	#MDP SIMULATED	AHFT HISTORICAL	AHFT SIMULATED
1968	0.0	90.128	24.279	24.279	25.535	24.833
1969	0.0	86.992	25.045	25.045	26.599	25.236
1970	0.0	84.478	25.850	25.850	27.538	25.717
1971	82.860	82.859	26.466	26.466	28.560	26.306
1972	0.0	83.000	27.038	27.038	29.457	26.624

TABLE 5 Continued

STATE OF CALIFORNIA --CHECK FIT OF INDIVIDUAL EQUATIONS TO HISTORICAL DATA

	BEDN		OHMO		AHPT	
	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED
1968	0.0	81.920	1.414	1.501	12.239	11.893
1969	0.0	89.937	1.586	1.585	12.924	12.220
1970	0.0	98.200	1.828	2.010	13.564	12.652
1971	106.754	106.831	1.861	2.020	14.259	13.125
1972	0.0	108.559	1.852	2.027	14.906	13.590

	OPVP		IR-0		PNFT	
	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED
1968	11.020	11.233	5.259	5.373	12.129	11.770
1969	12.265	11.976	5.405	6.002	12.744	12.090
1970	13.909	13.021	5.550	6.167	13.314	12.472
1971	14.322	14.503	6.220	7.288	13.937	12.965
1972	14.165	14.707	6.725	7.246	14.512	13.157

	OPVG		IRDG		PNPT	
	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED
1968	4.791	4.305	4.329	4.321	9.150	9.350
1969	4.199	5.127	4.624	4.428	9.229	9.642
1970	5.543	4.447	4.918	4.589	9.252	9.960
1971	5.252	5.757	5.227	5.186	9.291	10.307
1972	5.480	5.424	5.607	5.705	9.278	10.604

	OPVN		IRFG	
	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED
1968	15.811	15.811	0.251	0.215
1969	16.464	16.464	0.277	0.236
1970	19.452	19.452	0.303	0.233
1971	19.574	19.574	0.321	0.321
1972	19.645	19.645	0.390	0.360

TABLE 6

STATE OF CALIFORNIA --DYNAMIC CONTROL SOLUTION OF THE MODEL - HISTORICAL PERIOD

	PD-P		P-OP		INRE	
	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED
1968	13.753	12.895	8.010	8.475	4.580	4.613
1969	14.381	13.766	9.110	9.993	4.901	5.021
1970	14.516	14.585	9.980	11.711	5.221	5.334
1971	14.459	14.581	12.230	13.555	5.548	5.782
1972	14.541	14.803	15.990	15.504	5.997	6.061

	P-HP		OPV		MDHP	
	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED
1968	80.000	80.223	21.146	20.873	5.994	6.076
1969	90.840	91.212	21.734	21.907	6.487	6.633
1970	105.900	102.528	25.087	23.192	7.049	7.072
1971	119.280	114.096	25.254	24.116	7.409	7.641
1972	133.840	126.157	25.534	24.963	7.849	8.007

	OCCP		PVGM		E-RN	
	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED
1968	74.940	71.529	81.325	79.941	51.042	50.225
1969	76.209	73.054	82.702	83.034	51.852	50.650
1970	73.881	73.719	85.436	84.600	52.713	51.604
1971	71.162	71.262	86.702	85.119	53.714	52.040
1972	68.924	70.365	88.720	85.516	54.248	52.264

	BEDP		P-GM		W-RN	
	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED
1968	50.280	49.393	7.920	7.964	7.748	7.495
1969	51.700	51.627	8.467	8.374	8.554	7.868
1970	53.830	54.202	9.105	9.096	9.469	8.730
1971	55.666	56.057	9.735	9.672	10.384	9.483
1972	57.800	57.637	10.035	10.154	11.297	10.123

	PD-G		PVSS		E-AH	
	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED
1968	4.895	4.963	35.325	35.063	31.655	30.735
1969	4.968	4.834	36.258	37.667	33.061	31.575
1970	4.774	4.758	38.564	39.544	34.320	32.511
1971	4.840	4.725	39.795	40.560	35.690	33.241
1972	4.267	4.582	41.347	41.635	36.910	33.819

	OCCG		P-SS		W-AH	
	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED	HISTORICAL	SIMULATED
1968	68.071	66.551	256.480	258.479	8.770	8.709
1969	66.553	66.255	269.683	271.749	9.412	9.083
1970	66.261	66.711	286.309	293.803	10.370	10.105
1971	65.380	67.235	306.114	311.200	11.327	10.867
1972	62.680	66.844	317.605	325.659	12.285	11.517

TABLE 6 Continued

STATE OF CALIFORNIA --DYNAMIC CONTROL SOLUTION OF THE MODEL - HISTORICAL PERIOD

	BEDG HISTORICAL	BEDG SIMULATED		#GPP HISTORICAL	#GPP SIMULATED		E-NM HISTORICAL	E-NM SIMULATED
1963	19.700	20.432	1968	6.695	6.591	1968	156.092	156.130
1969	20.450	19.989	1969	6.568	6.500	1969	165.737	171.208
1970	19.740	19.540	1970	6.539	6.364	1970	174.681	183.991
1971	20.283	19.253	1971	6.388	6.231	1971	184.214	193.177
1972	18.652	18.780	1972	6.262	6.056	1972	192.995	203.412

	PDSH HISTORICAL	PDSH SIMULATED		#MSP HISTORICAL	#MSP SIMULATED		E-PN HISTORICAL	E-PN SIMULATED
1968	22.787	21.999	1968	5.577	5.517	1968	16.703	16.713
1969	23.291	22.543	1969	5.780	5.709	1969	17.359	17.153
1970	22.810	22.862	1970	6.078	5.887	1970	17.940	17.692
1971	22.567	22.575	1971	6.272	6.092	1971	18.583	18.256
1972	21.780	22.358	1972	6.433	6.283	1972	19.152	18.422

	BEDH HISTORICAL	BEDH SIMULATED		GPMS HISTORICAL	GPMS SIMULATED		W-PN HISTORICAL	W-PN SIMULATED
1968	81.589	81.433	1968	12.272	12.108	1968	5.741	5.999
1969	83.495	82.960	1969	12.348	12.210	1969	6.240	6.519
1970	84.249	84.421	1970	12.617	12.251	1970	6.877	7.239
1971	85.139	84.501	1971	12.660	12.323	1971	7.514	7.936
1972	85.459	85.425	1972	12.695	12.339	1972	8.151	8.568

	PDNH HISTORICAL	PDNH SIMULATED		#SSP HISTORICAL	#SSP SIMULATED		RNFT HISTORICAL	RNFT SIMULATED
1968	0.0	25.412	1968	7.194	7.179	1968	39.837	38.876
1969	0.0	29.738	1969	7.384	7.435	1969	39.689	38.548
1970	0.0	30.839	1970	7.770	7.669	1970	39.944	38.579
1971	32.286	31.482	1971	8.018	7.939	1971	40.286	38.264
1972	0.0	32.706	1972	8.243	8.187	1972	39.827	37.725

	P-NH HISTORICAL	P-NH SIMULATED		#OSP HISTORICAL	#OSP SIMULATED		RNPT HISTORICAL	RNPT SIMULATED
1968	12.930	13.810	1968	4.813	4.749	1968	22.409	22.698
1969	0.0	14.190	1969	5.313	4.937	1969	24.326	24.202
1970	0.0	15.595	1970	5.463	5.093	1970	25.538	26.050
1971	0.0	16.727	1971	5.788	5.255	1971	26.857	27.552
1972	0.0	17.657	1972	6.100	5.386	1972	28.841	29.077

	OCCN HISTORICAL	OCCN SIMULATED		#MDP HISTORICAL	#MDP SIMULATED		AHFT HISTORICAL	AHFT SIMULATED
1968	0.0	80.904	1968	24.279	24.035	1968	25.535	24.800
1969	0.0	82.783	1969	25.045	24.581	1969	26.599	25.340
1970	0.0	82.085	1970	25.850	25.013	1970	27.538	25.921
1971	82.860	81.882	1971	26.466	25.516	1971	28.560	26.362
1972	0.0	82.092	1972	27.038	25.912	1972	29.457	26.629

TABLE 6, Continued

STATE OF CALIFORNIA --DYNAMIC CONTROL SOLUTION OF THE MODEL - HISTORICAL PERIOD

BEDN	HISTORICAL	SIMULATED
1968	0.0	85.960
1969	0.0	98.418
1970	0.0	102.929
1971	106.754	105.336
1972	0.0	109.153

OHMD	HISTORICAL	SIMULATED
1968	1.414	1.462
1969	1.586	1.612
1970	1.828	1.738
1971	1.861	1.858
1972	1.852	1.946

AHPT	HISTORICAL	SIMULATED
1968	12.239	11.871
1969	12.924	12.470
1970	13.564	13.182
1971	14.259	13.758
1972	14.906	14.381

OPVP	HISTORICAL	SIMULATED
1968	11.020	11.233
1969	12.265	12.018
1970	13.909	12.670
1971	14.322	13.286
1972	14.165	13.704

IR-O	HISTORICAL	SIMULATED
1968	5.259	5.372
1969	5.405	5.837
1970	5.550	6.163
1971	6.220	6.624
1972	6.725	6.847

PNFT	HISTORICAL	SIMULATED
1968	12.129	11.994
1969	12.744	12.235
1970	13.314	12.540
1971	13.937	12.875
1972	14.512	12.855

OPVG	HISTORICAL	SIMULATED
1968	4.791	4.305
1969	4.199	4.619
1970	5.543	4.887
1971	5.252	5.149
1972	5.480	5.371

IRDG	HISTORICAL	SIMULATED
1968	4.329	4.399
1969	4.624	4.761
1970	4.918	5.023
1971	5.227	5.415
1972	5.607	5.648

PNPT	HISTORICAL	SIMULATED
1968	9.150	9.440
1969	9.229	9.836
1970	9.252	10.305
1971	9.291	10.761
1972	9.278	11.134

OPVN	HISTORICAL	SIMULATED
1968	15.811	15.538
1969	16.464	16.637
1970	19.452	17.557
1971	19.574	18.436
1972	19.645	19.074

IRFG	HISTORICAL	SIMULATED
1968	0.251	0.215
1969	0.277	0.260
1970	0.303	0.310
1971	0.321	0.368
1972	0.390	0.414

TABLE 7 Continued

STATE OF CALIFORNIA --DYNAMIC SOLUTION OF THE MODEL--HOSPITAL BEDS RESTRICTION

OCCG

	BASELINE	EXPERIMENT
1973	65.784	65.784
1974	64.580	64.580
1975	63.467	63.467
1976	62.265	62.263
1977	60.825	60.826
1978	58.929	58.929
1979	56.204	56.204
1980	51.925	51.925

P-SS

	BASELINE	EXPERIMENT
1973	346.178	346.178
1974	366.385	366.386
1975	388.320	388.322
1976	411.190	411.191
1977	435.560	435.562
1978	461.274	461.275
1979	488.455	488.457
1980	517.033	517.037

W-AH

	BASELINE	EXPERIMENT
1973	12.120	12.120
1974	12.722	12.722
1975	13.418	13.419
1976	14.119	14.120
1977	14.862	14.863
1978	15.621	15.622
1979	16.408	16.409
1980	17.209	17.211

BEDG

	BASELINE	EXPERIMENT
1973	17.933	17.933
1974	17.130	17.130
1975	16.122	16.122
1976	14.930	14.930
1977	13.560	13.560
1978	12.010	12.010
1979	10.269	10.269
1980	8.329	8.329

#GPP

	BASELINE	EXPERIMENT
1973	6.069	6.069
1974	5.916	5.916
1975	5.746	5.746
1976	5.558	5.558
1977	5.350	5.350
1978	5.124	5.123
1979	4.875	4.875
1980	4.604	4.604

E-NM

	BASELINE	EXPERIMENT
1973	238.370	238.370
1974	257.869	257.884
1975	275.799	275.780
1976	297.106	297.059
1977	317.677	317.607
1978	340.577	340.491
1979	363.682	363.591
1980	388.529	388.421

POSH

	BASELINE	EXPERIMENT
1973	21.138	21.139
1974	21.059	21.060
1975	20.898	20.899
1976	20.703	20.705
1977	20.480	20.482
1978	20.231	20.234
1979	19.951	19.954
1980	19.638	19.642

#MSP

	BASELINE	EXPERIMENT
1973	6.651	6.651
1974	6.948	6.948
1975	7.268	7.268
1976	7.613	7.613
1977	7.983	7.983
1978	8.379	8.379
1979	8.803	8.803
1980	9.255	9.255

F-PN

	BASELINE	EXPERIMENT
1973	18.911	18.911
1974	19.385	19.385
1975	20.311	20.309
1976	21.277	21.276
1977	22.350	22.349
1978	23.486	23.484
1979	24.697	24.695
1980	25.985	25.982

HEDH

	BASELINE	EXPERIMENT
1973	85.285	85.286
1974	84.794	84.796
1975	84.208	84.210
1976	83.526	83.529
1977	82.744	82.749
1978	81.857	81.862
1979	80.852	80.859
1980	79.716	79.724

GPMS

	BASELINE	EXPERIMENT
1973	12.720	12.720
1974	12.864	12.864
1975	13.014	13.014
1976	13.171	13.171
1977	13.333	13.333
1978	13.503	13.503
1979	13.678	13.678
1980	13.859	13.859

W-PN

	BASELINE	EXPERIMENT
1973	8.941	8.941
1974	9.602	9.601
1975	10.364	10.362
1976	11.195	11.194
1977	12.099	12.097
1978	13.087	13.085
1979	14.169	14.167
1980	15.358	15.354

PUNH

	BASELINE	EXPERIMENT
1973	35.431	35.430
1974	37.307	37.307
1975	39.547	39.547
1976	41.928	41.928
1977	44.472	44.472
1978	47.210	47.209
1979	50.172	50.171
1980	53.387	53.386

#SSP

	BASELINE	EXPERIMENT
1973	8.524	8.524
1974	8.907	8.907
1975	9.317	9.316
1976	9.755	9.755
1977	10.222	10.222
1978	10.719	10.719
1979	11.246	11.246
1980	11.804	11.804

RNFT

	BASELINE	EXPERIMENT
1973	39.195	39.195
1974	39.492	39.492
1975	39.171	39.170
1976	39.162	39.162
1977	38.767	38.767
1978	38.401	38.401
1979	37.727	37.728
1980	36.921	36.921

TABLE 7 Continued

STATE OF CALIFORNIA --DYNAMIC SOLUTION OF THE MODEL--HOSPITAL BEDS RESTRICTION

P-NH	BASELINE	EXPERIMENT
1973	18.262	18.251
1974	19.202	19.201
1975	20.184	20.182
1976	21.223	21.221
1977	22.332	22.330
1978	23.508	23.503
1979	24.750	24.753
1980	26.081	26.077

OCCN	BASELINE	EXPERIMENT
1973	83.226	85.226
1974	83.139	83.139
1975	83.463	83.463
1976	83.767	83.766
1977	84.066	84.066
1978	84.363	84.363
1979	84.660	84.660
1980	84.957	84.957

BEDN	BASELINE	EXPERIMENT
1973	116.635	116.635
1974	122.939	122.940
1975	129.817	129.817
1976	137.134	137.133
1977	144.936	144.934
1978	153.316	153.313
1979	162.363	162.360
1980	172.166	172.162

OPVP	BASELINE	EXPERIMENT
1973	14.414	14.414
1974	14.645	14.645
1975	14.842	14.842
1976	15.015	15.015
1977	15.172	15.173
1978	15.322	15.323
1979	15.470	15.471
1980	15.619	15.619

OPVG	BASELINE	EXPERIMENT
1973	5.666	5.666
1974	5.399	5.399
1975	6.139	6.139
1976	6.385	6.385
1977	6.641	6.641
1978	6.907	6.907
1979	7.183	7.183
1980	7.469	7.469

#OSP	BASELINE	EXPERIMENT
1973	6.389	6.389
1974	6.730	6.730
1975	7.068	7.068
1976	7.406	7.406
1977	7.742	7.742
1978	8.078	8.078
1979	8.415	8.415
1980	8.751	8.751

#MDP	BASELINE	EXPERIMENT
1973	27.634	27.634
1974	28.500	28.500
1975	29.399	29.399
1976	30.331	30.331
1977	31.297	31.297
1978	32.300	32.300
1979	33.339	33.339
1980	34.414	34.414

OHMD	BASELINE	EXPERIMENT
1973	2.090	2.090
1974	2.146	2.146
1975	2.198	2.198
1976	2.247	2.247
1977	2.296	2.296
1978	2.346	2.346
1979	2.396	2.396
1980	2.449	2.449

IR-O	BASELINE	EXPERIMENT
1973	7.242	7.242
1974	7.527	7.527
1975	7.783	7.783
1976	8.034	8.034
1977	8.288	8.289
1978	8.551	8.552
1979	8.827	8.828
1980	9.117	9.118

IRDG	BASELINE	EXPERIMENT
1973	6.178	6.178
1974	6.496	6.496
1975	6.807	6.807
1976	7.135	7.136
1977	7.491	7.492
1978	7.884	7.884
1979	8.319	8.319
1980	8.803	8.804

RNPT	BASELINE	EXPERIMENT
1973	31.438	31.438
1974	34.879	34.879
1975	38.077	38.077
1976	41.833	41.832
1977	45.676	45.675
1978	49.991	49.990
1979	54.587	54.585
1980	59.658	59.656

AHFT	BASELINE	EXPERIMENT
1973	26.379	26.379
1974	28.239	28.239
1975	27.515	27.516
1976	28.446	28.446
1977	28.396	28.396
1978	28.946	28.946
1979	29.108	29.108
1980	29.472	29.472

AHPT	BASELINE	EXPERIMENT
1973	13.614	13.614
1974	16.090	16.090
1975	16.399	16.400
1976	18.079	18.080
1977	19.008	19.008
1978	20.511	20.512
1979	21.799	21.800
1980	23.370	23.371

PNFT	BASELINE	EXPERIMENT
1973	13.421	13.421
1974	13.299	13.299
1975	13.635	13.634
1976	14.020	14.019
1977	14.459	14.458
1978	14.898	14.897
1979	15.333	15.332
1980	15.755	15.754

PNPT	BASELINE	EXPERIMENT
1973	10.980	10.980
1974	12.172	12.171
1975	13.352	13.351
1976	14.513	14.512
1977	15.782	15.781
1978	17.176	17.175
1979	18.727	18.726
1980	20.459	20.457

TABLE 7

STATE OF CALIFORNIA --DYNAMIC SOLUTION OF THE MODEL--HOSPITAL BEDS RESTRICTION

PD-P	BASELINE	EXPERIMENT
1973	14.020	14.020
1974	14.361	14.363
1975	14.647	14.651
1976	14.930	14.935
1977	15.219	15.224
1978	15.518	15.524
1979	15.830	15.836
1980	16.155	16.163

P-OP	BASELINE	EXPERIMENT
1973	18.483	18.483
1974	20.937	20.934
1975	23.404	23.397
1976	25.921	25.910
1977	28.512	28.499
1978	31.198	31.183
1979	33.995	33.976
1980	36.915	36.891

INRE	BASELINE	EXPERIMENT
1973	6.592	6.592
1974	6.927	6.927
1975	7.245	7.245
1976	7.567	7.567
1977	7.901	7.901
1978	8.255	8.255
1979	8.633	8.634
1980	9.039	9.040

P-HP	BASELINE	EXPERIMENT
1973	147.022	147.022
1974	161.107	161.072
1975	175.599	175.537
1976	190.614	190.533
1977	206.232	206.139
1978	222.523	222.420
1979	239.561	239.433
1980	257.412	257.235

OPV	BASELINE	EXPERIMENT
1973	26.390	26.390
1974	27.306	27.306
1975	28.225	28.225
1976	29.162	29.163
1977	30.130	30.131
1978	31.141	31.142
1979	32.202	32.203
1980	33.320	33.322

MDHP	BASELINE	EXPERIMENT
1973	8.682	8.682
1974	9.073	9.073
1975	9.443	9.443
1976	9.814	9.815
1977	10.197	10.198
1978	10.600	10.601
1979	11.029	11.030
1980	11.488	11.489

OCCP	BASELINE	EXPERIMENT
1973	65.733	65.983
1974	66.426	66.633
1975	66.761	66.931
1976	67.001	67.138
1977	67.198	67.320
1978	67.382	67.624
1979	67.557	67.975
1980	67.728	68.374

PVGM	BASELINE	EXPERIMENT
1973	85.184	85.184
1974	85.251	85.251
1975	85.228	85.228
1976	85.087	85.087
1977	84.807	84.807
1978	84.383	84.383
1979	83.820	83.820
1980	83.111	83.111

E-RN	BASELINE	EXPERIMENT
1973	54.914	54.914
1974	56.931	56.931
1975	58.209	58.209
1976	60.079	60.078
1977	61.605	61.604
1978	63.396	63.396
1979	65.021	65.020
1980	66.750	66.749

BEOP	BASELINE	EXPERIMENT
1973	58.437	58.216
1974	59.231	59.057
1975	60.109	59.974
1976	61.051	60.947
1977	62.048	61.957
1978	63.097	62.893
1979	64.198	63.828
1980	65.348	64.763

P-GM	BASELINE	EXPERIMENT
1973	10.785	10.785
1974	11.417	11.417
1975	12.104	12.104
1976	12.822	12.822
1977	13.588	13.588
1978	14.395	14.395
1979	15.249	15.249
1980	16.149	16.149

W-RN	BASELINE	EXPERIMENT
1973	11.575	11.575
1974	12.280	12.280
1975	13.067	13.067
1976	13.893	13.892
1977	14.770	14.769
1978	15.693	15.692
1979	16.670	16.669
1980	17.699	17.697

PD-G	BASELINE	EXPERIMENT
1973	4.306	4.306
1974	4.038	4.038
1975	3.735	3.735
1976	3.393	3.393
1977	3.010	3.010
1978	2.583	2.583
1979	2.107	2.107
1980	1.579	1.579

PVSS	BASELINE	EXPERIMENT
1973	41.837	41.837
1974	42.411	42.411
1975	43.017	43.017
1976	43.628	43.628
1977	44.227	44.227
1978	44.812	44.812
1979	45.395	45.395
1980	45.976	45.976

F-AH	BASELINE	EXPERIMENT
1973	33.186	33.186
1974	36.284	36.284
1975	35.715	35.715
1976	37.486	37.486
1977	37.900	37.900
1978	39.201	39.202
1979	40.008	40.008
1980	41.157	41.158

TABLE 7 Continued

STATE OF CALIFORNIA --DYNAMIC SOLUTION OF THE MODEL--HOSPITAL BEDS RESTRICTION

	OPVN			IRFG	
	BASELINE	EXPERIMENT		BASELINE	EXPERIMENT
1973	20.080	20.080	1973	0.414	0.414
1974	20.545	20.545	1974	0.432	0.432
1975	20.981	20.981	1975	0.438	0.438
1976	21.400	21.401	1976	0.431	0.431
1977	21.813	21.814	1977	0.410	0.410
1978	22.229	22.230	1978	0.371	0.371
1979	22.653	22.654	1979	0.314	0.314
1980	23.088	23.090	1980	0.236	0.236

TABLE 8

STATE OF CALIFORNIA --DYNAMIC SOLUTION OF THE MODEL--PHYSICIAN DECREASE

PD-P	BASELINE	EXPERIMENT
1973	14.020	14.021
1974	14.361	14.362
1975	14.647	14.649
1976	14.930	14.932
1977	15.219	15.221
1978	15.518	15.521
1979	15.830	15.833
1980	16.155	16.158

P-HP	BASELINE	EXPERIMENT
1973	147.027	147.015
1974	161.107	161.092
1975	175.599	175.575
1976	190.614	190.581
1977	206.232	206.189
1978	222.523	222.469
1979	239.561	239.496
1980	257.412	257.334

DCCP	BASELINE	EXPERIMENT
1973	65.733	65.735
1974	66.426	66.430
1975	66.761	66.766
1976	67.001	67.106
1977	67.198	67.204
1978	67.382	67.388
1979	67.557	67.564
1980	67.728	67.735

DEDP	BASELINE	EXPERIMENT
1973	58.437	58.437
1974	59.231	59.232
1975	60.109	60.111
1976	61.051	61.054
1977	62.048	62.052
1978	63.097	63.103
1979	64.198	64.205
1980	65.348	35.357

PD-G	BASELINE	EXPERIMENT
1973	4.306	4.306
1974	4.038	4.038
1975	3.735	3.735
1976	3.393	3.393
1977	3.010	3.010
1978	2.583	2.583
1979	2.107	2.107
1980	1.579	1.579

P-OP	BASELINE	EXPERIMENT
1973	18.483	18.483
1974	20.937	20.936
1975	23.404	23.401
1976	25.921	25.916
1977	28.512	28.507
1978	31.198	31.191
1979	33.995	33.986
1980	36.915	36.904

OPV	BASELINE	EXPERIMENT
1973	26.390	26.390
1974	27.306	27.306
1975	28.225	28.225
1976	29.162	29.163
1977	30.130	30.130
1978	31.141	31.141
1979	32.202	32.202
1980	33.320	33.321

PVGM	BASELINE	EXPERIMENT
1973	85.184	85.349
1974	85.251	85.421
1975	85.228	85.402
1976	85.087	85.265
1977	84.807	84.987
1978	84.383	84.568
1979	83.820	84.008
1980	83.111	83.303

P-GM	BASELINE	EXPERIMENT
1973	10.785	10.784
1974	11.417	11.416
1975	12.104	12.103
1976	12.822	12.821
1977	13.588	13.586
1978	14.395	14.393
1979	15.249	15.247
1980	16.149	16.146

PVSS	BASELINE	EXPERIMENT
1973	41.837	41.835
1974	42.411	42.409
1975	43.017	43.014
1976	43.628	43.625
1977	44.227	44.224
1978	44.812	44.809
1979	45.395	45.391
1980	45.976	45.971

INRE	BASELINE	EXPERIMENT
1973	6.592	6.571
1974	6.927	6.906
1975	7.245	7.222
1976	7.567	7.543
1977	7.901	7.877
1978	8.255	8.229
1979	8.633	8.606
1980	9.039	9.010

MDHP	BASELINE	EXPERIMENT
1973	8.682	8.660
1974	9.073	9.051
1975	9.443	9.420
1976	9.814	9.791
1977	10.197	10.172
1978	10.600	10.574
1979	11.029	11.002
1980	11.488	11.459

E-RN	BASELINE	EXPERIMENT
1973	54.914	54.892
1974	56.931	56.923
1975	58.209	58.192
1976	60.079	60.068
1977	61.605	61.590
1978	63.396	63.385
1979	65.021	65.007
1980	66.750	66.738

W-RN	BASELINE	EXPERIMENT
1973	11.575	11.561
1974	12.280	12.263
1975	13.067	13.048
1976	13.893	13.871
1977	14.770	14.746
1978	15.693	15.666
1979	16.670	16.640
1980	17.699	17.665

E-AH	BASELINE	EXPERIMENT
1973	33.186	33.188
1974	36.284	36.285
1975	35.715	35.716
1976	37.486	37.487
1977	37.900	37.901
1978	39.201	39.202
1979	40.008	40.008
1980	41.157	41.158

TABLE 8 Continued

STATE OF CALIFORNIA --DYNAMIC SOLUTION OF THE MODEL--PHYSICIAN DECREASE

	OCCG BASELINE	OCCG EXPERIMENT	P-SS BASELINE	P-SS EXPERIMENT	W-AH BASELINE	W-AH EXPERIMENT
1973	65.784	65.784	346.178	346.153	12.120	12.122
1974	64.580	64.580	366.385	366.355	12.722	12.724
1975	63.467	63.467	388.320	388.284	13.418	13.421
1976	62.265	62.263	411.190	411.150	14.119	14.121
1977	60.825	60.826	435.560	435.514	14.862	14.865
1978	58.929	58.929	461.274	461.221	15.621	15.624
1979	56.204	56.204	488.455	488.395	16.408	16.411
1980	51.925	51.925	517.033	516.964	17.209	17.213

	BEDG BASELINE	BEDG EXPERIMENT	#GPP BASELINE	#GPP EXPERIMENT	E-NM BASELINE	E-NM EXPERIMENT
1973	17.933	17.933	6.069	6.070	238.370	239.345
1974	17.130	17.130	5.916	5.917	257.869	258.968
1975	16.122	16.122	5.746	5.748	275.799	276.936
1976	14.930	14.930	5.558	5.561	297.106	298.369
1977	13.560	13.560	5.350	5.355	317.677	319.017
1978	12.010	12.010	5.124	5.129	340.577	342.052
1979	10.269	10.269	4.875	4.882	363.682	365.265
1980	8.329	8.329	4.604	4.613	388.529	390.259

	PDSH BASELINE	PDSH EXPERIMENT	#MSP BASELINE	#MSP EXPERIMENT	E-PN BASELINE	E-PN EXPERIMENT
1973	21.138	21.139	6.651	6.584	18.911	18.912
1974	21.059	21.060	6.948	6.879	19.385	19.386
1975	20.898	20.899	7.268	7.195	20.311	20.311
1976	20.723	20.725	7.613	7.537	21.277	21.277
1977	20.480	20.482	7.983	7.903	22.350	22.351
1978	20.231	20.234	8.379	8.295	23.486	23.486
1979	19.951	19.954	8.803	8.715	24.697	24.697
1980	19.638	19.642	9.255	9.162	25.985	25.985

	HEDH BASELINE	HEDH EXPERIMENT	GPMS BASELINE	GPMS EXPERIMENT	W-PN BASELINE	W-PN EXPERIMENT
1973	85.285	85.286	12.720	12.654	8.941	8.942
1974	84.794	84.796	12.864	12.796	9.602	9.603
1975	84.208	84.210	13.014	12.943	10.364	10.364
1976	83.526	83.529	13.171	13.098	11.195	11.196
1977	82.744	82.749	13.333	13.258	12.099	12.100
1978	81.857	81.862	13.503	13.424	13.087	13.088
1979	80.852	80.859	13.678	13.597	14.169	14.170
1980	79.716	79.724	13.859	13.775	15.358	15.358

	PUNH BASELINE	PUNH EXPERIMENT	#SSP BASELINE	#SSP EXPERIMENT	RNFT BASELINE	RNFT EXPERIMENT
1973	35.431	35.430	8.524	8.439	39.195	39.181
1974	37.307	37.307	8.907	8.818	39.492	39.491
1975	39.547	39.547	9.317	9.224	39.171	39.165
1976	41.928	41.928	9.755	9.657	39.162	39.164
1977	44.472	44.472	10.222	10.120	38.767	38.769
1978	47.210	47.209	10.719	10.612	38.401	38.408
1979	50.172	50.171	11.246	11.134	37.727	37.737
1980	53.387	53.386	11.804	11.686	36.921	36.937

TABLE 8 Continued

STATE OF CALIFORNIA --DYNAMIC SOLUTION OF THE MODEL--PHYSICIAN DECREASE

	P-NH BASELINE	P-NH EXPERIMENT		#OSP BASELINE	#OSP EXPERIMENT		RNPT BASELINE	RNPT EXPERIMENT
1973	18.262	18.262	1973	6.389	6.325	1973	31.438	31.422
1974	19.202	19.202	1974	6.730	6.663	1974	34.879	34.866
1975	20.184	20.184	1975	7.068	6.997	1975	38.077	38.055
1976	21.223	21.223	1976	7.406	7.332	1976	41.833	41.809
1977	22.332	22.332	1977	7.742	7.665	1977	45.676	45.643
1978	23.506	23.506	1978	8.078	7.997	1978	49.991	49.953
1979	24.756	24.756	1979	8.415	8.331	1979	54.587	54.539
1980	26.081	26.081	1980	8.751	8.663	1980	59.658	59.601

	OCCN BASELINE	OCCN EXPERIMENT		#MDP BASELINE	#MDP EXPERIMENT		AHFT BASELINE	AHFT EXPERIMENT
1973	83.226	83.226	1973	27.634	27.418	1973	26.379	26.380
1974	83.139	83.139	1974	28.500	28.277	1974	28.239	28.239
1975	83.463	83.462	1975	29.399	29.164	1975	27.515	27.516
1976	83.767	83.766	1976	30.331	30.087	1976	28.446	28.447
1977	84.066	84.065	1977	31.297	31.042	1977	28.396	28.396
1978	84.363	84.363	1978	32.300	32.033	1978	28.946	28.946
1979	84.660	84.660	1979	33.339	33.062	1979	29.108	29.108
1980	84.957	84.956	1980	34.414	34.124	1980	29.472	29.472

	BFDN BASELINE	BFDN EXPERIMENT		OHMD BASELINE	OHMD EXPERIMENT		AHPT BASELINE	AHPT EXPERIMENT
1973	116.635	116.635	1973	2.090	2.089	1973	13.614	13.615
1974	122.939	122.939	1974	2.146	2.146	1974	16.090	16.091
1975	129.817	129.811	1975	2.198	2.198	1975	16.399	16.400
1976	137.134	137.124	1976	2.247	2.247	1976	18.079	18.080
1977	144.936	144.925	1977	2.296	2.296	1977	19.008	19.009
1978	153.316	153.303	1978	2.346	2.345	1978	20.511	20.512
1979	162.363	162.350	1979	2.396	2.396	1979	21.799	21.801
1980	172.166	172.151	1980	2.449	2.449	1980	23.370	23.372

	OPVP BASELINE	OPVP EXPERIMENT		IR-O BASELINE	IR-O EXPERIMENT		PNFT BASELINE	PNFT EXPERIMENT
1973	14.414	14.414	1973	7.242	7.242	1973	13.421	13.422
1974	14.645	14.645	1974	7.527	7.527	1974	13.299	13.300
1975	14.842	14.842	1975	7.783	7.783	1975	13.635	13.635
1976	15.015	15.015	1976	8.034	8.034	1976	14.020	14.021
1977	15.172	15.173	1977	8.288	8.288	1977	14.459	14.459
1978	15.322	15.324	1978	8.551	8.552	1978	14.898	14.898
1979	15.470	15.471	1979	8.827	8.827	1979	15.333	15.333
1980	15.619	15.620	1980	9.117	9.118	1980	15.755	15.755

	OPVS BASELINE	OPVS EXPERIMENT		IRDG BASELINE	IRDG EXPERIMENT		PNPT BASELINE	PNPT EXPERIMENT
1973	5.666	5.666	1973	6.178	6.153	1973	10.980	10.980
1974	5.899	5.899	1974	6.496	6.466	1974	12.172	12.172
1975	6.139	6.139	1975	6.807	6.771	1975	13.352	13.352
1976	6.385	6.385	1976	7.135	7.095	1976	14.513	14.514
1977	6.641	6.641	1977	7.491	7.445	1977	15.782	15.783
1978	6.907	6.907	1978	7.884	7.831	1978	17.176	17.176
1979	7.183	7.183	1979	8.319	8.260	1979	18.727	18.727
1980	7.460	7.460	1980	8.803	8.737	1980	20.459	20.460

TABLE 8 Continued

STATE OF CALIFORNIA --DYNAMIC SOLUTION OF THE MODEL--PHYSICIAN DECREASE

	OPVN			IRFG	
	BASELINE	EXPERIMENT		BASELINE	EXPERIMENT
1973	20.080	20.085	1973	0.414	0.418
1974	20.545	20.545	1974	0.432	0.440
1975	20.981	20.981	1975	0.438	0.451
1976	21.400	21.40[illegible]	1976	0.431	0.449
1977	21.813	21.813	1977	0.410	0.431
1978	22.229	22.229	1978	0.371	0.398
1979	22.653	22.653	1979	0.314	0.346
1980	23.088	23.089	1980	0.236	0.273

Comparative Description and Modeling for Organization of Treatment and Preventive Medical Care in The European Region of WHO

D.K. Sokolov

INTRODUCTION

One of the prime tasks set out in the long-term Sixth General Program of Work of WHO is a search for completely new ways of improving the health care system, directly linked with the hygienic living conditions and the economic, demographic, medico-geographic and other factors affecting the lives of the community.

As applied to Europe, factors of this kind may include:

- Scientific and technical progress in industry and agriculture, the international distribution of labor, a highly developed transport and communications network; and the existence of States with differing socio-economic systems and standing at differing levels of development;

- Urbanization and the growth of cities, causing changes in human living conditions, for example, increased psychological stress owing to the growing speed of modern life;

- Changes in the demographic situation and in family living conditions, accelerated physical and mental development of modern man and the relative aging of populations;

- Alterations to the health and way of life of the community, partly displayed in the rising proportion of chronic diseases, in the spread of harmful habits and in the wide utilization of electricity, chemicals and artificial materials; and

- Environmental pollution and changes in certain ecological processes, the opening up of new areas, particularly Arctic areas which had previously remained uninhabited.

Naturally, such matters are bound to affect the state and shape of medical care and the methods of delivering it to the community and of organizing public health.

If we use the forms of motion of matter as the basis for subdividing the fundamental sciences, it is simple to perceive medicine as lying between biology and sociology, namely, mechanics, physics, chemistry, biology, medicine, and sociology. Contrary to what happened in the past, social factors, rather than biological considerations, are now of prime importance in the development of health in general and medicine in particular. The changes taking place in the way in which medical care is organized under the impact of these social factors can be formulated in the following manner:

- The trend towards compartmentalization and the swift development of theoretical and practical medicine, whose organizational system has differing patterns and status at differing stages of development in different European countries (State, insurance, private, etc.);

- The increasing importance of the physician's role in modern society, accompanied, in a number of countries, by a shortage of qualified medical, scientific and auxiliary personnel and by slow training rates;

- The increasing degree of specialization and the rising cost of medical care; the increasing scale on which technology is employed and the growing size of health care institutions; new methods of care and prevention of disease, injury and degenerative processes; the search for, and wide application of, more effective drugs;

- The concentration of medical institutions in urban areas, uneven delivery of treatment and preventive care to various social classes and groups of the community; and

- The multitude of modern health problems such as environmental protection or the control of epidemics that have changing patterns of global distribution.

All these changes can be successfully handled through international cooperation.

One promising form of cooperation is to make a comparative study and model of the organization of preventive care and treatment in different areas of the European Region, taking into account existing economic and geographical, social and hygienic, demographic and other conditions.

To carry out work of this kind, the merit of which was noted by members of the WHO Regional Committee for Europe at their meeting at Algiers in September 1975, it is essential first of all, for the different participants to use a common terminology. This possibility now exists: the WHO Regional Office for Europe issued in 1975, a special Glossary of Health Care Terminology by James Hogarth, which, used in conjunction with the dictionary compiled earlier by V.V. Guzov, provides a good basis for understanding.

Furthermore, over the last few years, the WHO Regional Office for Europe has accumulated considerable documentation about the development of health services in Europe. The study could therefore provide a logical continuation and synthesis of individual uncoordinated projects earlier implemented in the Region:

- The conference on health planning (Bucharest);
- Work on the study and evaluation of health planning methods in different countries of the European Region;
- Group work and courses on operational research and health planning; and
- The study of "health services in Europe".

In the execution of this type of work, it would be rational to use such new methods as:

- Mathematical modeling, operational research, information retrieval;
- Systems analysis, medico-economic accounting methods;
- Futurology, modern planning and evaluation methods; and
- A range of computer techniques.

It is recommended that this work be carried out in conjunction with the International Institute for Applied Systems Analysis, Laxenburg, Austria.

Implementation phases include:

- Collection of (background) information for use in preparing a model (this phase has already been initiated);
- The development of systems analysis plans, algorithms for solution and models (including mathematical models) (first two years); and
- The search for optimum methods of solving the problem (subsequent years).

We understand the study as being primarily concerned with the protection and continuing improvement of the health of every individual and of society as a whole in the light of the concept of health enshrined in the Constitution of WHO as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity".

This type of modeling would permit:

- The development of a multifactorial approach towards solving strategic and practical problems faced by theoretical and practical medicine, which may be utilized by health agencies in any sphere, to select the best of the various options;

- The development of recommendations on ways to improve medical care and to coordinate the implementation of individual programs at the national and international level;

- The synthesis and dissemination of experience acquired by individual countries of the Region in solving actual medical and health problems; and

- The creation of model health systems whose basic components would reflect the structural composition of existing European medical care systems.

As a start, the following principles might be incorporated into the model:

- Community health protection--this is not merely the individual business of the patient and his physician, but is a priority for society and the State as a whole. This principle is based on the Constitution of WHO, where it is stated: "Governments have a responsibility for the health of their peoples which can be fulfilled only by the provision of adequate health and social measures".

- The system must provide the community as far as possible not only with modern and qualified diagnosis and treatment of diseases and conditions but also with a widely based preventive system. It must at the same time promote environmental health. The last named has assumed particular importance in the light of the technical discussion at the twenty-seventh session of the World Health Assembly (1974) on the role of health services in preserving or restoring the full effectiveness of the human environment in the promotion of health.

- Whatever special significance may be attached to individual sectors of a functioning system, the highest degree of success can be achieved only through the strengthening and development of each and every sector, so that the activities of health agencies and establishments are based on a highly developed economy, scientific and material progress, a wide network of medical institutions fully staffed with qualified personnel, that have at their disposal the necessary technology, equipment, instrumentation and supplies and continuous improvement in the public's practice and understanding of healthful behavior.

The future use of modeling will promote the successful implementation of the programs envisaged by the WHO Regional Office for Europe for the period 1978-1983.

In addition to permitting the development of comparative indicators for functioning systems in different countries and a more accurate assessment of current results, it will contribute to a convergence of views on the protection of community health.

The Health System: Boundaries, Supports and Dynamics†

Mark G. Field

In a series of papers written earlier [1-10], I have defined and examined the "health system" from a sociological, macroscopic viewpoint, and have attempted to move forward toward the conceptualization of that system, particularly at the national and at the transnational, comparative level, as an input-throughput-output societal mechanism. The purpose of this paper is to outline briefly the major aspects of the conceptualization so far, to pose a series of questions, and to attempt to see whether or not one can glimpse common traits and features in the health systems of national industrial societies, and perhaps a drift toward a "convergence" both in the nature of the health problems faced and in the type of health systems that are likely to emerge or be devised in such societies. If one can see, and document, the plausibility of such a convergence (convergence defined within broad limits, of course), then nations might be better prepared to plan for their future health services.

A GENERAL SOCIOLOGICAL VIEW OF HEALTH AND ILLNESS

The view that I have espoused in this work is that a critical aspect of any social system or human grouping whatever its size or complexity, is the concept of role, and, particularly, the concept of the performance of socially expected roles on which society depends.

Capacity to perform, (whether it be the performance of physical, mental, or a combination of both, tasks) may thus be seen as *a natural resource* of society.

This "capacity-to-perform" resource, we may call "health". Like any other resource, it is neither inexhaustible nor infinite. Since the capacity to perform social roles is dependent both upon physical *and* mental well-being, it is fully justified to bracket somatic and psychic health as part of the resources of society, and indeed, it is likely that as society becomes increasingly dependent on nonhuman sources of physical power and of simple types of mental activities, mental health, (including

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personal stability and organization), will assume greater importance in the mix of activities aimed at dealing with impairments to the health resource.

There is thus a *societal* aspect to health and illness that transcends the individual, clinical, side. Although it is true that most societies, particularly industrial ones, tend to be more concerned with the impact of ill-health on economic occupational roles than on other roles, failure to perform in *any* sphere may be devastating (the sick mother, for example).

Inasmuch as role performance is a universal phenomenon of social groups, morbidity is also a universal functional phenomenon given the principal and psychological nature of human actors. It is in the response to that universal functional problem that one sees an amazing diversity and range of defensive behaviors and structures. Broadly speaking, such responses can be conceptualized in at least four levels, only the last two of which need concern us here: physiological homeostatic processes, psychological defense mechanisms, cultural and socio-structural responses. The cultural response consists of the definitions and symbolic meanings of ill-health elaborated by the specific group and of the means of attempting to deal with it, whether these be religious, magical, supportive-psychological or technical-medical or most likely, a combination of these.* The sociological-structural response consists of the actual arrangements, the commitments (ideological and political), the resources (human and material) or the "investments" any society or subgroup has earmarked or set aside specifically and formally to deal with the ill-health question. In the aggregate, they constitute the health "sector", "program" or "system" of any society or part thereof (Figure 1).

Generally speaking, the health system consists of two types of internal elements and one external element. The internal elements are the arrangements for the recruitment, training and deployment of personnel (professional and nonprofessional); the other internal element is research or the elaboration of available knowledge and technology for application to illness states. The external element, which we may call here "services", consist of what health personnel and institutions of the health system actually do to deal with ill-health or premature mortality.

These services or practices consist, in the main and in modern society, of the application of six major modalities: prevention, diagnosis, treatment, rehabilitation, custody, and health education. The totality of these services or practices constitute the Gross Medical Product (GMP) of the society. That Gross Medical Product is concerned with the five D's (Death,

*For a more detailed discussion of these responses, see [1].

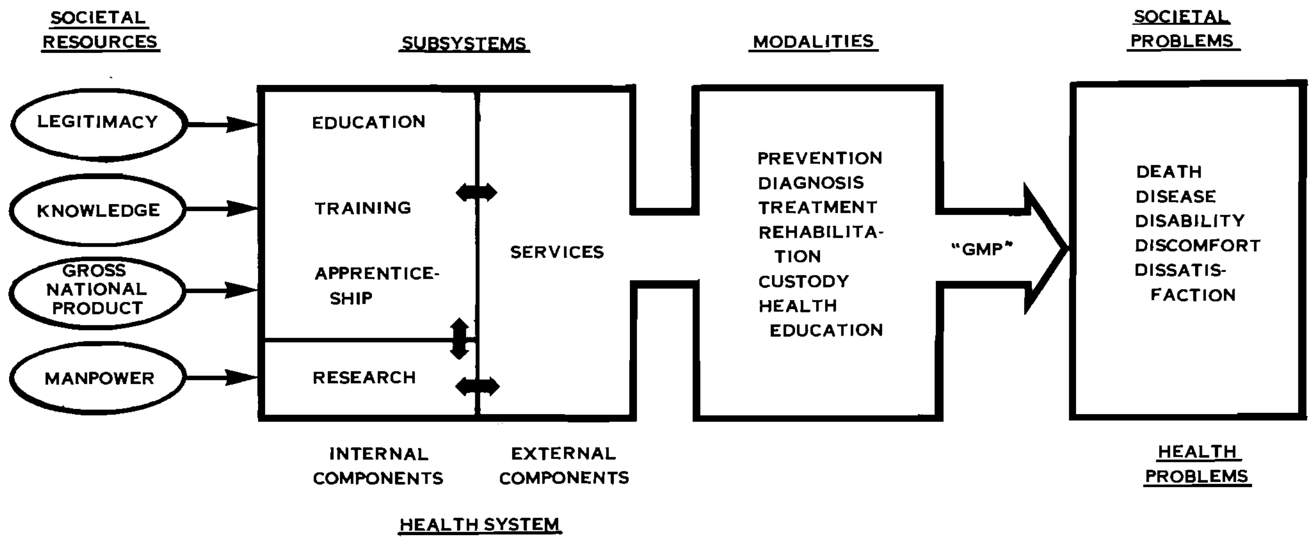

Figure 1. The social system and the health subsystem: problems, modalities, resources.

Disease, Disability, Discomfort and Dissatisfaction) or--and this is quite fundamental--with whatever a society or a group defines as its "health problems". There is indeed a trend in modern society toward the "medicalization" of a series of problems, whether these be mental illness (mentioned earlier), alcoholism, juvenile delinquency and crime and even recently, at least in the United States, hyperactivity among children.

Thus, the very question of the mandate of the health system and the limits of its legitimate responsibilities are moving targets that make analysis difficult and time bound. It goes without saying that an enlargement of the mandate of the health sector through medicalization (as well as possible shrinkages of that mandate, for example, following the decline of the prevalence of tuberculosis or poliomyelitis, or more recently, in the United States at least, the demedicalization of homosexuality) will affect the size of the health system.

BOUNDARIES

Perhaps the following classification for inclusion within the health system might be hazarded, preliminary to a more detailed inventory.

Full

These components are both human and material. At the human level, they include physicians in all categories and specialities, dentists and other professionally qualified personnel concerned with health; health administrators and managers; nurses, midwives, licensed practical nurses, associate and assistant physicians, x-ray technicians, medical dietitians and librarians; and, all those who, though not trained specifically for a health-related occupation, are working in a supportive occupation within the health system and thus directly or indirectly involved in fashioning a "medical product" and thus contributing to the GMP: ambulance drivers, hospital cooks, plumbers, carpenters together with janitors, secretaries, filing clerks, attendants, orderlies, etc. The list is extensive and, indeed, growing, as the health sector increases in size and becomes internally increasingly differentiated. Indeed, in that corpus of personnel just mentioned, physicians and the professionally qualified now constitute only a small, though dominant, minority of about 15 percent of all those in the health system in most industrial societies; and the prognosis is that this figure may shrink even further. In the physical or material category, I would include the medical and allied facilities and the instrumentalities in and by means of which health personnel perform their mandated functions: the hospitals of all categories (long-term or chronic, short-term, intensive care, specialized, mental and so on); the out-patient clinics, polyclinics and screening centers; the private offices of physicians at their homes or in the community;

the whole panoply of medical instruments from the lowly clinical thermometer or stethoscope to the most sophisticated achievements of biomedical technology--transplantation and open heart surgery units. This would also include the prescription items and other pharmaceuticals physicians use in their practices. It should be noted that this is an inclusive category making no distinction between private, voluntary or public institutions or categories of patients or conditions treated.

Partial

These are components that usually *straddle* the health and nonhealth sectors where a judgment must be made as to what proportion of the component is part of the health system. For example, in the United States, the pharmacists working in a hospital would without question be included under the *full* category. But where is the pharmacist to be fitted who either owns or works in a drugstore and who, makes up physicians' prescriptions in addition to selling cigarettes, candy and toiletries? I think that one would have to regard the time spent on the former task as part of the health system; the latter would not be included. What about the social worker? Here again, attribution of time is difficult, since one might argue that every aspect of the client's life has a potential bearing on health. And what of construction industry which builds hospitals, the chemical industry, indispensable for pharmaceuticals, the transportation network without which ambulances would be useless or even agriculture which produces, among other things, the pancreas needed for insulin? In all these cases one might say that a certain proportion should be included under the health system.

Indeterminate

These are the elements that have a *bearing* on health and the functions of the health system, without being unequivocally a part of it; their contribution is so intertwined with other elements that it is difficult to determine its size with any degree of accuracy. Among these, certainly the "environment" plays a central role and, in the eyes of some observers, the determining element in either the etiology and/or treatment of a large variety of conditions. It has been stated recently that about 80 percent of the variance in cancer can be attributed to the nature of the milieu in which the poeple live in industrialized and urban societies and that a "solution" to the problem will have to be found there, rather than in viral research, for example. The environment as a "therapeutic mileau" is, of course, a very old notion, going back to Hippocrates, and is well established in psychiatry. It is, however, a question to what extent of the environment can be said to be part of the health system. Other indeterminate elements are: the level of economic well-being of a population; nutritional sufficiency or insufficiency particularly as it applies to infants and young children whose mental, intellectual and emotional development can be affected by both undernourishment or cultural malnutrition (for example, what happens to young children who spend hours in front of an electronic baby-sitter-television?). Granted that every aspect of society has potentially, an impact of the health of its people, such a view is hardly useful in an analytical and systems approach and in attempting to calculate the size and the types of supports the health system requires to operate.

SUPPORTS

To an important degree, establishing what we mean by the "health system", and delineating its responsibilities, should serve as a guide, within a general framework of cultural values, goals and available resources, to the kinds of structural supports necessary to the maintenance and the functioning of that system.

I have previously delineated what I felt were the four major types of structural supports necessary to maintain a differentiated and identifiable subsystem of society such as the health system. They are summarized below.

The first is *legitimacy* which includes mandate, responsibility, information on health problems, and so on. By legitimacy I mean much more than "legality". It is a term that defines the existence and the activities of a sector of a society and its practitioners as proper. It is not only "proper" for a surgeon to bring cold steel to live flesh, but often mandatory: a surgeon who, in some circumstances, failed to plunge a scalpel into a patient's body might be accused of negligence, whereas anyone outside of medicine might be accused of attempted murder. I think that the legitimacy input is an important one, in view of the fact that in no country yet (I believe) does the entire population accept "scientific medicine" and the scientific medical culture as taught in the medical schools and practiced in the health system as the only one universally and exclusively valid. Given the uncertainty of outcome and the need of patients for emotional comfort and reassurance, scientific medicine often fails to provide the answers.

The closeness of religion and medicine (particularly in the past) does not have to be emphasized; the importance of "magic" even in the most modern health system, and the existence of a variety of competing medical cultures rooted in traditional or folk medicine, as well as the survival in most societies of quacks or charlatans, points to the significance of that input.

The second type is *knowledge* which is sometimes known as the art and science of medicine (or healing). This is essentially a "cultural" resource--i.e., a nonfinite resource, in that once knowledge or technique has been developed, it can be applied over and over again. It is a dynamic and even revolutionary element, particularly the unfolding of scientific medicine over the last hundred years; it is constantly evolving and easily diffused, even across national boundaries, and is dependent on the state of science and of technology in the world at large. Although this input is, as I said, nonfinite in the cultural sense, its availability and its applications involve increasing and seemingly endless investments of personnel efforts and material resources, thereby increasing the "bill" society must pay for its health services.

Manpower is another type of support that is (in theory at least) much easier to quantify than the first two above, and one whose rate of growth and attrition requires constant new inputs in the form of recruits into the various schools that prepare them for careers in health. Such quantification requires first a qualitative listing and differentiating among different types of personnel and secondly a count of each category and subcategory. At any one time, it is thus possible to calculate what percentage of the total labor force, or of the active labor force, is employed by the health system.

The last support, *material resources*, covers the wide range of physical means the health system requires in order to function. Basically, these can be expressed in monetary values and calculated as part of the Gross National Product. In view of the fact that health services tend to be labor intensive, the size of money transfers to personnel is relatively large. In addition, contrary to the usual experience in industry, the introduction of capital equipment in the health field is not necessarily labor saving; in many instances such an introduction leads to an increased labor input. The reasons for the utilization of a great deal of equipment and the cost-benefit calculations in the health field are quite different from industry. It would lead me too far afield to open up here the question of the "rational calculability" of capital investments in the health field, since here I am only concerned with the size and the nature of the flow of material or financial resources into the health system, rather than the gates controlling this flow. All I would like to add here is that there is a "moral" pressure arising from the availability of procedures, techniques, and instruments in the sense that once a new procedure or instrument has been developed it is impossible for the physician to say to a patient, "Medicine knows of no way of helping you." But the application of that new way (for instance renal dialysis) is likely to be very costly and to entail important "opportunity costs".

The structural supports listed are problematic and must be the subject of greater investigation to understand the health system *qua* system and to locate it among other differentiated, but complementary, social subsystems, such as education. It is necessary to examine how the competition among subsystems for the allocation of scarce resources is regulated: is it the result of mutual adjustments, of demand and supply (often supply determines demand), of political adjustments or of conscious planning by a central authority? We must reconstruct not only the amount of available resources, but also the relative priority of the health system in the total social system and finally the *quid pro quo* under which the health system operates in any society, i.e., its efficiency in dealing with the problems it is mandated to cope with.

What is needed is a test of the null hypothesis formulated as follows: suppose that at a given time the entire health system of society A ceases to function altogether.

What would happen?

Fundamentally, there are three possible results:

- The health status of the population is negatively affected;

- Life goes on pretty much as before; and

- The population's state of well-being improves.

The first possibility which is the one on which the existence of the health system is predicated, shows the effectiveness of the health system, by demonstrating the negative consequences when its functions cease. The second possibility would demonstrate the waste of all resources invested in the system, the major function of which would then be described as providing employment for health personnel. The last possibility illustrates the idea that the health system is counter-productive.

It has been reported (apocryphally, no doubt) that mortality went down when doctors struck in Saskachewan and that the health level of the American population actually rose during World War II when a great many physicians were away in the armed forces. One increasingly sees, in the industrialized world, attacks on the health (or the medical) establishment that parallel the anticlericalism of earlier days. Critics (e.g. [11]) portray the health system as a fraud, perpetrated by a self-renewing and self-governing medical elite that is beyond self-evaluation and criticism*, and call for the demystification of medicine, for simple remedies, self-treatment, community treatment and so on. Such criticism has enough validity to raise doubts about assumptions that seemed beyond challenge at an earlier time.

*(Footnote next page.)

Closely allied to this last point is the more complex question of the degree to which a society, or parts of it, deliberately or unknowingly creates madness or illness which it then sets out to treat. It is clear that no simple answer can be given to these questions. However, they serve to remind us of the basic complexity of concepts such as "ill-health", and to the naiveté of imagining that in most instances these states are easily definable and can be solved by the technological fix.

DYNAMICS

As with any other part of the social system, examining the health system is like looking at a slowly moving target. The further we try to see into the future the more our vision is subject to distortion. But perhaps a view of the past helps to make our guesses better informed.

Perhaps the most significant development of the past 100 years has been the industrialization and urbanization which has transformed society and has been accompanied by scientific developments and technological applications in all spheres of life, including medicine. To some degree, this development has been extraordinarily beneficial to the treatment and prevention of a whole series of diseases and has made the protection of health an increasingly effective aspect of the modern world. However, it has also led to a series of problems due to the fact that the worldwide infatuation with technology and the many devices introduced in the care of the sick has somehow deflected medicine from concern with man as a sentient human being and has led to what the Soviets and others have sometimes labelled "veterinary medicine"--and exaggerated emphasis on man as an organ system.

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*In an earlier, traditional type of society, there was a strong belief in an after-life. Access to this after-life was controlled by the priesthood and the church. Martin Luther attacked the Catholic Church, among other things, because it intervened between man and God, and made man's salvation dependent on the intercession of the Church. In the modern secular world, there is a strong belief in only one life and that man passes this way but once. Hence the importance of the medical profession (and the unimportance of the clergy) which claims it can preserve, enhance, and lengthen this "one-opportunity" thing. And the attacks of Illich aim precisely at removing the "medical priesthood", which he claims has "expropriated" health, establishing again a direct relationship between man and his health. As Illich [11] pointed out in a recent public lecture at Boston University, in Spanish the word for health and for salvation is the same (*salud*).

It is symptomatized by the trend toward increasingly narrow specialisms in medicine--what I call the "upper left nostril specialist".

The consequent lack of concern about the patient as a whole person has, in my mind, both emotional *and* technical consequences. There are emotional consequences in the sense of increased estrangement of the patient who already lives in an alienating society, and who expects from the health system, and from the physician particularly, a counter to that trend. This is the result of what might be called the modern "medicine of the absurd"--a Kafkaesque combination of biomedical abundance in the midst of therapeutic poverty. The reawakening interest in general practice and the continued popularity of healers and charlatans who provide an emotional input to the patient are evidence of this problem.

There are technical consequences in the sense that an increased internal differentiation of the health system through an advanced division of medical labor needs a parallel dedifferentiation or generalization if only to integrate the increasingly fractionated and splintered outputs of specialized health personnel.

The second trend is the increased size of the health system compared to other systems in industrial societies: for example, in the United States, the percentage of the GNP invested in health has doubled in the last forty years; health care is probably the largest single employer and expenditures on health are greater than those on defense. The question is: will this continue and, if so, at what opportunity cost?

My impression is that there will be increased questioning about the wisdom of expenditures on the health system, a call for a review of its actual impact on the health of the population, and increasing pressures for it to become more cost-conscious and better organized perhaps through regionalization and a more effective utilization of available human and material resources. This will lead to an increased bureaucratization of health services, with a corresponding decrease in private entrepreneurial medicine.

I foresee that an important issue will be the management of a very complex health establishment. This complexity must be seen both as an extension of specialism and superspecialism (among physicians and nurses particularly) and an increase in the number of levels of personnel working in the health system, leading to the downward transfer of functions to those with lesser qualifications so that the more highly qualified can concentrate on these specific functions they alone are able or are allowed to perform. Such "deskilling" raises a whole host of problems relating to what T.R. Fox calls the "greater medical profession".

Closely linked with this question is the future role of the hospital. In the historical perspective, the hospital has followed the development of large manufacturing plants, in the division of labor and the use of capital equipment that would be uneconomic for single practitioners or even small groups of such practitioners. One can claim economies of scale up to a certain point but beyond this, problems of diminishing returns of over-complexity and bureaucratization begin to affect the way in which large organizations discharge their functions.

Then there is the question of the medicalization of society's social and other problems. I think this issue may be conceptualized in two conflicting views: the first is that the doctor has received an expensive training in the somatic aspects of disease and thus his responsibility should be primarily individual and clinical; he should let someone else worry about other questions and problems.

The other view is that illness cannot be conceived within such a narrow framework which would be like trying to bail an endlessly leaking boat instead of repairing the leaks. The latter view is in line with the traditional thinking of preventive and social medicine, but with a broader concern about society's production of illness and a focus on "health" rather than "sickness". I think this dialogue must be considered an important element of the internal dynamics of the health system.

Any conceptualization of the health system must also take into account the effective demand for health services of all types; it must consider the demographic changes brought about by industrialization and to a large extent by medical achievements (particularly the increasing numbers of old people), and it must reckon with the fact that demand is fuelled by ideological, political and indeed functional considerations. Thus to an important degree, the health system is continually affected by the external dynamics operating in society and in the world at large.

And finally, it seems to me, that an examination of the development of the health systems of several major industrial societies with different backgrounds, histories and cultures, suggests that with time the problems and the solutions that these societies apply and will apply to their health problems tend to increasingly resemble each other; that the options available to them are narrowing; and that in the future these health systems will have more and more elements in common than differences. If this "convergence" hypothesis should prove correct, it might have a predictive value of some usefulness.

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The Concept of Positive Health and the Planning Of Health Care Systems

David Cardus and Robert M. Thrall

The economic loss caused by death is inevitable and unimportant as compared to the economic social burden of disease. This fact has stimulated interest in the analysis and discussion of indicators of "health" as objective means of evaluating the health status of human communities at certain points in time. The concept of health is, indeed, an elusive one, and perhaps for this reason has been frequently banished from practical consideration, but to continue to disregard it might entail undesirable consequences.

ON THE CONCEPT OF HEALTH

Several questions have been raised in attempting to define health. One of them is, "Is it possible to define health?" Another is, "Is it necessary to define it in order to measure it?"

We will set aside the question of whether or not it is possible to define health. The multiple attempts in recent literature to define health [7,8,11,30,40,41] indicate that in this area, as in others, there are optimists and pessimists. We will lay aside the question because the discussion is fundamentally philosophical and this Conference might not seem the proper place to spend time on it. Another, more important, reason for avoiding a precise definition is that the development of measurements of health may not require a definition on which there is total agreement. The difficulties of measuring health may be analogous to the difficulties of defining time. Although time, as an independent entity, has not been defined, this has not prevented the development of multiple procedures for measuring it. The concept of health is probably also a relative one, for which the related dimensions must be discovered.

In fact, health probably can only be defined if it is recognized that there are at least three systems that interact: the psycho-biological system that is man, the physical and biological system that constitute man's natural environment, and the social system that he has created (Figure 1). It is a truism to say that each of these systems is highly complex, but perhaps it is not so generally perceived that man must be considered as a complex system himself and not simply as a component of the natural and social systems. If the simultaneous existence of these three

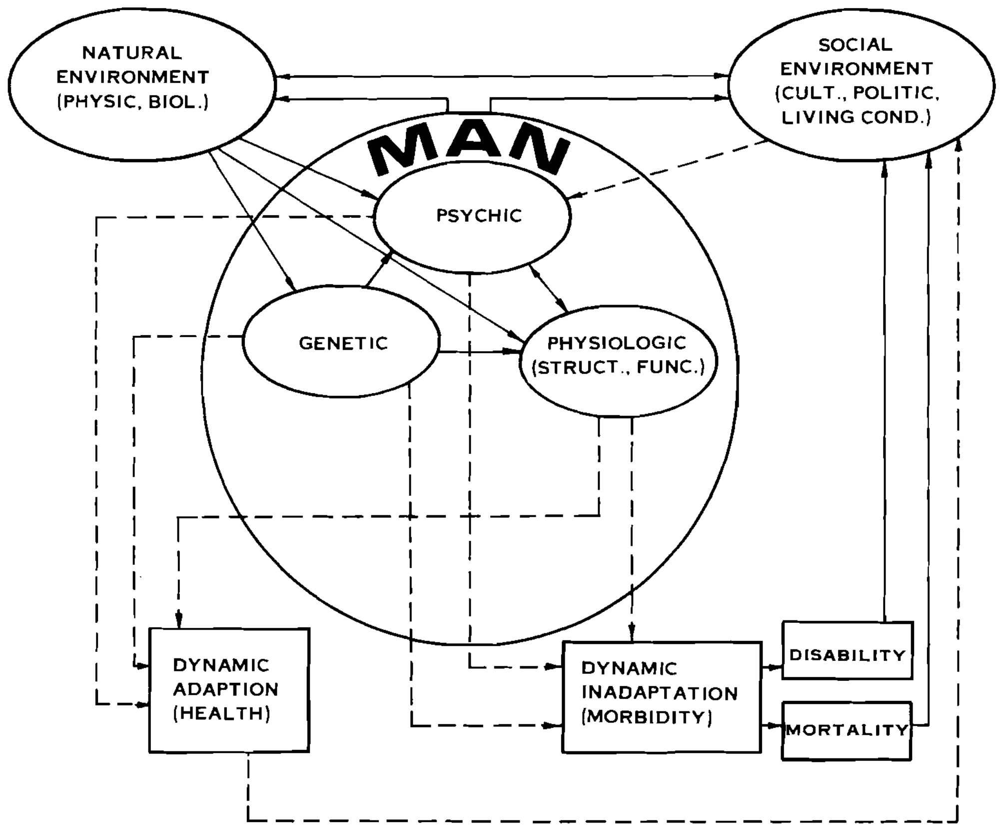

Figure 1. Interacting elements to be considered in developing a concept of health. Relationships indicated by broken lines deserve immediate attention.

systems is recognized, it is possible to define health from three relativistic points of view: from the viewpoint of the physician, who considers man as an organismic system; from the point of view of the ecologist, who considers man as an element of nature; and from the point of view of the administrator, who considers man as a source of needs that must be satisfied by the available resources within his control.

THE MEASUREMENT OF HEALTH

Several investigators in the USA and other countries have tried to construct indices of "health" for the purpose of assessing health status and detecting changes in this status over time. The problem is that these indices relate more to disease than health [19]. The current use of disease indicators or of criteria of health services utilization as measurements of health is tenable only because parameters or indicators of positive health have not been proposed or explicitly defined.

Given the fact that indicators of positive health are not presently available for statistical analysis, several "health" indices, based on disease and its impact upon the individual and society, have been proposed since the late thirties [33]. These indices vary as regards the object of study, the variables selected, the methods of data collection and the computational models used. The object of study is either the individual [9,15,17,24,25], or a population [1,16,22,35], or a health care system [14,20,36]. The variables may be biological, environmental, or data relating to health services or other activities. The methods of information gathering have varied from multipurpose or specific-purpose surveys [15] to the use of medical and behavioral observations [17], patient tracers [14] or actuarial data [1]. The models may consist of simple, intuitive algebraic expressions [22] or more sophisticated, stochastic, probabilistic formulations [5]. Among all of these efforts, there has been only one [2] that has attempted a quantitative approach to the WHO definition of health as the "physical, mental and social well-being (of the individual), not merely the absence of disease or infirmity". Laudable as it is, the prospects of this effort are also limited because, although the three dimensions of health are considered, the variables used are still essentially disease indicators.

Some of the most elaborate models [9] emphasize level of function and prognosis as the two major parameters in the construction of health indices models. The concept of prognosis, as applied to populations rather than to individuals, may be useful to the administrator, but is of much less value to the individual or to the physician who is interested in progressive medical science. From their point of view, prognosis should be based on biological parameters rather than measures of prevalence or incidence. The probability of moving from one state of health or disease to another is fundamentally dependent on individual biological parameters.

Theoreticians [10,23,34] have postulated conditions or criteria that health indices should meet. Some of these criteria are so closely tailored to the present situation that their indiscriminate adoption might inhibit the exploration of new possibilities. The condition that an index of health must be made of measurable components [34] is necessary, but not sufficient. The measurable component must also be as directly as possible related to health. Failure to realize this conceptual thrust encourages the tendency to select indicators on the basis of measurability rather than of strict and positive relationship to health. The deficiencies of mortality rates as indicators of health clearly illustrate that use of surrogate indicators does not reduce the need to continue seeking indicators that have a higher validity in respect to what is to be measured, that is, health. In the mind of many investigators, health and disease are treated as complementary concepts. Even if it could be proven that they are, the totality of health is not known. The same "amount" of disease may have quite different consequences in two individuals depending on the status of health of each individual. Freedom from disease is not equivalent to health. From a methodological standpoint, it will always be a weak philosophical approach to try to define things by what they are not, rather than by what they are.

It has been said [23] that at present the occurrence of illness and premature death are more compelling events in deciding the allocation of resources than the consideration of positive health. This is true, but it can only be accepted as a good argument for policy making if it can be shown that such an attitude is accompanied by a continued rise in health benefits: for example, a reduction in mortality. Now, a recent analysis of mortality rates in the USA [23] indicates that mortality from chronic diseases and accidents is likely to keep the death rate near its present level until major advances are made in the control of death from these two causes. It is difficult to imagine that progress in the control of chronic disease will be achieved except through medical and environmental research. On the other hand, the predictive aspect of any index of health can be improved only if disturbances in function, structure and adaptation that herald disease are identified in man as early as possible.

The weaknesses of indices based on mortality have been pointed out by several investigators in the field and desirable criteria for "health" indicators have been proposed [23,29,34]. Most of the proposed criteria deal with practical considerations relating to the collection and processing of data, to the comprehensibility of the models and interpretation of results and to the adequacy of their utilization in connection with specific purposes. Unfortunately, the criteria for indices of "health" so far proposed do not include any dimension of *health*. This deficiency exists because measurements or indices of *health* can most probably be obtained only from the individual.

Measurement of individual and of social health may require different approaches even though the two are clearly related. If health could be measured for each individual, the assessment of community health would certainly be simplified. The hypothesis that the health of a community should be considered as an "emergent" phenomenon [18], a whole whose properties cannot be predicted by referring merely to the properties of the parts, is one that should be considered. To be accepted, though, this hypothesis will have to be proved and this means that it will be necessary to measure individual health as well as community health.

If, as Figure 1 suggests, the measurement of health must be based on characteristics of the organismic system in relation to the natural and social environments, then the measurement of health requires:

- The identification of the environmental factors which affect health;
- The determination of the range of variation of these factors within which life is possible;
- The study, in quantitative terms, of the physiological, biochemical and psychic responses to changes and rates of change in the environment;
- The study of the adaptability of the individual to the environment, that is, the human capacity to realize physiological, structural and mental adaptive changes to meet stressful changes in the environment.

The conditions in the environment that are necessary for the existence of life (presence of oxygen, carbon dioxide, solar radiation, moderate temperature and water) must, of course, be satisfied. Moreover, higher forms of life tolerate narrower variations of physical factors than lower forms of life. The physical factors which affect human health, including temperature, light, noise, vibration, acceleration, atmospheric pollution by gases and particles, water pollution and radiation, must therefore be considered. To these physical factors one must add biological factors in the form of micro-organisms or nutrients and the psycho-social factors that are making an increasing impact on each person's life.

Thus, as far as man, the organismic system, is concerned, the dimensions of health are structural, physiological, biochemical and psychic.

An up-to-date concept of health should be based on the study of human performance in response to a variety of physical and nonphysical factors. Total human performance can be described in terms of:

- The capacity to perform certain functions;
- The optimality with which these functions can be performed, considering the state of the organism;
- The adaptability of the organism to environmental changes.

Thus, from the standpoint of capacity, man can be characterized by a profile of his abilities and inabilities, by his capacity for physical work, by his functional reserves and by his responses to physical and psycho-social stimuli. From the standpoint of optimality, man can be characterized by the efficiency with which he is able to fulfill physiological and psychological functions, by modalities of functional regulation, by development of functional hierarchies and by the mechanisms of adjustment to the environment [3,4,32]. From the standpoint of adaptability, man can be described in terms of his potential to learn new things, to overcome physical incapacity and to adapt himself to the ever-expanding world in which he lives.

Structural integrity is normally associated with good health, but lack of structural integrity does not necessarily imply disease. One of the most encouraging efforts in present clinical research is the application of scientific knowledge and modern technology to overcome disability in spite of structural and functional deficiencies.

Physiological performance is, indeed, a major indicator of health. Studies of functional capacity at the motor, sensorial and psychic levels are possible today with satisfactory testing procedures. The periodic administration of these testing procedures is proving of value in providing an objective description of the process of aging. One of the most obvious manifestations of aging is the decline in the ability to exercise and work. Since the rate of deterioration in the process of aging differs from one individual to another [26,31], measurements of the rate of deterioration in relation to age could be correlated to the prevalence and incidence of disease and thus be validated as possible measures of health and as predictors of morbidity.

Exercise testing is a good means of evaluating the total cardiorespiratory fitness of an individual [31]. Other quantitative tests, facilitated greatly by modern technology, are available for assessing muscular strength, range of articular motion, nerve conduction velocity, hepatic and renal function, vision acuity and hearing ability.

Adaptation to short and prolonged changes in the environment constitute another parameter of health. Progress in procedures to test the adaptability of the various organ systems of the body has not been equally rapid for every system or organ but tests are available for many of them. The medical requirements created by man's exploration of space have been a great incentive to the development of such new testing techniques.

From a biochemical standpoint, it has been amply documented that, as far as the biochemical parameters used in clinical evaluation are concerned, there is a high degree of uniqueness in each individual [38]. Much is then to be gained in developing a methodology for the determination of human health that compares the individual with himself rather than with a usually undefined population. It should be recognized once and for all that normalcy and health are not equivalent concepts. Normalcy is a statistical concept, whereas health is a biological one. In terms of health, to compare an individual with a population norm is practically meaningless, since, for the parameter considered, the intraindividual and interindividual variations over time are both relatively large. It has been suggested that for each individual the range of values of any blood constituent established during a period of optimum health is a better criterion than the statistical values obtained in population samples [39].

In the dimension of mental health, it has been suggested [12] that indicators of positive mental health should be sought:

- In the attitudes of an individual toward his own self;
- In what a person does with his self over a period of time;
- In a central synthesizing psychological function recognizable in each person;
- In the individual's degree of independence from social influences;
- In the adequacy of an individual's perception of reality;
- In the individual's capacity for environmental mastery.

The extent to which these indicators can be used to formulate expressions of mental health that can be quantitated according to an appropriate scale is not clear at this time. On the other hand, the two-way relationship of mental processes to somatic function is an open field for investigation, although some of its aspects are presently attracting the attention of able investigators [6,13].

It has long been surmised that genetic endowment is a major determinant of health. The relationship between the genetic make-up and certain diseases is not in doubt; but we are just beginning to understand the basic nature of this relationship. Although it is only logical to assume that if genetic factors relate to disease, they must also relate to health, we have not yet reached the point where genetic indicators of positive health have been identified. An investigation of such genetic factors and of their interaction with the physical and psycho-social environments is a major and promising task in health research.

An interesting step toward using biological parameters and other risk factors to predict disease has been made at the Preventive Medicine Institute--Strang Clinic of New York [21] and as a result of the Heart Disease Epidemiological Study conducted in Framingham, Massachusetts, USA. The Framingham study resulted in a collection of data that permitted the calculation of the probability of developing coronary heart disease in six years in relation to seven risk factors: sex, age, cigarette smoking, arterial blood pressure, serum cholesterol, glucose tolerance and electrocardiographic abnormalities.

IMPLICATIONS FOR HEALTH SYSTEMS PLANNING

A system is usually conceived as an aggregate of subjects or components linked by some form of interaction so as to perform a specific function. The application of this definition to a health care system requires the description of:

- The functions of the system;
- The components of the system;
- The interaction among components.

The functions of a health care system were amply reviewed in the first IIASA Conference of 1974 [37]. These are:

- Medical research and accumulation of medical knowledge;
- Comprehensive individual and community measures for prevention of disease, with special emphasis on infant and child care and environmental health;
- Timely diagnosis of diseases and their adequate treatment and cure.

It should be recognized that not all the health care systems that exist or are being planned are capable of fulfilling all these functions [27]. On the other hand, not all the functions that a health care system should fulfill are mentioned above. If it is admitted that health can be improved, as it is readily admitted that it can be impaired, that disease can be resisted and that the process of natural biological deterioration has a different tempo for differnt individuals and perhaps can be retarded, then the promotion and restoration of health, the early detection and prevention of disease and the rehabilitation of the physically and sociogenically disabled must be part of the functions to be fulfilled by a health care system. In particular, studies aimed at the identification of determinants of positive health should be part of the research goals of health care systems. The identification of determinants of positive health should provide the basis for a predictive medicine. Predictive medicine must be conceived as the measuring stick against which the effectiveness of preventive measures can be assessed. It is widely recognized that one of the major goals of a health care system is the prevention of disease. The promotion of health should also be added. It is, therefore, of paramount importance that, in planning health care systems, the concept of positive health not be overlooked.

The interest in applying systems theory to the organization and operation of health delivery systems is that, if the objectives, components and relations among the components are known, then the theory that has been developed in connection with systems should be useful in the regulation and evaluation of any health system in relation to its goals. It should be realized, though, that health systems deal with living components and that the characteristic of living components is that they are adaptive. It is, therefore, important that a health system be conceived as a system that will have the ability to adapt dynamically to changes in man and in the natural and social systems. The theory of systems analysis has not been particularly developed in the direction of adaptability so that it can be readily applied to health systems. In applying systems theory principles to health systems, it may well become necessary to expand the underlying theory so that the adaptive characteristics of health systems can be properly incorporated.

The planning of future health systems should include the positive health approach. Additional objectives to be included in a health system that takes into consideration the concept of positive health are:

- The quantification of individual (biological and mental) parameters that describe the process of aging;

- The identification of individual and natural and social environmental factors associated with low morbidity, longevity and causes of mortality;

- The construction of a model of health that includes individual and environmental parameters such that it can be used for the determination of health status in the individual and in populations.

Thus, as a first step in this direction, research should be conducted to identify parameters of health in man and in the natural and social systems. Then, a selection of suitable parameters should be made, due consideration being given to how essential they are for describing health and how easy they are to measure in physical and economical terms. Next, provisions should be made to monitor these parameters in at least a few health systems strategically located at the national level and throughout the world. Finally, procedures should be developed that would allow these parameters to be entered into the information systems [28] that support each of the collaborative health systems participating in a joint effort organized according to a commonly agreed experimental design.

The move toward a philosophy of health systems delivery which incorporates the concept of positive health is timely, not only because it is a realistic need that draws support from present trends in medical research, but also because chronic disease and poor health are being perceived as two major factors of morbidity and are becoming the building blocks of social demand for progressive public health action.

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Benefit-Cost Modeling in the Presence of Multiple Decision Criteria†

Robert M. Thrall and David Cardus

INTRODUCTION

The purpose of this paper is to consider the role of benefit-cost modeling for health care and, in particular, to see how such modeling can contribute to the dynamic approach outlined by Dr. Kiselev [1]. The paper presents a brief discussion of the Kiselev approach to the micro-, intermediate and macro-levels of modeling. A hypothetical micro-level problem is introduced and further elaborated on. A general benefit-cost model for health care programs is developed, and lastly, a brief status summary is given.

In our discussion of benefit-cost decision making in the presence of multiple objectives and goals, five main stages are considered: identification of objectives, measurement of levels of achievement of each objective, scaling of each objective in a multidimensional value space, determination of relative weights for several value dimensions by relevant classes of evaluators, and synthesis of the outputs of the earlier stages by the responsible decision maker. It seems worthwhile to obtain general agreement among all evaluators in the first three stages, but this should not be expected at the fourth stage nor should one expect the model to prescribe to the decision maker the value judgments inherent in his final synthesis. Indeed, failure to recognize this significant feature of benefit-cost modeling has resulted in rejection of many otherwise promising models.

The model developed in this paper is linear. The authors are fully aware that there are significant nonlinearities in the real-world situations being modeled, and regard the present linear model as a first step toward the development of more realistic nonlinear models. Moreover, the linear case is sufficiently rich to justify consideration on its own and its analytic simplicity should enhance understanding by those who might be unwilling to attempt understanding or who use more general and complex models.

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†This paper is an extension of an earlier one: R.M., Thrall, Benefit/Cost Estimation, Alternatives, Requirements, Advantages, and Disadvantages, forthcoming in the *Proceedings of the SAMS 1975 Annual Meeting*.

MACRO-, INTERMEDIATE AND MICRO-MODELS

In a recent paper, *A Systems Approach to Health Care* [1], Dr. A. Kiselev has proposed a strategy for tackling this "complex dynamic object". In this introductory paper, he suggests the application to health of some of the dynamic modeling principles that Forrester [2] and his school have brought into prominence in other problem areas, e.g. industrial, urban and world-dynamics. (References [3,4,5] provide an instructive review and defense of industrial dynamics.)

The Forrester models share with macro-economic models the characteristic of selecting a few important variables and attempting to set up viable relationships among them which can be used to forecast system behavior.

One of the weaknesses of macro-models is their inability to deal effectively with major changes in policy, e.g. in environmental conditions, in technology, or in other important factors. For example, in the USA, the effects of the recent quadrupling of the price of petroleum seems to have stretched macro-models of the national economy beyond their ranges of validity.

One way to maintain some meaning at the macro-level is to set up a hierarchy of models--micro, intermediate and macro. In the petroleum example, one starts with micro-models at the individual factory level to find what adjustments in its production processes will optimize operations under the new petroleum prices. Then one passes to intermediate level input-output models whose coefficients can be adjusted using information gleaned from the micro-models. Next, the intermediate level models can be employed to simulate the entire national economy, and finally, outputs from the intermediate model can be aggregated and fed into macro-models to yield predictions in terms of relatively few, but generally well recognized and important variables.

One of the strengths of the Kiselev approach is that he realizes the necessity of, and provides for, intermediate level modeling (itself embodying dynamic features). His three figures [1] provide a useful display of health care indices and important interrelations among them.

It is not clear, however, from his introductory paper just what role he has assigned to the micro-level of modeling. A health care measure will generally depend for its success on its effects on individual patients, physicians, health facility managers, and the "paymasters" (e.g., government agencies, insurance companies or private donors).

The authors have recently witnessed one phase of a massive medical program face failure, not because of any internal flaws, but because it had not taken into account the fact that the position of Mexican-American males in their own social structure reduced their (voluntary) participation in the program far below the level essential for its functioning. It is true that this particular example is associated with the mode of operation of health care in the USA. Can we be certain, however, that micro-level phenomena will not be significant in any health care system? Are such factors likely to be accounted for at any level above the micro-model and can we accept a methodology which does not provide for their identification?

EXAMPLE OF A MULTI-OBJECTIVE PROBLEM

Measures of benefits and costs are clearly important at all levels of modeling. Let us focus on their role at the micro-level. Consider a hypothetical rehabilitation program. Its objectives might include:

- Patient-Centered:
  - Restoration of earning power;
  - Relief of pain;
  - General enhancement of the quality of life;
  - Increased capacity for self care.
- Physician-Centered:
  - Increased scientific understanding of the basic medical problem;
  - Improvement in methods of treatment.
- Facility-Centered:
  - Enhanced cost-effective handling of in-patient care;
  - Enhanced cost-effective handling of out-patient care.

It would not be difficult to find additional relevant objectives, but this list is already long enough to illustrate that, even at the micro-level, we are dealing with a vector valued objective function. We will return to this example as we develop a general framework for evaluation.

BENEFIT-COST MODELING

The use of benefit-cost analysis as an aid to decision making has been considered in many areas. There are several good reasons why its actual use has not been more widespread. Major among the reasons is the difficulty of devising generally acceptable models for measuring benefits and costs [6]. This difficulty is compounded by the presence of multiple criteria, e.g., economic, social, political.

In the health care area, both the objectives and the decision criteria seem especially diverse. Moreover, measurement for any single criterion is far from simple. For example, a few years ago in the United States, Department of Health, Education and Welfare instructions were to measure only direct economic benefits and costs where "direct" was interpreted to mean "related to the national budget". When applied to rehabilitation these instructions were far from clear since they required comparing near-term costs for rehabilitation with long term savings in custodial care. Now, although some of the near-term costs can be rather well calculated, the long term phenomena are stochastic with little known distributions so that even calculation of expected economic benefits and costs is not clear cut.

Even if one could obtain generally accepted measures for each of the criteria, there would remain substantial differences among decision makers as to the relative weights to be allocated to economic, social and political benefits.

If we return to the rehabilitation example, we note that the patient benefits are cumulative over individuals whereas the physician-centered benefits are not.

We may also note that restoration of earning power is an economic benefit, whereas the other three patient-centered benefits are either noneconomic or only partly economic. An important key to handling this distinction is to measure each objective on its own specially constructed scale and defer any comparison between scales till a later stage of the modeling.

Consider restoration of earning power over a subject population S of N individuals $s_1, \ldots, s_N$. If the restoration for individual s_i has economic value $e(s_i)$ then the benefit over the entire population is

$$e(S) = e(s_1) + \ldots + e(s_N) \quad . \tag{1}$$

Similarly, relief of pain and enhanced quality of life could have respective measures

$$r(S) = r(s_1) + \ldots + r(s_N) \tag{2}$$

and

$$q(S) = q(s_1) + \ldots + q(s_N) \quad , \tag{3}$$

which might even have a common unit of measure, clearly not the same one as for $e(S)$.

Increased capacity for self-care would have both economic and social benefits and so would be measured by a vector valued function

$$sc(S) = sc(s_1) + \ldots + sc(s_N) = \begin{bmatrix} sc_1(S) \\ sc_2(S) \end{bmatrix} \tag{4}$$

with $sc_1(S)$ measured on the same scale as $e(S)$ and $sc_2(S)$ on the same one as $r(S)$ and $q(S)$.

There is an important special case where the functions e, r, q, sc_1, sc_2 are constant for all members of S. Then $e(S) = Ne(s_1)$, etc., and the total patient benefit for the population S would be given by the 2-component vector

$$B_{pa}(S) = N \begin{bmatrix} e(s_1) + sc_1(s_1) \\ r(s_1) + q(s_1) + sc_2(s_1) \end{bmatrix} = \begin{bmatrix} B^1_{pa}(S) \\ B^2_{pa}(S) \end{bmatrix} . \tag{5}$$

The physician-centered benefits might be measured on another scale and have the value

$$B_{ph} \tag{6}$$

which is independent of the size N of the patient population S.

The facility-centered benefits might be described by a sum of the form

$$B_{fa} = NB^1_{fa} + B^2_{fa} \tag{7}$$

where B^1_{fa} represents the facility savings per patient and B^2_{fa} represents possible capital savings, both measured in the economic unit already used for earning power.

In this miniature example we have a three-component vector

$$B = \begin{bmatrix} B_1 \\ B_2 \\ B_3 \end{bmatrix} = \begin{bmatrix} N(e(s_1) + sc_1(s_1) + B_{fa}^1) + B_{fa}^2 \\ N(r(s_1) + q(s_1) + sc_2(s_1)) \\ B_{ph} \end{bmatrix} \tag{8}$$

which measures various benefit attributes. Continuing to assume linearity, a total benefit V(B) will take the form

$$V(B) = w_1B_1 + w_2B_2 + w_3B_3 = W^TB \tag{9}$$

where $W = \begin{bmatrix} w_1 \\ w_2 \\ w_3 \end{bmatrix}$ is a *weight* vector determined by the

decison maker concerned. For example, a patient might select

$$W_{pa} = \begin{bmatrix} 3 \\ 7 \\ 2 \end{bmatrix}, \tag{10}$$

a physician,

$$W_{ph} = \begin{bmatrix} 3 \\ \cdot 3 \\ 6 \end{bmatrix} \tag{11}$$

and a health administrator

$$W_{ad} = \begin{bmatrix} 7 \\ 3 \\ 2 \end{bmatrix}. \tag{12}$$

If not one, but two rehabilitation programs (I and II) are being evaluated, these variations in the weight vectors could result in disagreements as to which program (I or II) was better even though one were able to obtain agreement among all concerned on the respective attribute vectors B(I) and B(II).

A GENERAL BENEFIT-COST MODEL

We now turn to the construction of a general benefit-cost model for health care programs. This model builds on concepts discussed in the preceding section but is written in abstract form so that it can be broadly applied.

We realize that few natural phenomena are truly linear, but choose to assume linearity in this paper since:

- Nonlinear functions frequently have good linear approximations;
- Development of a nonlinear model requires far greater abstraction and thus makes communication between model builder and reader more difficult; and
- Construction of a linear model initially will not preclude (and might even aid in) development of nonlinear models later on.

Consider a health care program HC which is designed with a set

$$0_1,\ldots,0_p \tag{13}$$

of *benefit factors* or *objectives* of which the first p_1

$$0_1,\ldots,0_{p_1} \tag{14}$$

are individual or *direct* benefit factors and the remaining $p_2 = p - p_1$

$$0_{p_1+1},\ldots,0_p \tag{15}$$

are *indirect* benefit factors. We suppose that the *target population* S consists of N individuals

$$S = (s_1,\ldots,s_N) \quad . \tag{16}$$

By definition, individual benefit factors are cumulative over the entire target population, whereas the indirect benefit factors (e.g., advances in understanding of some category of disease or illness) are independent of the size of S.

We assume that benefits of each objective can be assessed by a vector whose components quantitize effects on a set of measurement *categories*. For example

$$M_1,\ldots,M_q \tag{17}$$

of which the first q_1,

$$M_1,\ldots,M_{q_1}, \tag{18}$$

represent benefits (economic, political, social, scientific, etc.) and of which the remaining $q_2 = q - q_1$;

$$M_{q_1}+1,\ldots,M_q \tag{19}$$

represents costs (also economic and political).

Let m_{ij} measure the effect of one unit of objective j in the ith category measurement scale. For $i \leqq q_1$, $m_{ij} \geqq 0$ and for $i > q_1$, $m_{ij} \leqq 0$.

Next, let

$$y_j = \begin{bmatrix} y_{1j} \\ \vdots \\ y_{p_1 j} \end{bmatrix} \qquad (j - 1,\ldots,N) \tag{20}$$

where for each $i(= 1,\ldots,p_1)$, y_{ij} represents the amount of objective i conferred on individual j under the health care program HC.

Then, because of our linearity assumption we can measure the contribution of HC to the subject population via *direct* benefits as

$$Y_{DIR} = \begin{bmatrix} y_1 \\ \vdots \\ y_{p_1} \end{bmatrix} \tag{21}$$

where

$$y_i = y_{i_1} + \ldots + y_{iN} \qquad (i = 1,\ldots,p_1) \ . \tag{22}$$

Let the vector

$$Y_{IND} = \begin{bmatrix} y_{p_1+1} \\ \vdots \\ y_p \end{bmatrix} \tag{23}$$

measure the contribution of HC to the indirect benefits; then the p-vector

$$Y = \begin{bmatrix} Y_{DIR} \\ Y_{IND} \end{bmatrix} = \begin{bmatrix} y_1 \\ \vdots \\ y_p \end{bmatrix} \tag{24}$$

measures the extent to which each of the p-objectives has been achieved by HC.

Now, let

$$D = \begin{bmatrix} d_1 \\ \vdots \\ d_q \end{bmatrix} \tag{25}$$

represent the total measure of HC (through all of its objectives) on the q measurement categories. Then, again relying on our linearity assumption, we see that

$D = MY$, or, equivalently

$$d_i = \sum_{j=1}^{p} m_{ij} Y_j \quad . \tag{26}$$

EVALUATORS AND WEIGHTS

The vector D measures the effects of the health care program HC in terms of q different categories which to this point have not been given comparative values. Indeed, the possibilities and the propriety of comparing these different categories (for example, life versus money) have both been questioned by many thoughtful persons interested in health care.

However, decisions are made every day from which we can deduce such comparisons (to a degree of precision which increases with the number of observable decisions). This concept of "inverse valuation" is an important contribution of systems analysis methodology.

Inverse valuation is far more reliable when applied to actions of a single decision maker or evaluator than at a group level (regional, national, international).

Consider, a collection of r evaluators,

$$E_1, \ldots, E_r \tag{27}$$

each of whom has his own *weight vector*

$$W_k = \begin{bmatrix} w_{1k} \\ \vdots \\ w_{qk} \end{bmatrix} \tag{28}$$

and corresponding over-all scalar valuation

$$V_k = W_k^T D = w_{1k}d_1 + \ldots + w_{qk}d_q \tag{29}$$

for HC. The r-vector

$$V = \begin{bmatrix} V_1 \\ \vdots \\ V_r \end{bmatrix} = W^T D \qquad (\text{where } W = [W_1, \ldots, W_r]) \tag{30}$$

contains all of the evaluators' scalar valuations of HC.

It seems to us unreasonable to expect the evaluators to agree on a common weight and we consider this feature of our model is a key one.

There is a substantial methodology related to social choice algorithms [see, for example, 7]. One of the simpler ones that could be considered here is somehow to select a vector Z of *societal weights* $z_1, \ldots, z_r$ for the r evaluators, then

$$BE = BE(HC) = Z^T V = z_1 V_1 + \ldots z_r V_r = Z^T W^T MY \tag{31}$$

gives a societal net benefit in terms of a single scalar measure.

We have no easy method to propose for the selection of the vector Z. We would presume that its selection would be the object of negotiations between the evaluators. This negotiation might be expressible in game theoretic terms.

In many contexts, selection of the vector Z is regarded as a management prerogative. If a decision maker is responsible for the consequences of his decision, he may insist on determining his own weights, even though a wise manager may feel it important to consider the views of those impacted by his decision.

We review the five main stages of the model construction:

- Stage One. Identification of objectives: see $0_1,\ldots,0_p$, Equations (13), (14), and (15).
- Stage Two. Measurement of levels of achievement of each objective: see the y_{ij} and y_j, Equations (20) - (24).
- Stage Three. Scaling of each objective in a multidimensional value space: see $M_1,\ldots,M_q$ and D, Equations (17), (18), (19), (25), and (26).
- Stage Four. Determination of relative weights for the several value dimensions by relevant classes of evaluators: see w_{jk} and V_k, Equations (27) - (30).
- Stage Five. Synthesis of the outputs of the earlier stages by the responsible decision maker: see Z, Equation (31).

MEASUREMENT IN BENEFIT-COST MODELS

The most universal and primitive level of measurement is the *nominal* one [see 8 p. 28]. This level is encountered here in identifying the benefit factors and the measurement categories. For the calculations in Stage Four, the model parameters m_{ij}, y_{ij}, y_i, w_{ij}, and z_j must be measured as real numbers; since all these have a natural zero point, they all require *ratio scales* [see 8 p. 34, and 9]. However, ratio scales are not always readily available and one may have to be content initially with a *simple order scale* and then use decision theory methods to strengthen the scale.

A benefit-cost model has been developed by the authors [6]. An application of this methodology to research project selection, sponsored by the Social and Rehabilitation Service (SRS), was carried out at the Texas Institute of Rehabilitation and Research by an interdisciplinary team led by Dr. William A. Spencer. This team issued 12 (working paper) reports in 1973 under the acronym AARPS (Analytic Aid for Research Project Selection). The central benefit-cost model is described by Thrall and Cardus [6]. The benefit term has the form

$$B = P_S(P_U NB_I + B_S) + B_F \tag{32}$$

where

P_S = Probability of success,

P_U = Probability of utilization if successful,

N = Number of individuals in the target population,

B_I = Expected benefit per individual (or unit) impacted if successful,

B_S = Indirect benefits if successful,

B_F = Benefits of funding research whether or not it is successful.

Each of these six terms requires its own analysis. One feature of the analysis was a Delphi study which identified 23 components for B_I and another 23 components for B_S. A change of administration in SRS resulted in a new philosophy of R&D management under which the AARPS benefit model was not used. However, the 46 benefit components have been incorporated into the SRS proposal structure.

Baker and Freeland [10] have surveyed the status of benefit measurement and project selection methods, and Haimes and Hall [7] have developed a methodology for handling multiobjectives that they then applied to water resource systems analysis. One can obtain some appreciation for the breadth and extent of studies in benefit measurement by noting that none of Baker-Freeland's 49 references is included in the 36 listed in Haimes-Hall. We can expect some convergence of the several independent approaches as they are presented at professional meetings and as more applications are reported.

Since much of the measurement required for benefit-cost analyses is necessarily "soft", it may be useful to cite Raiffa's *Decision Analysis* [11] and a recent review by Linstone and Turoff [12] of the Delphi Method.

CONCLUSION

We have presented here a point of view which outlines an approach to benefit-cost analysis in the presence of multiple objectives and with a multiplicity of decision maker evaluators. What we have done represents only the first steps on a long trail that will need to be traversed before a definitive model is obtained. However, we believe that each step along this trail will provide useful insights. Each of the vectors and matrices in the model presents a research problem, and qualitative identification of the components should be of substantial use to planners.

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Strategic Modeling for Health Care Managers

Edward B. Roberts and Gary B. Hirsch

The complexity of today's health care environment requires more comprehensive tools to help managers establish suitable organizational goals, develop new programs and design overall policies and the plans needed to achieve them. Many health and social service programs fail because of flaws in their design that are quite obvious when viewed in retrospect. Others are able to remian in operation, but never really become effective at delivering the urgently needed services they were designed to provide. Outright failure or prolonged ineffectiveness is usually the result of a failure on the part of planners and administrators to consider all the factors impinging on program effectiveness.

During the past seven years, the strategic modeling methods developed initially for industrial organizations have been effectively adapted to the needs of health executives. These tools, based on practical applications of theories and computer techniques created at the MIT Sloan School of Management [1], allow simultaneous consideration of the complex set of factors that determine whether a health program will succeed or fail. Once an adequate strategic model incorporating these factors has been assembled, it can be used to help make decisions concerning program design, resource allocation and the choice of program policies. Models can also be used to assess (before any resources have actually been committed to it) the impact a health program will have on its socio-medical environment and the effect that changes in this environment will have on the program. Even before a program has been conceived, strategic models permit planners to study health problems and find the leverage points, i.e., where the investment of health care resources will bring the greatest return. The leverage points can assist in defining the program and determining the allocation of its inevitably limited resources.

Beginning with an illustrative example, this article indicates the areas of application of strategic modeling to health management issues and reviews the methodology needed for developing and using these models.

AN ILLUSTRATIVE EXAMPLE: PLANNING AN HMO

Difficulties encountered in the establishment of numerous prepaid group practices and HMOs (Health Maintenance Organizations) suggest that a model might help to anticipate areas of managerial problems. Such a model might first be limited to a visual tracing of the major causes and effects that arise in the development and operation of this type of health organization.

Basic Flows

The number of subscribers to an HMO grows as new subscribers enter and declines as dissatisfied subscribers leave. Subscribers present care needs that must be treated with outpatient services or by hospitalization. Because these needs cannot be dealt with instantaneously, a care backlog gradually builds up. The backlog is reduced at a treatment rate that is limited by the number of doctors employed by, or under contract to, the HMO. For any given number of doctors, the treatment rate can be increased to a degree by increasing individual workloads and by employing paramedical people. Beyond that point, however, the care backlog begins to grow. These overall system elements and the relationships among them are shown in Figure 1.

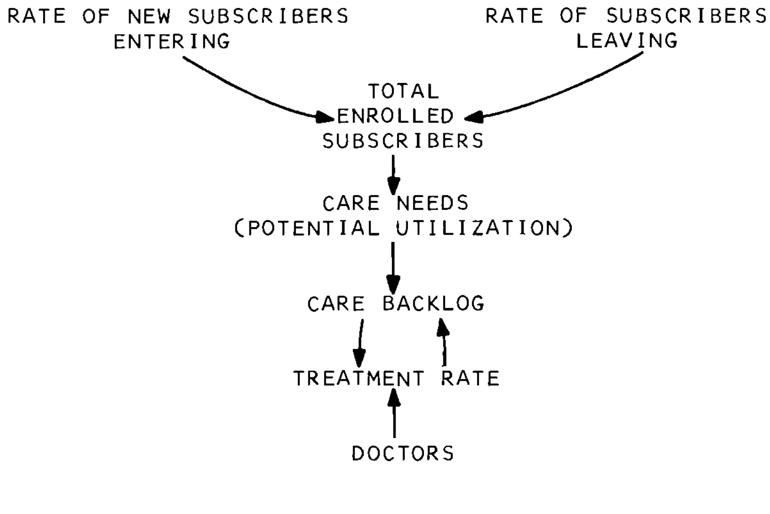

Figure 1. Simple representation of care delivery.

As the number of subscribers grows and their demands begin to exceed the treatment capacity of the available doctors, two mechanisms, in the form of negative feedback control loops, come into play to relieve the strain. The first, and more desirable of the two, is the adjustment of the number of doctors to match the care needs of the subscriber population. When care backlogs begin to grow, the required number of doctors also rises which motivates hiring. The rate at which new doctors can be hired may be dependent on the salary range offered by the HMO, as well as other influences. More doctors enable the treatment rate to be increased and backlog to be reduced. This adjustment mechanism is illustrated in Figure 2.

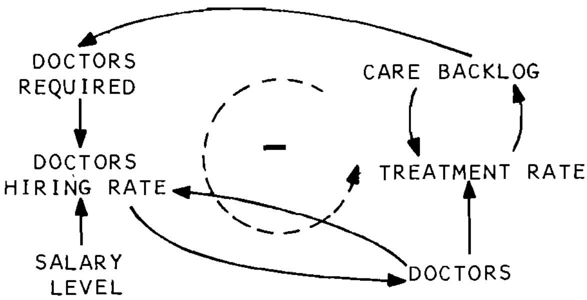

Figure 2. Medical staff expansion loop.

The negative sign on the dotted loop arrow indicates a set of closed relationships that move towards the desired goal: as the care backlog increases, the doctor hiring rises to increase the medical treatment rate, bringing the care backlog down.

The other mechanism that reduces the strain of large care needs is somewhat less desirable. As the care backlog rises, the delay in getting care also increases and has a negative impact on subscriber satisfaction. Subscribers sensitive to poor service may leave the HMO, reducing the number of subscribers. Care needs go down and the backlog is reduced. This second adjustment mechanism is shown in Figure 3. It is also a negative feedback loop: as care backlog increases, subscribers are gradually reduced, bringing down the care backlog.

The two mechanisms shown in Figures 2 and 3 are often able to adjust workload to a manageable level, but they do not always work. If the HMO's administration is very conservative about hiring or contracting for additional doctors or if patients are insensitive to delays because of inadequate access to other sources of care, the backlog continues to grow, putting increasing strain on the staff. A vicious cycle (positive feedback loop) may develop in which the overload causes doctors to begin leaving and the number of doctors declines. Treatment rate goes down and leaves the remaining doctors faced with an even larger care backlog. This vicious cycle can lead to a steadily deteriorating situation in which fewer doctors are available for

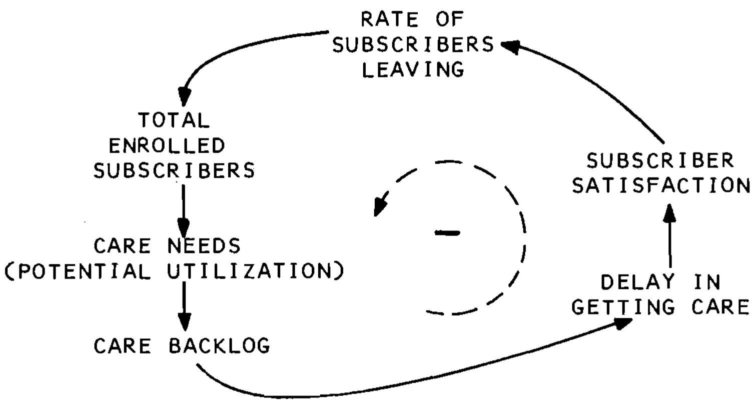

Figure 3. Subscriber dissatisfaction loop.

growing care needs. The factors underlying such a situation are shown in Figure 4. The positive sign on the loop arrow indicates a positive feedback loop, one that fosters self-amplifying change.

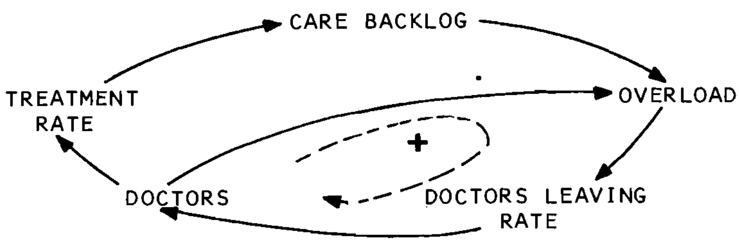

Figure 4. Doctors leaving due to severe overloads.

Such vicious cycles as in Figure 4, more typical of an urban public care program than a prepaid HMO, are clearly to be avoided. The management of the HMO must take measures to avoid situations like this. Limiting the growth in the number of subscribers or having a temporary source of part-time doctors to provide flexible capacity during the growth phase of the HMO are possible preventive measures. Dealing with situations as they arise, however, is often not enough. By the time a problem becomes evident, anything less than drastic measures may be inadequate. As the number of subscribers grows, the number of doctors available may still seem sufficient. However, after subscribers have been with the HMO for some time, they become more knowledgeable about the range of medical services available to them and utilize them more frequently for health maintenance as well as the treatment of illness. By the time this phenomenon becomes evident, it may be too late to control workload by limiting new subscribers. Before many new doctors can be hired, the vicious cycle of doctors leaving and increasing workload per doctor may begin. If the HMO gets a reputation for having a very heavy workload, it will encounter difficulties in recruiting new doctors and the vicious cycle may have devastating effects on the HMO's operations.

Another set of vicious cycles can also have serious detrimental effects on the HMO. Unlike a conventional medical insurance program that has no fixed overhead other than administrative costs, a large proportion of an HMO's expenses (for example, salaries, rents, contracts) are fixed and must be paid regardless of the subscriber population. These large fixed costs imply some breakeven point, a specific number of subscribers the HMO needs in order to operate without losing money. New HMOs usually set aside funds to deal with deficits during the start-up period without unfairly burdening those who are among the first to become subscribers. Suppose, however, that the growth in the number of subscribers during the start-up period is slower than anticipated. Difficulties in signing up subscribers as rapidly as expected might stem from peoples' perception of the HMO as a provider of "clinic medicine" or from the fact that there are already well-established sources of health care in the community. For a limited period, the start-up reserve can act as a buffer between subscribers and the very high total cost per actual subscriber enrolled. Eventually, though, these high costs have to be reflected in higher premiums unless some of the staff are released. Because an HMO's professional staff is often under contract, this remedy is frequently not available or, for other good reasons, administrators are reluctant to apply it. Should higher premiums result, the HMO would become even less attractive compared to conventional arrangements, new enrollments would decline even further, and some of those in the HMO would decide that it had become too expensive and drop out. The cost per subscriber would then increase even further and the remaining subscribers would have to pay still higher premiums. This vicious cylce might cause a promising HMO to die before it ever really got off the ground. The causal factors that could produce this cycle are shown in Figure 5, which includes a positive feedback loop affecting subscribers leaving.

The existence of a causal structure that can produce this kind of problem suggests a need for at least two measures to protect the fledgling HMO. One is the provision of a line of credit through governmental or private sources for HMOs that find their start-up reserves inadequate to cover initial losses. The other measure is the gradual acquisition of staff and facilities by the HMO during its growth period. Both measures would help to prevent the HMO from falling into the vicious cycle

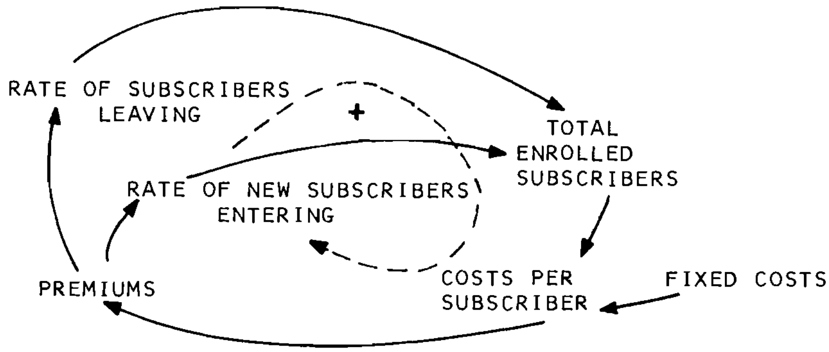

Figure 5. Cost increases resulting from slow growth.

described. The allocation of more resources to marketing activities would also help.

The last problem to be discussed in the context of this simple illustrative model is another vicious cycle that can affect an HMO in either its growth phase or its long-term phase of stable operations. If the efficiency of the HMO's operations begins to decline, more staff have to be hired and facilities acquired to serve the same number of subscribers. Costs per subscriber go up and are eventually reflected in higher premiums. People who are often ill and require care may not be bothered by the higher premiums, feeling that they can still get their money's worth. People who are healthier and get less use out of a health program would be less willing to join the HMO as its premiums rise. Similarly, healthier people already enrolled in the HMO may be motivated by higher premiums to drop out while those who utilize services more frequnetly will be less sensitive to premium increases. The expensive HMO, in effect, becomes a filter, drawing in people who require more care while discouraging and driving out those who are healthier and would not utilize its services very frequently. The average morbidity of subscribers increases as a result of this filter effect and care needs go up. If the HMO improves benefits to compensate partially for the higher premiums, utilization can go up even further and the HMO may also become even more attrative to those who are very ill. Higher utilization creates larger backlogs and greater resource requiremtns, especially more doctors. As doctors are hired and other resources acquired, costs go up and force higher premiums to complete the cycle. The structure that produces this behavior is shown in Figure 6.

Two strategies can be employed to prevent or get out of this vicious cycle. The HMO should have a cost-accounting system that reveals whether excessive cost increases are due to operating inefficiencies or are caused by a rising average

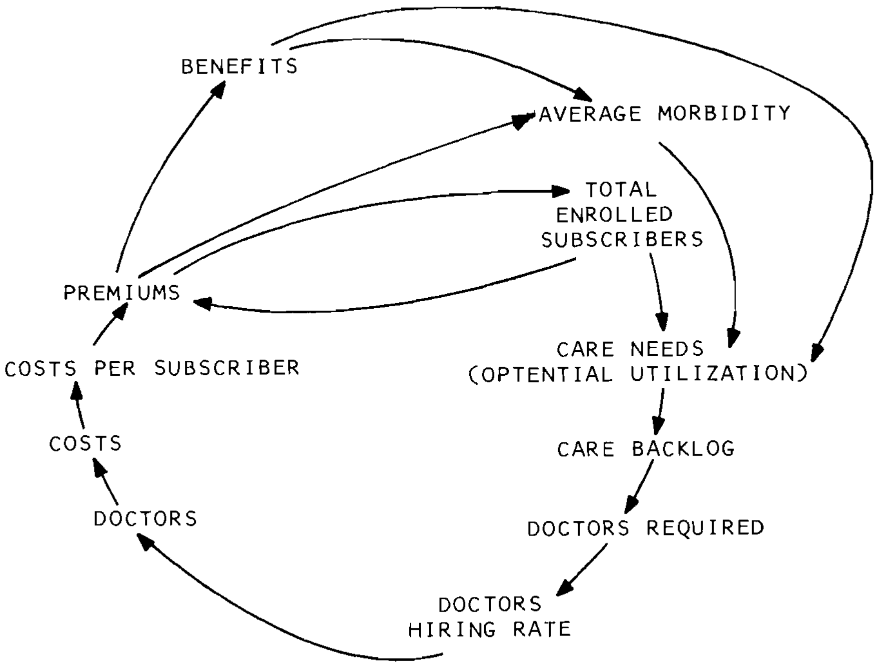

Figure 6. Factors that generate higher costs and greater average morbidity. (dotted loop arrows are omitted for simplification.)

morbidity among subscribers. If inefficient operations are shown to be the cause of rising costs, a strategy should be used that focuses on cost control and allocates more effort to cost-saving studies, measures to improve efficiency and the introduction of labor-saving technology. If, on the other hand, the HMO's costs seem to be rising because it is serving higher cost subscribers, a strategy of selective marketing is in order. Selective marketing can be carried out in several ways. Efforts to stimulate new enrollment can be directed at groups that are expected to contain mostly low utilizers. Experience rating under which groups with proven low utilization are offered lower premiums is another way of overcoming high utilization problems. Adjustment of the benefit package in a way that would not affect low utilizers very much but would discourage high utilizers is a third alternative. The use of at least one of these alternatives may be necessary if the rising average morbidity--high cost cycle is to be avoided.

The complete model structure as developed thus far is shown in Figure 7.

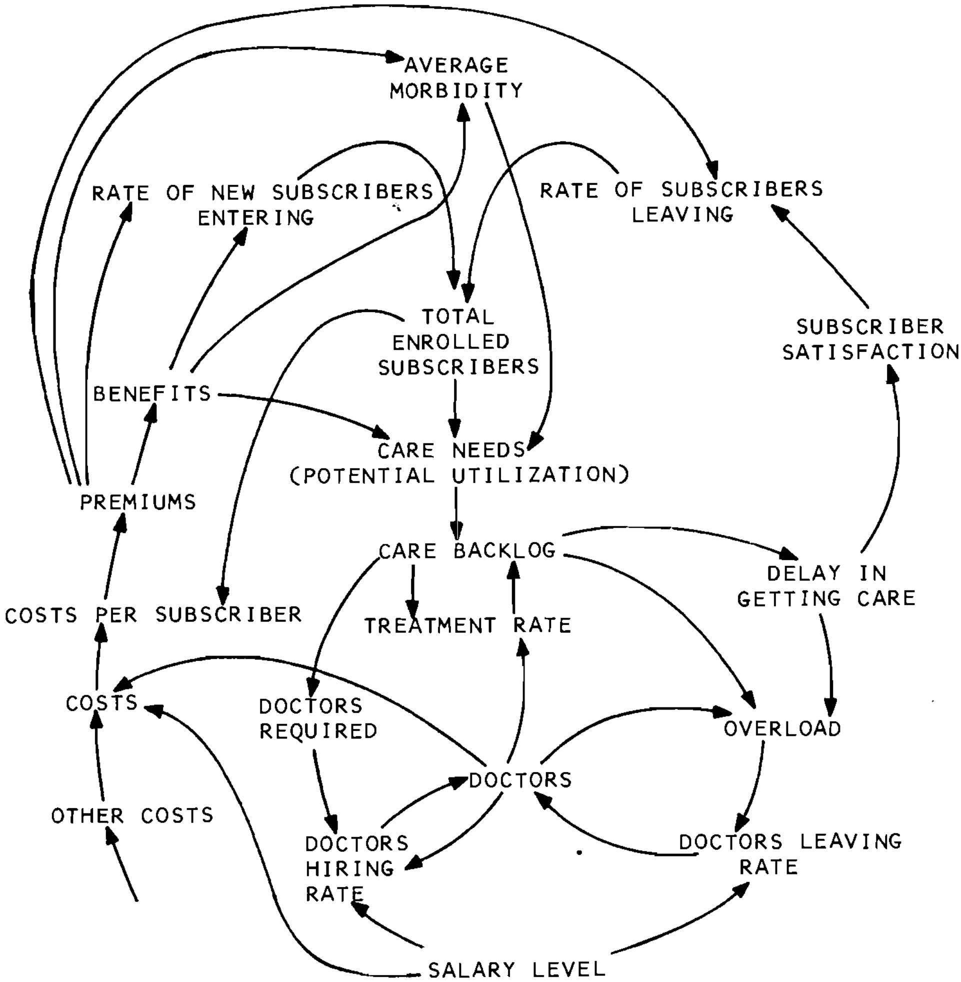

Figure 7. Complete HMO model structure for illustrative example.

Using the Model

The process of developing a visual cause-and-effect model of the type illustrated is useful in planning strategy. It helps to unite a multidisciplinary staff in pursuit of a common goal and on policy issues that stand in the way of effective program design. When staff perceive the interrelationship between the different functional areas of a health organization, they come to understand their common object and interdependence. The use of visual modeling to help in solving problems and to decide on future strategy has now been applied successfully to several complex health orgainzations [2].

But in many cases the complexity will warrant further elaboration and detailing of the visual model and representation in computer language to enable more rigorous analysis. For the type of model illustrated in Figure 7 a special language has been developed, called DYNAMO [3], that permits easy translation of the visual model into mathematical equations in computer form. The computer can then simulate the effect on the model over a period of time of a variety of possible or likely scenarios. This is of assistance in forecasting the results of various management policies.

For example, even with the simple HMO model described, a set of DYNAMO simulations can help to answer some of the following questions:

- What problems (in addition to the ones discussed) are likely to arise during the growth phase or stable operation of the HMO?

- What policy of hiring doctors will yeild the lowest cost for the HMO while creating the highest possible levels of satisfaction for both subscribers and doctors?

- What policies for reflecting costs in premiums should be followed? Allowing premiums to lag very far behind costs will, of course, lead to bankruptcy. Adjusting premiums too quickly in response to rising costs may lead to the high cost--high morbidity vicious cycle. Simulations carried out with the model can indicate the proper balance necessary to avoid either situation.

Even this simple a model can help the decision makers in the HMO to choose the right policies for healthy growth and smooth operation. A more detailed model can help them with decisions on a wider range of issues.

In fact, a model reflecting many of the issues discussed above was developed as part of an HMO planning process for the Albert Einstein College of Medicine in New York [4]. The model contained far more detail, taking into consideration specific characteristics of a variety of potential subscribers, as well as several alternative treatment programs. Development and computer simulation of that model helped to persuade the medical school that an HMO would be relatively ineffective and overly expensive under the then existing environmental conditions. They therefore decided not to proceed with the HMO. An earlier version of a similar HMO model was helpful in planning the development of the Harvard Community Health Plan, a medical school sponsored HMO in a very different setting.

DEVELOPING STRATEGIC HEALTH CARE MODELS

The most useful models for solving strategic care delivery problems and for planning new health education or health service programs are those developed by teams of senior managers and program leaders working in collaboration with model-building specialists. Active participation of the health organization's leadership group assures that the model more accurately represents the real world system and improves its chances of being used by planners and decision makers. This group of participants provide the model-builders with an initial set of impressions, experiences, anecdotes, and intuitive feelings which, when combined with hard data and documented case studies, become the basis for a visual model structure.

As the visual cause-and-effect model evolves, those team members with experience of health problems criticize and modify its formulations until an acceptable structure is achieved. The model is then represented by equations in the special-purpose computer language and "run" to determine its basic behavior under a baseline set of data and assumptions. Its behavior is studied by the experts. If it is deemed unrealistic, its structure is further revised. An attempt should be made to avoid collecting unnecessary and extensive data. Attention should be confined, at least initially, to the relatively few parameters whose accuracy is significant in explaining system behavior. Experience has shown that wide variation in most of a model's parameters has little effect on system behavior. Usually only a few parameters have much influence. These sensitive parameters are found by performing baseline runs with changes in only one parameter per run. The few that produce major behavior shifts are then more carefully researched.

Once the model has been developed in this manner, the health services people in the modeling team help to suggest topics for research, develop hypotheses, propose experiments, and evaluate the implications for program planning of simulation results. Their participation is also essential to achieve the implementation of the appropriate set of programs, organizational forms, policy sets and linkages among service units and provision of supportive services in an operating program.

Model building is useful because it forces team members to clarify their assumptions about the causes of service delivery problems. Where these assumptions differ, the model serves as a vehicle for achieving consensus. In the course of building a model, many interesting (and sometimes at first sight, unlikely) hypotheses are evolved about the structure of the system and the corresponding effect on behavior. These can then be tested by means of the model. As a completed model emerges, its feedback loops become more apparent and more elaborate behavioral hypotheses can be formulated.

The completed model has several uses. Primarily, it enables the health care manager or planner to ask "What if?" questions and perform simulations to get the answers. Simulation helps to prevent experimental tampering with existing programs or setting up new ones that may have critical flaws. Further sensitivity analysis can be done with the completed model to identify leverage points and suggest additional topics for research. Operating models can also serve to inform poeple who were not involved in building the model. By observing the effects on its behavior of changes in policies and parameters, such people can better understand the dynamic forces at work in the real-world system. Models are open-ended and can always be modified to include analyses of more detailed aspects of the system structure. If a group of health program planners have a fairly good model of the operations and economics of their plan, but are wondering about community reaction to the program, a community response sector can be added to the model. Many such issues can be handled in this manner.

AREAS OF APPLICATION OF STRATEGIC HEALTH CARE MODELING

Although dynamic health system models have been under development for only seven years, they have already been applied to management issues in academic medical centers, hospitals and community care organizations; they have also been used in several manpower planning and health policy areas. For example, in addition to the HMO planning models for Einstein and Harvard described above, the models built for three other medical schools have revealed a set of causal factors common to all three schools and the problems they face. One of these models focuses on future patient utilization of a medical school's teaching hospital and problems that may cause utilization to decline below levels needed for teaching purposes. Another deals with the number of students that can be accomodated in the various programs at an academic health center without detriment to the quality of training and of patient care provided by the health center, focusing on the problems associated with enrolling too many students. A third model deals with difficulties encountered by a medical school in its relationships with a number of its affiliated hospitals. Despite the apparent diversity of the problems and the great differences in the schools on whose behalf they are being modeled, the relationships diagrammed in Figure 8 seem applicable in all three cases. (They are, of course, represented in the figure at the overall level; the set of relationships involved in each model is much more complex.)

In each of these medical center projects, the interplay between a medical school and one or more teaching hospitals was central to the principal problem analyzed. Work has been carried out in appraising strategic planning issues at several other hospitals as well. For example, [2] describes the modeling of a community-based hospital facing a decline in the numbers of both out- and in-patients which seriously threatened the viability of the whole organization. Figure 9 suggests part of the predicament faced by that hospital.

The diagram indicates that if the Out-Patient Department (OPD) "dries up", the hospital census will decline and the acute services would eventually have to be discontinued. That is

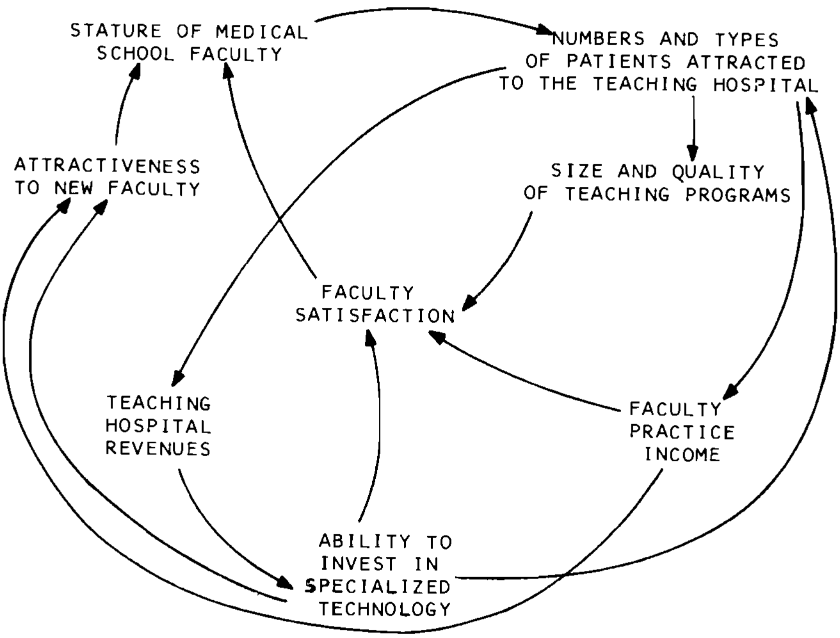

Figure 8. Some of the causal relationships affecting the performance of academic medical centers.

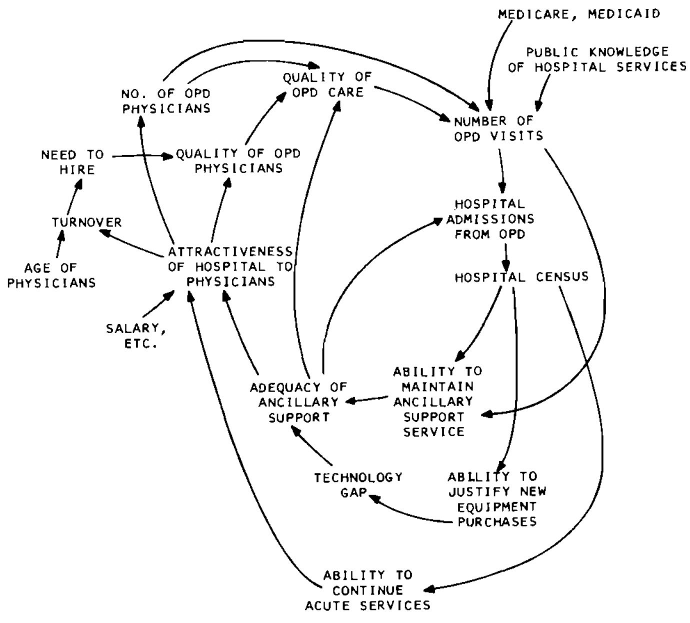

Figure 9. Interdependencies between out-patient department and hospital services.

because a declining hospital census will make it harder to maintain the ancillary support services (for example, lab, x-ray) and to justify the purchase of needed equipment. This will in turn reduce the attractiveness of the hospital to physicians, reduce the quality of OPD care, and further reduce the number of hospital admissions (i.e., OPD will have to refer more patients elsewhere). This downward spiral could result in the discontinuation of acute services, which would lead to a further decline in the quality of OPD care.

In that hospital, the building of the model led to a broad program of institutional change, now largely implemented, that has reversed the downward spiral. The hospital is now past its crisis phase and is steadily improving in health. Other strategic models have focused upon mental hospitals [5] and community mental health centers [6], ambulatory care [7] and emergency care [8]. The model specialists have also been commissioned by neighboring Boston-area institutions and have built models dealing with issues at Massachusetts General Hospital, New England Medical Center Hospital, Boston City Hospital, and Cambridge Hospital.

Manpower planning is the focus of two major current modeling projects, which seek to understand supply, demand and impact upon care in the separate areas of dental care and nursing. Earlier efforts in the dental area [9] have now been expanded into the largest computerized dynamic model yet developed, treating over 2000 detailed variables relating to the future of dentistry. A similar effort in the nursing field is now underway in collaboration between the Division of Nursing of the Western Interstate Commission on Higher Eduction (WICHE) and Pugh-Roberts Associates of Cambridge, Massachusetts.

In broader aspects of health policy, strategic modeling has attempted to cope with the complexities of comprehensive health planning, with defensive medicine [10], and the total system of urban heroin addiction, its consequences and the various strategies for dealing with it [11]. The latter work exemplifies the type of comprehensive analysis that is possible using dynamic models. At a time when the nation was acclaiming the apparent end of the drug problem, the analysis concluded that drug abuse persisted and would not soon be eradicated, an assessment now firmly supported by the latest nationwide studies.

As indicated above, strategic models can serve a number of useful functions for health program administrators and planners. For some of the basic managerial functions such as problem diagnosis, resource allocation, decision making, cost-benefit analysis, evaluation of alternative program and assessment of the results of proposed programs, they can be extremely useful to any health program, planned or operating. There are several other specific areas in which it might be worthwhile to use models:

- Analyzing the relationship between living conditions and health to identify the most effective public health measures to help maintain good health. This would involve developing models that related to the overall health of the client population such environmental factors as poor nutrition, overcrowding, inadequate pre-natal and child care, lead poisoning and the tensions of living in areas of extreme poverty. Such models would allow planners to find the most effective allocation of resources among the corresponding public health programs.

- Designing programs to deal with illnesses whose treatment is complicated by the fact that they are regarded as socially reprehensible. Models representing the forces impinging upon such problems as alcoholism and narcotics addiction (for example, how people become involved, punitive societal response, etc.) help planners to design comprehensive programs that deal with every aspect of the problem, including prevention, treatment, rehabilitation, follow-up and changing community attitudes to the problem.

- Exploring needs for program and technolgical development in order to determine high-priority topics for research and development, i.e., analysis of the problems confronting the care delivery system by using models to find the points at which technological or programmatic innovations would be especially useful in reducing the cost of care or improving its quality. This approach has been used in other industries, but not yet in the area of health care technology.

- Epidemiological models can be developed to design a comprehensive approach to particular diseases and health programs. These models can be used to evaluate the cost effectiveness of various strategies and to find the most effective measures of prevention and mass treatment. Academic models showing the feasibility of this approach already exist [12,13].

Strategic models represent flexible tools for decision making, resource allocation, policy design and program evaluation. As demonstrated with the HMO example, models can be built to include the important causal factors that determine the success or failure and effectiveness of any program. With these models, it is possible to take the right steps to make programs successful and avoid many of the pitfalls that spell the end of well-intentioned but poorly designed programs. The causal factors underlying particular health problems can also be assembled into models that reveal the set of programs and policies needed to alleviate them. Many remedial efforts, when based on an incorrect or incomplete understanding of problems, fail to have any effect or actually make matters worse. Through strategic models, managerial planners and problem-solvers can understand better the causes of problems and foresee the effects of remedial efforts; they can choose the most effective remedial programs and eschew harmful ones.

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Modeling the Austrian Health Care System

Peter Fleissner

THE RESEARCH TEAM AND ITS STRUCTURE

At the beginning of 1972, a group of 20 scientists started to analyze the long-term development of medical care in Austria.* Sponsored by the Austrian Prime Minister and located at the Institute for Advanced Studies, Vienna, under the scientific leadership of Professor Naschold (University of Konstanz, FRG), the group did a political and economic analysis of this critical sector of Austrian society. An interdisciplinary approach was needed to deal with the different aspects of the medical care systems (MCS); and this is reflected in the composition of the team (see Figure 1):

PROFESSION	NUMBER		TOTAL
MEDICAL DOCTORS:			
- INTERNAL MEDICINE	1		
- SURGERY/OCCUPATIONAL HEALTH	1		3
- PSYCHIATRY	1		
SOCIAL SCIENTISTS:			
- ECONOMICS	3		
- SOCIOLOGY	1		6
- POLITICAL SCIENCE	2		
SYSTEMS ANALYSTS:	1		1

Figure 1. Composition of the team.

*The report of the study *Systemanalyse des Österreichischen Gesundheitswesens* is available in German from the Institute for Advanced Studies, Vienna.

THE SCOPE OF THE PROJECT*

The scope of the project was very broad. Starting from the meaning and history of health and illness in different types of societies, the team proceeded to an analysis of market-oriented countries, focusing on the Austrian MCS. The following main features of the Austrian system were considered:

- Public health insurance, which covers more than 95 percent of the population;

- Private monopolies or oligopolies such as the pharmaceutical, construction, and electronic industries, private general practitioners, specialists, and private health insurance companies which coexist with public health insurance;

- Unequal distribution of medical facilities and institutions, low density in low-income districts (in rural areas and in districts where blue-collar workers live);

- Cost explosion in the hospital sector and increases in general practitioner (GP) fees and in prices of pharmaceuticals;

- Very poor results in overall health indices of the population, lack of improvement in life expectancy for males, high infant mortality, high rates of liver cirrhosis and lung cancer, unsatisfactory hospital care for the elderly, nonintegrated occupational health care system.

The team isolated five sectors of the Austrian MCS for detailed investigation: the private GP system, hospital care, problems of distribution of medical care in rural areas, psychiatric disease and care, and occupational health.

Strategies were developed for more equal distribution of the MCS. Preventive rather than curative measures were elaborated, as for example, the following:

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*Besides their scientific work, the team communicate their ideas and results to the public. They cooperated in a TV film on sickness in Austria, and for one month had daily use of one or two pages of the biggest Austrian newspaper. Soon other newspapers took up the issue, and headlines appeared dealing with medical care in Austria. Although this campaign was successful, no change in the health care system has yet taken place. Indeed, the situation is worse than before because of economic difficulties; governmental budgets are expected to be very tight next year.

- An integrated health care system that included occupational health and was responsible to workers' councils and labor unions;
- Reforms of the pure food and drug laws;
- In the transportation and road traffic sector, measures for reducing pollution and road accidents;
- Revised standards for the construction of nuclear power plants.

THE USE OF SYSTEMS ANALYSIS

To integrate the various disciplines, the team decided to apply the technique of systems analysis. During the initial phase of the project, internal seminars were held to familiarize the team with the basic elements of systems analysis, and the decision was made to use causal loop diagrams in the team reports. With the growing knowledge of this tool, communication became easier and misunderstandings were reduced. Integration was facilitated by adopting as a working technique the preparation of reports in each of the different fields of interest; these were later discussed in plenary sessions, from which quidelines emerged for further individual work. Thus the knowledge of each team member about important problems in other specialties was improved.

THE MODEL

After the early plenary sessions it became evident that the MCS cannot be modeled in isolation; account had to be taken of the most important subsystems surrounding the health sector which influence or are influenced by the MCS. This is necessary because of the long-term orientation of the research project. Changes in sectors external to the MCS may induce changes inside the MCS.

Since it generates the basic dynamics of the society, the economic system of Austria had to be included in the model. In this predominantly market-oriented system, economic factors such as inflation, wage structure, distribution of income over different social strata and the influence of the public sector govern the financial resources allocated to the MCS and to other government services. The economy and its level of development are directly related to the living and working conditions that influence the health status of Austrian society. The health status of the working population is in turn related to the amount of sick leave, thereby influencing productivity and output of the economy.

For long-term considerations, the age structure of the population and certain other demographic data are useful for assessing the possible load of the MCS. Therefore a population model was constructed, from which the economy model derives its potential labor force. The medical care of children and elderly can also be differentiated with this submodel.

To ensure the realistic and relevant behavior of the model, a political subsystem of health care was developed, reflecting certain political issues. Changes in the MCS are usually preceded by changes in the power structure of different interest groups, which depends on the socio-economic conditions of different strata. The political subsystem deals with the interplay of power and describes its results in terms of indicators of the political situation.

The project team had first intended to include five issues in this sector: 1) the changing emphasis of MCS from treatment to prevention; 2) public or private financing of the MCS; 3) ownership of the means of medical production; 4) equal care; and 5) the degree of cooperation on the part of population with the MCS. (Owing to lack of manpower and time on the part of the team, this subsystem must be regarded as a pilot study).

However, because only 10 percent of the team's manpower could be allocated to the construction of the model, only points 1 and 2 above were represented in this subsystem. Nearly 50 hours of discussion were needed by the political scientists to establish the dynamics of each of the issues and to reach agreement about the system's behavior.

The result of the design process was a hierarchical two-level model, where the socio-economic foundations are formed by the submodels of the MCS, the economy, and the population. The upper level is represented by the health politics subsystem (Figure 2).

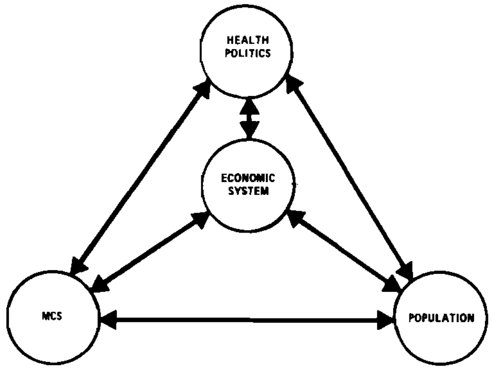


Figure 2. Structure of the model.

The two strata are connected by causal relationships. The socio-economic model is used for the derivation of indicators of political power of the different interest groups. The powers are treated as vectors which can be added and subtracted. The resultant power changes the status indicator of the political issue in question. This indicator changes the values of certain coefficients or variables of the socio-economic model. The feedback loop is completed by the socio-economic indicators resulting from the changed coefficients.

In accordance with the political assessment of future development, different variants were considered. In theory, a great variety of possible futures can be envisaged. In conformity with political terminology, the broad spectrum of future development was reduced to the following five classes:

- The *reform* variant: This is the most probable variant for Austria during the coming years. It is characterized by a higher degree of collective financing of the MCS and a tendency towards preventive measures. The social welfare institutions are very influential because they have popular support. Social mobility increases. There is a trend towards equal chances for all.

- The *conservative* variant: The MCS is more or less frozen in its treatment orientation. Individually paid fees and individual financing are strengthened. The social welfare institutions ally themselves with the specific interests of the medical profession, into an objective supported by firms producing pharmaceuticals, electronic devices, and other goods used in the MCS.

- The *revolutionary* variant: As the production and distribution of health services are no longer subject to the logic of profits, the health requirements of the population become guidelines for the development of social patterns. In politically activated groups, the population itself changes and shapes its living and working conditions in the direction of primary prevention. The population is integrated into a centrally-planned medical care service, consisting of an occupational health branch, medical centers for rural and urban populations, and hospitals connected with these centers.

- The *reactionary* variant: After the abolition of public health insurance, purely capitalist interests exert their control by means of the political and administrative system. The health care system is narrowed down to low-quality curative medicine. Marginal groups are excluded from health care. Private health insurance is available to the rich. "Solidarity" schemes are established.

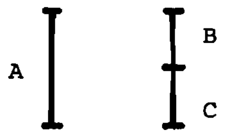
- The *standard* variant: As a "waste product" this variant, where the political system is not explicitly considered, extrapolates the system behavior of the past. Most of the current simulation and econometric models fall under this heading.

Given the present political power set up in Austria and the level of development of the theory of social revolution, it seems impossible to contemplate the revolutionary variant. The reactionary variant seems to be very unlikely at the moment. So the team decided to model the *reform*, the *conservative*, and the *standard* variants only.

OBSERVATIONS ON METHODOLOGY

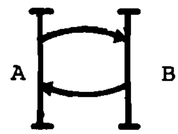
In analyzing a certain sector of society, one has to deal with interrelations and/or contradictions among variables. There are internal and external interrelations. The internal relations are formalized by equilibrium equations and definition equations. There is no causal ordering and the elements of the equilibrium equations exist simultaneously. On the other hand, external relations between A and B can be analyzed by isolating the effect of A on B and vice versa. For the model, the team introduced the following graphical representation:

Internal relation



For example, $A = B + C$, or $A = B \cdot C$

External relation

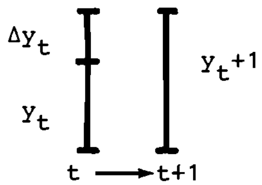


That is: $A = f(B)$, and $B = g(A)$,

In discrete time systems, very often a stock-flow equation is used:

$$y_{t+1} = y_t + \Delta y_t \quad . \tag{1}$$

Although this equation could be interpreted as an external relation between the same variable, it is useful to regard it as an equilibrium at different points of time. Therefore we represent it in the following way:



With the help of only two elements, equilibrium and causal influence, we can construct nearly every model in the field of econometrics or social sciences. One advantage of this representation is its simplicity. Furthermore, one is not restricted to recursive models (as is the case in using DYNAMO [1]).

The causal relationships were econometrically estimated whenever possible. The parameters of the economic subsystem were computed by ordinary least-squares on the data base for the period 1954-1970, using annual data. The estimation techniques used here are therefore not very interesting. Our argument is that errors of estimation are much smaller than errors of specification.

Since the resulting system of economic equations is simultaneous and nonlinear, the economic subsector was dealt with by iterative procedures. To speed up convergency, we used a modified Gauss-Seidel method with linear approximations of the fixed point. About 10 iterations are necessary for a stable solution for each year of model time. The rest of the model is recursive. The complete model produces numerical values for about 500 variables per year, from 1961 up to 1995 for each of the political variants.

MODELING THE MCS [2]

A set of indicators was selected for health and illness, the load of hospital and out-patient care, the producers of medical services, and the amount of money necessary. The reasons for this selection are as follows: living and working conditions in Austria are generating a tendency towards a growing number of morbid episodes. These episodes represent a preprofessional concept of nonhealth, composed of subjective and objective factors [3]. Productivity was taken as a rough indicator of living and working conditions. Only one-quarter to one-third of these morbid episodes will be treated in the professional MCS; the remaining must be coped with by the ailing persons themselves. Filter coefficients convert the number of morbid episodes into the number of ambulatory patients treated. The patient load of a panel doctor will affect his inclination to shift patients to the hospital.

Data on the sick leave of manual and nonmanual workers, male and female, were processed separately. It was interesting to see a significant influence of the business cycle on the sick leaves per capita for manual workers; this did not apply to nonmanual workers.

The related regression equations are:

$$y_1 = \underset{(38)}{1.37} + \underset{(71)}{0.0127}g - \underset{(30)}{0.44}y_{1,t-1} \qquad (2.1)$$

$$y_2 = \underset{(30)}{0.987} + \underset{(74)}{0.0061}g - \underset{(30)}{0.182}y_{2,t-1} \qquad (2.2)$$

$$y_3 = \underset{(39)}{0.219} + \underset{(42)}{0.0047}\text{♀}_{t-1} - \underset{(31)}{0.403}y_{3,t-1} \qquad (2.3)$$

$$y_4 = \underset{(27)}{0.553} + \underset{(43)}{0.00040}\text{♀}_{t-1} - \underset{(30)}{0.458}y_{4,t-1} \qquad (2.4)$$

where y_1 is sick leaves per capita of male manual workers,

y_2 is sick leaves per capita of female manual workers,

y_3 is sick leaves per capita of male nonmanual workers,

y_4 is sick leaves per capita of female nonmanual workers,

g growth rate of the economy,

q productivity,

$t-1$ time lag of one year.

The figures in parenthesis represent the standard deviation divided by the coefficient as a percentage. About two-thirds of the variance of y is explained by these equations. The equations show in empirical terms that sick leave is a phenomenon influenced by health conditions and by socio-economic factors. The lagged terms on the right hand side indicate a damping behavior in sick leaves. The firms seem to have a rule of thumb: if last year sick leave was high, they try to reduce it this year; if low, they tolerate a rise.

Sick leave is further divided into eight groups according to diagnosis. The share of any given diagnosis group was taken to depend on the overall indicator of living and working conditions. With respect to respiratory diseases, for example, regression analysis showed negative correlation with productivity for male, and positive correlation for female workers. The coefficient of determination for male workers is more than twice that for female workers. Since the share of respiratory diseases in the total for all groups is, on the average low for females, a trend toward a similar pattern for both sexes can be seen.

Based on available data, hospital stays were divided by the following five strata: manual workers, nonmanual workers and public service employees, elderly persons (65 years and over), children (15 years and under), and farmers (participating in a farmer's health insurance scheme). The results show a very significant influence of the business cycle on hospital stays per capital and per stratum. Regression analysis leads to equations with very high R^2. For example,

$$y_n = \underset{(17)}{214.96} - \underset{(13)}{5.78g_{-1}} + \underset{(11)}{70.1^{c}_{-1}} \qquad R^2 = 0.963 \qquad (2.5)$$

$$y_e = \underset{(14)}{301.924} - \underset{(31)}{3.0g_{-1}} + \underset{(9)}{95.18c_{-1}} \qquad R^2 = 0.964 \qquad (2.6)$$

where y_n is the number of hospital stays per capita for nonmanual workers and

y_e that for elderly people,

g is the growth rate of the economy, and

c denotes the cases of ambulatory care.

If c increases, more people are transferred to hospital. The same holds for periods of slow economic growth. The theoretical explanation for these facts is not very developed. One could argue that it is more difficult to find a job in the year following a period of economic stagnation, and that people tend to overcome this situation by a stay in a hospital; but this would hold only for persons of working age. There is no such explanation for the elderly.

Similar variables influence the duration of the stay in the hospital. The regression equations determine the length of stay relative to the other strata. The absolute length of stay depends on the number of beds available.

Each visit to a GP and each day of hospital stay is associated with costs. The budget of the public health insurance in particular was analyzed in the model. Costs of medical care were combined with the rate of inflation of the consumer price index.

Three kinds of nonfinancial health resources were explicitly analyzed. There are the numbers of physicians, the number of nursing staff, and the number of beds available. For each of these a more or less elaborated model was developed. For purposes of illustration, the "physicians" model is graphically represented in Figure 3.

THE STRUCTURE OF THE HEALTH-POLITICAL SUBSYSTEM

In order to endogenize politics into the model, the political power of the interest groups of the MCS were explicated. Five groups were included in the model: general capital investment interests, medical capital investment interests, medical class interests, social welfare institutions, and interests arising from the health requirements of the population.

For each of the groups, a socio-economic indicator was chosen to represent its political power. As a typical transformation from the socio-economic to the power level, the following formula was used:

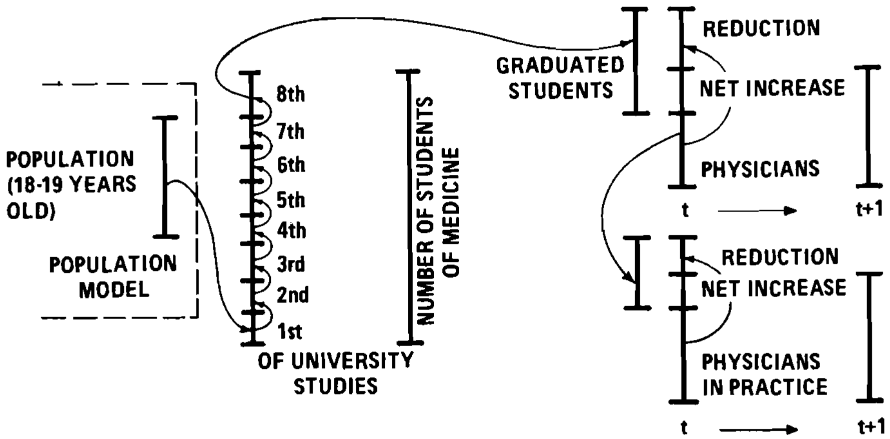


Figure 3. The training of physicians.

$$I_p(t) = I_p(t_o)[1+c(I_{se}(t)/I_{se}(t_o)-1] \tag{3}$$

where I_p is the power indicator,

I_{se} is the socio-economic indicator,

c represents the extent to which the power indicator is influenced by a percentage change in the socio-economic indicator. With $I_p(t_o)$ one can standardize initial conditions $(t=t_o)$. A subjective scale from -5 to +5 was used for assessment purposes.

The various power indicators were added. The adjusted resulting power I_{Res} was used as an increment of the indicator of the given political issue, I_I.

We used:

$$I_{Res} = \sum_{i=1}^{5} I_{P,i} \tag{4}$$

and

$$I_I(t+1) = \alpha \cdot (1-|I_I(t)|) \cdot I_{Res}(t) + I_I(t) \quad , \tag{5}$$

where $1 - |I_I(t)|$ represents a damping factor to include political resistance against puristic solutions. I_I is standardized between -1 and +1. $I_I = 1$ means, for example, wholly publicly-financed MCS, or completed investment in prevention and cure in the MCS; α converts the resulting power into the indicator of the political issue in question. Figure 4 is a graphical representation of the subsystem.

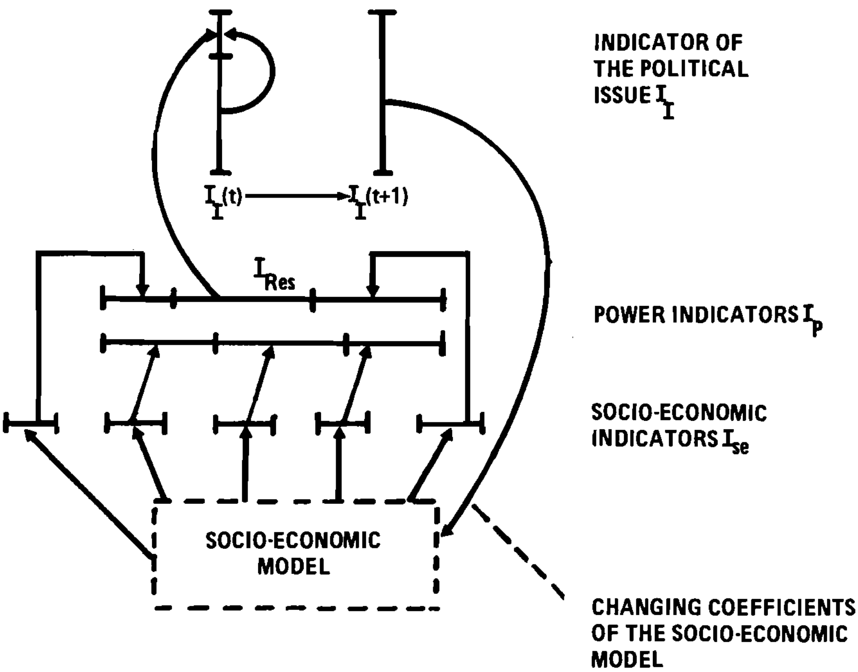


Figure 4. Structure of the health-politic subsystem.

APPLICATIONS

Although many questions within the health-politic subsystem remain unsolved, the model gains in relevance through the inclusion of the endgenized political sector. It should not be used solely as a predictive tool but should enable management in social planning to formulate its views more clearly and rationally.

It also helps in defining data needs in a structured form. Health indicators should be viewed not as separate and isolated variables but within the framework of theory; the connections and dependencies must be taken into account. The model presented here is currently being used in public health insurance in Austria as a tool for analyzing changes in health politics. The modular structure of the computer program enables the user to change the different parts of the model very quickly according to his own point of view, but he is obliged to use an integrated and comprehensive approach.

The development of the model itself took about three man-years and was not very costly; but one should bear in mind that some members of the team were experienced in model construction, especially in econometric modeling, and that a computerized data bank of economic data and different kinds of statistical programs were at their disposal. We would estimate the total cost of the model, including computer time, data collection and documentation, at less than one million Austrian Schillings.

It is likely that a much more integrated approach will be used in further developments of the model. There is a trend towards providing a defining framework in the shape of a socio-economic accounting scheme, integrating social structure, demographic characteristics and sickness into the national economic accounts. The resulting scheme is much more rigorous and theoretically based than the approach presented here. This socio-economic accounting scheme will make international comparisons easier.

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Summary: A Basic Model of the Human Environment

R. Miksl, et al.

In recent years, scientists all over the world have become increasingly concerned with the question of the environment. Their work has been hampered by the fact that hitherto researchers have worked within their own specialisms and the results have not been integrated into a multidisciplinary whole so as to produce a satisfactory overall model of the environment. The authors have therefore used a systems approach in an attempt to build such a model.

Basic problems are whether or not man should be regarded as part of the environment, how nature itself should be represented and what are the parameters of the model. The authors have adopted Marx's thesis that people consciously mould their environment and that a socialist community does so in a scientific way. The systems approach to the environment distinguishes the economic, scientific and political systems. The political system controls the other two as far as the environment is concerned.

The system of the environment is divided into three *material* subsystems and three *functional* subsystems. The material subsystems are dwellings, work places (working conditions being a component of this subsystem), and places of recreation. These subsystems are all man-made and have definable goals. Each has its implicit function and they are not specific to any location.

There are three functional subsystems which interrelate with the material subsystems, namely:

- Human social activities: elements of which occur in all the subsystems of the environment and enter into the political system. The requisite data and indicators are provided by sociology and demography. Independent factors regulating social activities, mainly in the work subsystem, enter from the economic system.

- Arts and culture: the creation and enjoyment of which is a requirement of the human psyche. Although it has not yet been formally described, it would be possible to assess the behavioral response. This functional subsystem may affect the outputs of the political system in both the human environment and the economic system and is in its turn affected by them.

- Services: largely linked with the material subsystems. The basic services are education, the health service,

communal services, transport, communications, distribution, banking and the administrative authorities. This subsystem is mainly influenced by inputs of the political and economic systems through the human environment. Implementation of such services is often regarded as a criterion of the success of a particular socio-economic formation.

Nature itself is not modeled as a system. Instead, factors in the environment affecting man are identified. These are physical, chemical, biological, socio-economic and psycho-social. It is useful to relate them to independent and dependent variables of the human environment.

The main criterion for the model is the quality of survival. In this respect, the environment may be classified into the following categories:

- Destructive: the population is incapable of economic or any other activity and cannot survive.

- Bad: the population has the bare means of subsistence. No activities other than economic. The population can survive but is incapable of improving the environment.

- Adequate: it ensures the material existence of the population and fundamental nonmaterial services but cannot prevent serious scarcities leading to occasional catastrophes. However, since it is interlinked with the other systems, positive development may occur under favorable conditions.

- Good: it enhances the physical and psychical capacity of the population. Environmental advance is scientifically controlled and cannot become negative.

- Unbalanced: population enjoys material security. Differences between groups of population lead to growing demands which can be satisfied only by harming another environmental subsystem. Development is therefore limited.

- Luxurious: material demands are immediately satisfied from vast material reserves, but it cannot survive or develop positively, since it merely consumes and does not produce.

In order to determine this criterion, it is necessary to decide upon qualitative and quantitative indices (standards) and a monitoring and evaluation system. The health status of the population is one of thèse indicators.

The model has not been built as part of an automated control system. All the dependent and independent variables are located in a space and expressed in numerical terms, whether they relate to quantitative or qualitative characteristics. The static and dynamic interrelationships are determined by factoral analysis and multiple regression coefficients, the model being both descriptive and analytic. The model indicates changes in the dependent variables caused by changes in the multifactoral relationships of the independent variables. In this way, it is possible to decide when modifications may improve the state of the whole and when the positive effects would not warrant the effort.

A graphic representation of part of the model is called an environment topogram. It is a description of components of the system which, although it may involve some loss of information, makes it possible to proceed to an analysis of the system's structure and dynamic behavior. Owing to its complexity, it is difficult to break the environmental system down into its basic components or to predetermine their interrelationships. The final goal, however, must be the description of the entire model. The topogram is a static model of reality, but it is necessary to know how changes and reestablishment of a state of equilibrium occur. The solution may be to automate a succession of topograms relating to particular points of time. The analysis of this trajectory of topograms will correspond to a localization in space. The objective may appear modest, but we are still at the beginning of environmental research dealing with a real system of complex access. The first step, which the authors attempted in the period 1972 to 1973, was to create matrices of the incidence and structure of the environmental variables.

The objective of the multiple regression coefficient is to provide the optimal estimate of dependent variables on the basis of independent variables. Factoral analysis endeavors to uncover new variables which explain the interrelationship between known variables. Objections have been raised to the use of factoral analysis but the writers found it a useful tool. The model deals only with quantitative relationships seeking to connect environmental variables through statistically revealed patterns. It has been built and tested by the authors.

It has 16 independent variables, namely: health care, water supply, provision of schools, disposal of waste water, provision of goods and services, collective transport, disposal of communal (solid) waste, air purity, aesthetic quality of the landscape in area under study, housing, work conditions in area under study, afforestation in area under study, climatic conditions of area under study, recreational water areas in area under study, percentage of those living on the land in area under study, population density in area under study. Health status, i.e. the capacity to work, was selected as a dependent variable.

The authors defend their representation of the value of variables on a discrete scale on the grounds that it does not change the character of the relationship between them, that in many cases there is no other way of measuring them and that a uniform system of measurement is required to work out correlation coefficients. They found closeness between independent and dependent variables, indicating the following relationship between four main variables and the independent variables:

- The first variable, affecting provision of goods and services (the commercial system) and work conditions, may be described as human work and services.

- The second variable, affecting the health status of the population, the percentage of those living on the land, afforestation and air purity, may be termed nature and population. (Note that the sign of saturation at a given percentage of those living on the land differs from the sign for other saturation points, i.e. the vector of the second variable is opposite to that of other regression variables in regard to the percentage of those living on the land. This is in agreement with the results of regression analysis.)

- The third variable, affecting the water supply, the provision of schools and housing and the recreational water areas, may be described as technical and cultural supplies.

- The fourth variable, affecting the disposal of water waste, communal waste and collective transport, may be termed engineering supplies.

The results may be interpreted by dividing the initial environmental variables into four groups. But some relationships appear to be only statistical and to have no reason or functional connection and clearly other variables should be sought. The model represents a comparatively open system.

The regression curves indicate how a change in one variable influences the path of other variables and which variable should be improved at any given time to maximize beneficial reactions in other variables.

To assess the state of the human organism and the independent variables, the following scale has been used: very good, good, satisfactory, unsatisfactory, bad, and very bad. In the case of human organisms, very bad would qualify for a disability pension. The dependent variable of health status was found using Cornell's public inquiry on the subject. These data were reclassified in accordance with the above scale, rounding down where applicable. The regression function (partly linear and partly second order), relates to health status, i.e. work efficiency, and has been calculated on the basis of these results.

The regression curve shows that the function reaches an absolute maximum for the independent variables when

X_1 equals 4.1 for health care;

X_3 is at the right edge of the branch for provision of schools;

X_5 equals 3.3 for the provision of goods and services;

X_6 is in the right area of the branch for collective transport;

X_8 equals 4.6 for air purity;

X_{10} equals 3.9 for housing;

X_{12} equals 3.8 for afforestation.

Furthermore, the function attains the minimum when X_{11} equals 2.0 for work conditions.

A methodology has been worked out to determine the health status of the population, the fundamental independent variables and their classification, (for inclusion in topograms), and a collection of programs to adapt the model and its functions to computer TESLA 200 (ES 1021). Finally, the authors have offered an investment strategy for improving the environment by relating the human environment system and its economic surroundings. This strategy is based on optimizing the relationship between the national revenue, working activities and environmental investments. It represents the highest point attainable with the research undertaken to date and it may prove a significant tool for decision making by higher organs.

USSR Automated System of Health Care Planning and Management

V.V. Golovteyev, G.G. Sudarikov, and V.M. Timonin

The economic, social and cultural development of a society is largely determined by scientific and technological revolution. In these conditions the updating of the forms and methods of management to take into account the planned development of socialist economics assumes particular importance.

The State system of health care in the Soviet Union is conducive to the practical application of the achievements of scientific and technological revolution. The health care service of the USSR comprises a set of state-sponsored measures, economic, social, sanitary and therapeutic and preventive, directed toward the prevention and treatment of disease and the creation of healthy working and living conditions, to produce a considerable capacity for work and increased life expectancy.

The health care system is based on a wide network of treatment and prevention, sanitary and epidemiological facilities, dispensaries and other medical institutions controlled by a hierarchically structured administration.

In contrast to a number of scientists (L. Bertalanffy, M.D. Mesarovic, R.L. Akoff, etc.), Academician P.K. Anokhin defines a system as a "set of selected components among which interactions and interrelations take on a character of mutual assistance oriented toward the attainment of a specific and beneficial result". This definition covers the concept of the health care system the functions of which are constantly being integrated or differentiated in the course of development and modernization. It is a complicated dynamic socio-economic system which claims the serious attention of specialists in up-to-date theories of organization and management, the application of systems analysis methods, simulation and the use of computers. The first dynamic model of a health care system was presented by a group of Soviet scientists.

A good deal of research, conducted in developed countries, has proved the advantages of the systems approach and application of computers to medicine in carrying out epidemiological, demographic and clinical statistical investigations by modern mathematical methods.

The work of British, Danish and American authors demonstrates that computers make it possible to select, systematize and simultaneously analyze a number of medical documents relating to a single individual. Specialized computer centers have been established in a number of medical institutions in the USA, Britain, Sweden, Japan and other countries and indeed whole regional systems of centralized medical data processing are being set up.

However, the desire to optimize planning and management of the health care system and, ultimately to establish a statewide medical information system, is much less marked in countries outside the USSR, apparently, owing to lack of a concerted national policy to apply computerization to the health care system, as well as the fact that the latter is not ready for integration.

In the USSR, research has been initiated on modernizing the system of health care management by the application of econometrics, computer techniques and means of communication.

In order to improve management of a complicated health care system, a project has been developed for an automated system of planning and management in the health administration and medical institutions of the country, namely, the Branch Automated System of Control (BASC) Public Health. Systems approach was extensively used in the project. According to J. Gvishiani's definition, "The essence of systems approach consists in studying the most general forms of organization, which presumes first of all investigating the parts of the system and the interactions between them and studying the processes which link the parts of the system to its objectives".

Therefore an analysis was made of the branch as an object of control, the objectives of the system being defined together with its structural and functional characteristics. First the stages in developing the BASC Public Health were distinguished, their effectiveness was assessed and the main trends in technical progress and software development were defined.

Development of BASC Public Health is obviously a difficult and labor intensive task. However, new scientific methods of planning and management must be introduced into the health care system owing to:

- The considerable increase in information about the state of public health and in the volume of treatment and prevention and sanitary and epidemiological measures carried out by health care organizations;

- Difficulties in selecting optimal solutions due to the increasing complexity and scale of the measures organized and implemented by such organizations;

- The increasing cost of a wrong decision when large sums of money are involved.

The existing system of management of the USSR health care service is based on the principle of subordination and control with county (Oblast) and branch subdivisions. The activities of the health care system are exercised at five levels: All-Union, Republic, county, district/city and the medical institution. The management structure consists of the administrative bodies in the: Ministry of Health of the USSR, Ministries of Health of the Republics, county and district/city departments of health, central district hospitals (CDH) (in country districts) and the medical institutions.

This structure has been retained as a basis for the automated system of control (Figure 1).

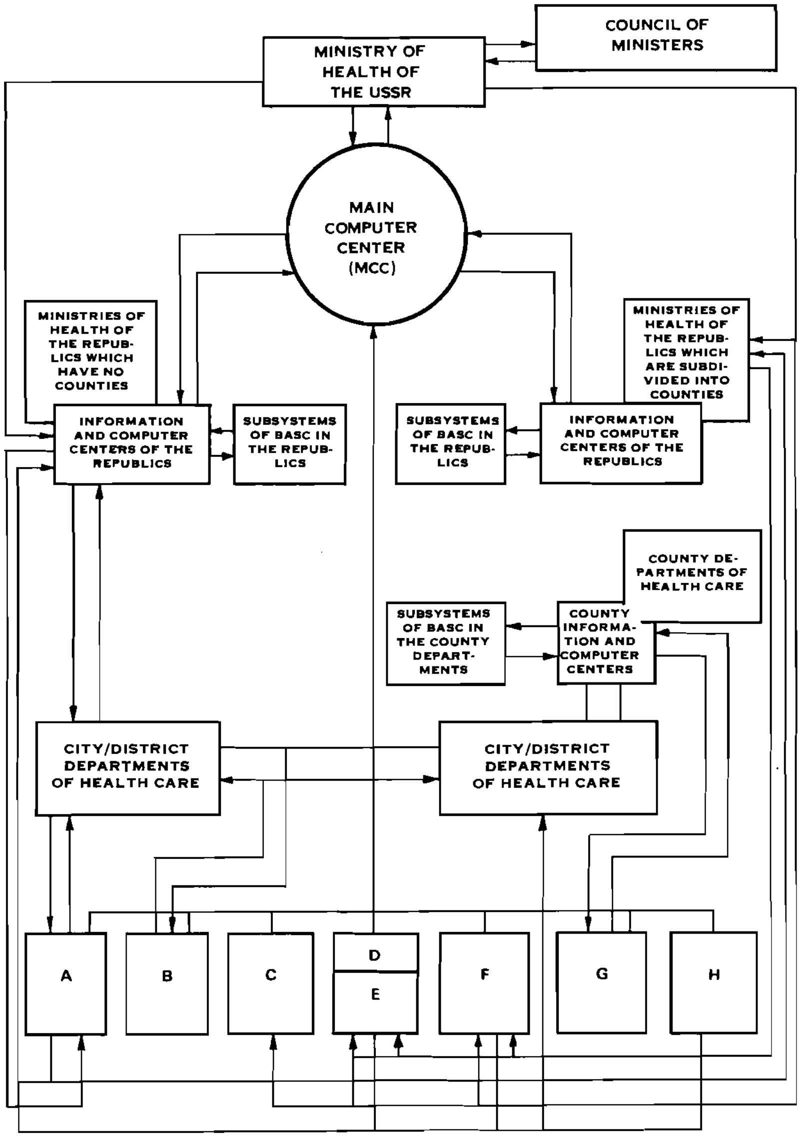
BASC Public Health is a set of subsystems interrelated by both "vertical" and "horizontal" links, in which a wide range of specialists interact with a combination of functional and technical means in the presence of both planned and random factors. BASC has been developed on the basis of matching objective functions and objective charts (Figure 2).

The main goals of BASC Public Health were stated to be:

- The optimal use of material resources and funds allocated by the state for the development of the health care system;
- Planning of effective geographical distribution of hospitals, polyclinics, dispensaries;
- Increased efficiency in the use of available beds;
- Increased efficiency of management;
- Evaluation of the population's health care needs and development of optimal plans to expand the health care system;
- Monitoring the implementation of plans;
- Organization and increased use of medical statistics and economic information.

The system as developed provides administrators at the Ministry of Health of the USSR with the necessary information to achieve the objectives of planning, evaluation and active management and regularly updates reference files and statistical data on the functioning of medical institutions, as required for this purpose.

All the problems to be solved by BASC Public Health are assigned to the appropriate functional subsystems supporting the organizational and functional subunits of the Ministry.



A – MEDICAL INSTITUTIONS SUBORDINATE TO DISTRICT DEPARTMENTS

B – MEDICAL INSTITUTIONS SUBORDINATE TO CITY DEPARTMENTS

C – MEDICAL INSTITUTIONS SUBORDINATE TO ALL-UNION MINISTRY

D – COMPUTER CENTER

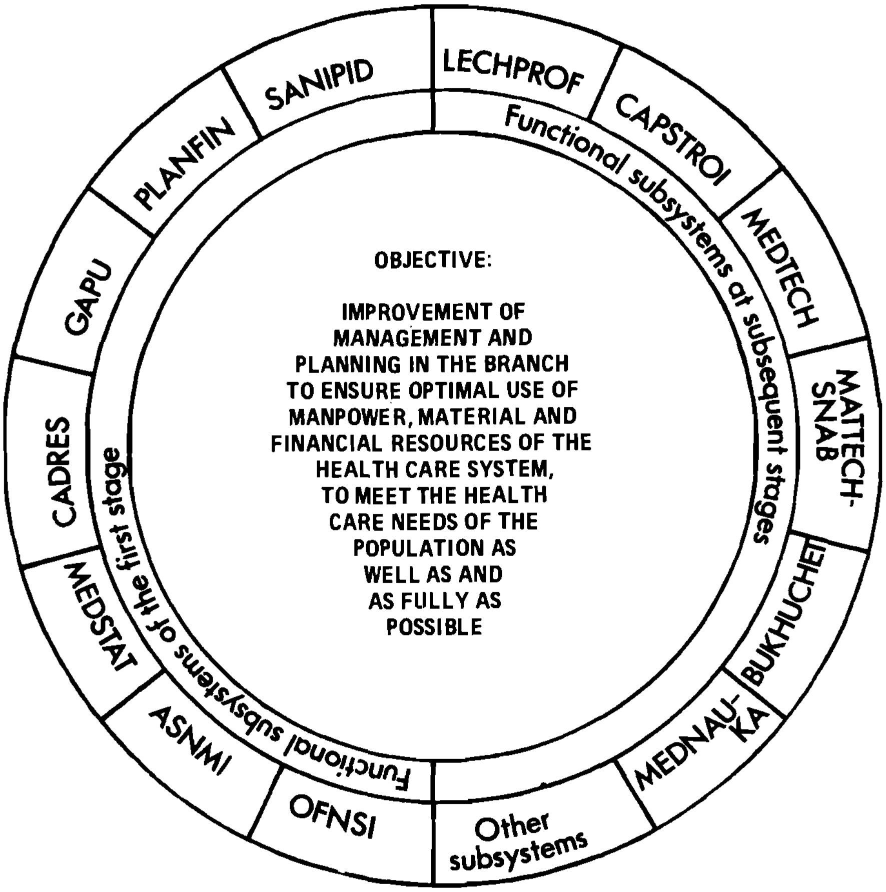
E – RESEARCH INSTITUTES

F – EDUCATIONAL INSTITUTES

G – MEDICAL INSTITUTIONS SUBORDINATE TO REGIONAL DEPARTMENTS

H – MEDICAL INSTITUTIONS SUBORDINATE TO MINISTRIES OF THE REPUBLICS

Figure 1. Branch automated system of control of the USSR health care service (BASC Public Health).



LECHPROF	Management of treatment and preventive care
SANIPID	Management of sanitary and epidemiological care
PLANFIN	Management of planning and financial activities
GAPU	Planning of supply of pharmaceuticals and management of dispensary network
CADRES	Planning and management of manpower resources, records of scientific and managerial personnel
MEDSTAT	Medical statistics
ASNMI	Medical scientific and medico-technical information system
OFNSI	Branch standard and reference bank
CAPSTROI	Management of investment in construction
MEDTECH	Management of supply, installation and repair of medical equipment
MATTECHSNAB	Management of technical and nontechnical supplies
BUKHUCHET	System of bookkeeping and financial control
MEDNAUKA	Management and coordination of research

Figure 2. Chart of objectives in developing BASC Public Health (All-Union level).

It should be noted that to a certain extent this division into subsystems is arbitrary. The criteria used for assigning a group of problems to a particular subsystem are: common targets, similarity in the methods employed, closely related nature of the selected group of problems, etc.

Because of the complexities of development and implementation, BASC Public Health is being developed in stages, by network diagram planning. Functional subsystems (CBMSs*) developed at the first stage included those (Figure 2) responsible for:

- Management of the sanitary and epidemiological service (CBMS Saniped) which is concerned with the management of preventive and antiepidemic measures, and also with carrying out epidemiological analyses and forecasting the morbidity of infectious diseases;

- Financial planning (subsystem Planfin) relating to the setting of targets development of current and long-term expansion projects for the health care system, estimates of expenditures, quarterly financing plans, etc.;

- Planning of supplies of pharmaceuticals and management of the national work of dispensaries (Gapu subsystem). This subsystem has been established: to handle the accounting and distribution of funds for pharmaceuticals and other goods, to monitor the spending of the allocated funds, to record and redistribute above-norm stores of pharmaceuticals, to plan and forecast the development of the network of dispensaries, etc.;

- Planning and management of manpower resources, keeping records of managerial, scientific and teaching personnel (CBMS Cadres). This subsystem keeps a register of individuals, carries out searches with the aid of prescribed tokens, analyses movements and changes in numbers of personnel, and provides information for statistical reports.

The following subsystems are the functional supporting subsystems which supply the Ministries with data and maintain information links between CBMS:

- Medical statistics subsystem (Medstat) carries out the automated compilation of aggregate statistical reports and calculates indices relating to the medical network, personnel and the functioning of treatment and prevention institutions;

*Computer Based Management System.

- The branch data bank (OFNSI) supplies the subsystems of BASC and the subunits of the Ministry of Health with necessary reference material;

- The medical and medico-technical information subsystem searches for and provides bibliographical and factual information on request, circulates to the appropriate bodies information about problems, collects and disseminates to scientists information about research in scientific medical centers.

The activities listed above are also being developed at the level of the Republics. One subsystem has been developed in detail and perfected as a standard model. Republics planning to use these projects carry out the necessary preliminary work and adapt the standard project for each subsystem. Elements of standard projects are also included in CBMS projects at the regional and city levels of the health care system.

As experience of development and practical application is accumulated, the systems for various levels will be expanded with regard to the number both of subsystems and of problems to be handled by them. Attention will be paid to automating the management of investment in construction, management of the installation and repair of medical equipment, supplies of technical and nontechnical goods to health care institutions, bookkeeping, coordination of research, etc.

BASC Public Health operates as a network of health care-oriented computer centers serving the corresponding administrative levels in the health care hierarchy and interacting with one another and with the state system of computer centers. Figure 3 illustrates the hierarchy of automated systems and computer centers used to plan and manage health care.

It is difficult to discuss the system as a whole in a short paper; we will therefore describe as an example of a functioning subsystem of BASC Public Health the management of sanitary and epidemiological care of the population (CBMS Saniped), operating at the All-Union, Republic and city levels (Figure 4).

The automated system of management in the sanitary and epidemiological service is used to improve the supervision of sanitary measures at the national level, to monitor the implementation of plans and to carry out sanitary, hygienic and antiepidemic measures.

The establishment of CBMS Saniped has helped to:

- Increase the effectiveness of the service;

- To bring about more scientifically informed and efficient decision making through organizing, and making

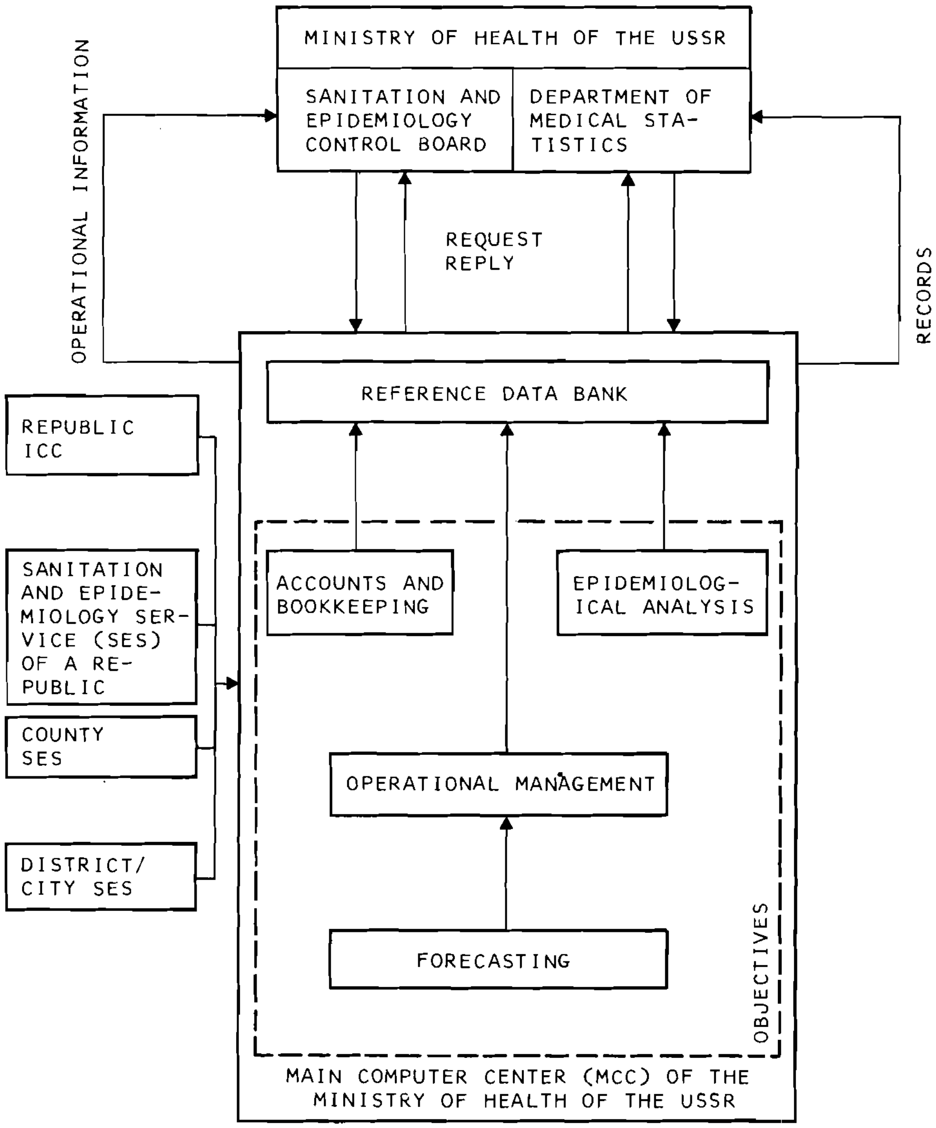


Figure 4. Informational links in CBMS sanitation and epidemiology service of the Ministry of Health of the USSR.

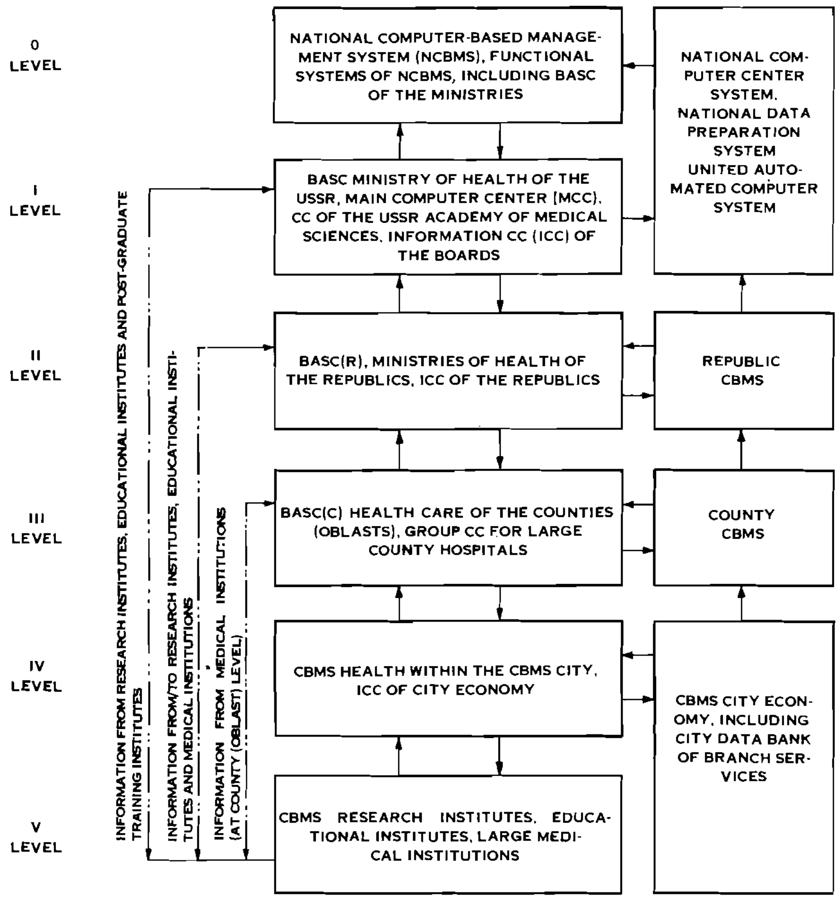


Figure 3. Hierarchy of BASC Public Health and its links with computer systems.

greater use of, available information for the purposes of analysis and forecasting epidemic situations.

The structure of this system is shaped by the problems which are to be solved by the sanitary and epidemiological service; automation is used for recording and compiling reports on morbidity of infectious diseases and on preventive and antiepidemic measures; epidemiological analysis and forecasts; and operational control and monitoring of morbidity.

As its information base, the subsystem uses the data retrieved from reports on changes in morbidity and on preventive and antiepidemic measures. The first stage of the system processes the data and produces over a thousand printouts a year. They show the distribution of various infectious diseases, changes in the ages and occupational categories of the patients, hospitalization and proportion of the population covered by vaccinations and antiepidemic measures. These data are grouped under various registers and are then used for epidemiological analysis and forecasts. The system is a set of several dozen files with direct access to magnetic disks and specially organized data arrays, making the information easy to handle.

The technical base of CBMS Saniped is the RYAD series of computers and a network of nodes for the accumlation of information from the Republics and counties and its transmission to the Ministry of Health of the USSR.

The software of the subsystem was devised for disk storage using the problem-oriented BASIC FORTRAN language and the machine-oriented Assembler language. This software contains 52 programs and has a high level of automation through a special control program.

CBMS Saniped provides information at the All-Union level to the Central Sanitation and Epidemiology Board of the Ministry of Health of the USSR; at the Republic level, to the corresponding government departments and sanitation and epidemiology services of the Republic concerned and at the city level to the city sanitation and epidemiology services.

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The Use of Systems Investigation and Simulation to Increase the Efficiency of Health Care Organizations At Various Levels

V.V. Bessonenko, et al.

The present paper describes investigations on the optimization of health care activities, carried out at various organizational levels in a number of cities in the Union of Soviet Socialist Republics. These investigations employed the principles and methods which have been applied in recent years to the most diverse scientific and practical activities and are known under the general heading of "systems approach". This approach consists of a set of interrelated principles and techniques which reflect the achievements of various branches of science in today's scientific and technical revolution. The basic principles that we used (the principles of totality, hierarchy, structurization, functionality, etc.) are treated in a number of publications which have appeared in this country and abroad [1,2,3, 4,5,6,7,8].

Simulation is one of the most important methods in the systems approach and one of the most versatile methods of looking at the world. We applied two different forms of simulation: the formal logic variant and the real object variant. The first of these requires the construction of a formal logic model of the system under study by using methods of cybernetics, operational research, optimal programming theory, etc., and attempts to find the optimal organization of the object under study by varying the parameters of the model. The second form involves the establishment of a real organization of specific composition and structure and testing its efficiency in practice.

In the USSR, the health care service is an integrated hierarchical system which corresponds at most of its levels to the hierarchical structure of the life and activities of the population (Figure 1).

We used methods of analytical simulation to solve a number of optimization problems at the levels of a treatment and prevention facility, a city health care system, and the health care organization of a Republic. The health care system was modeled at the city level as part of the life sustaining cycle.

SIMULATION AT THE LEVEL OF A TREATMENT AND PREVENTION FACILITY

One of the problems solved at this level was that of optimizing the structure of diagnostic subunits in a large multiprofile hospital.

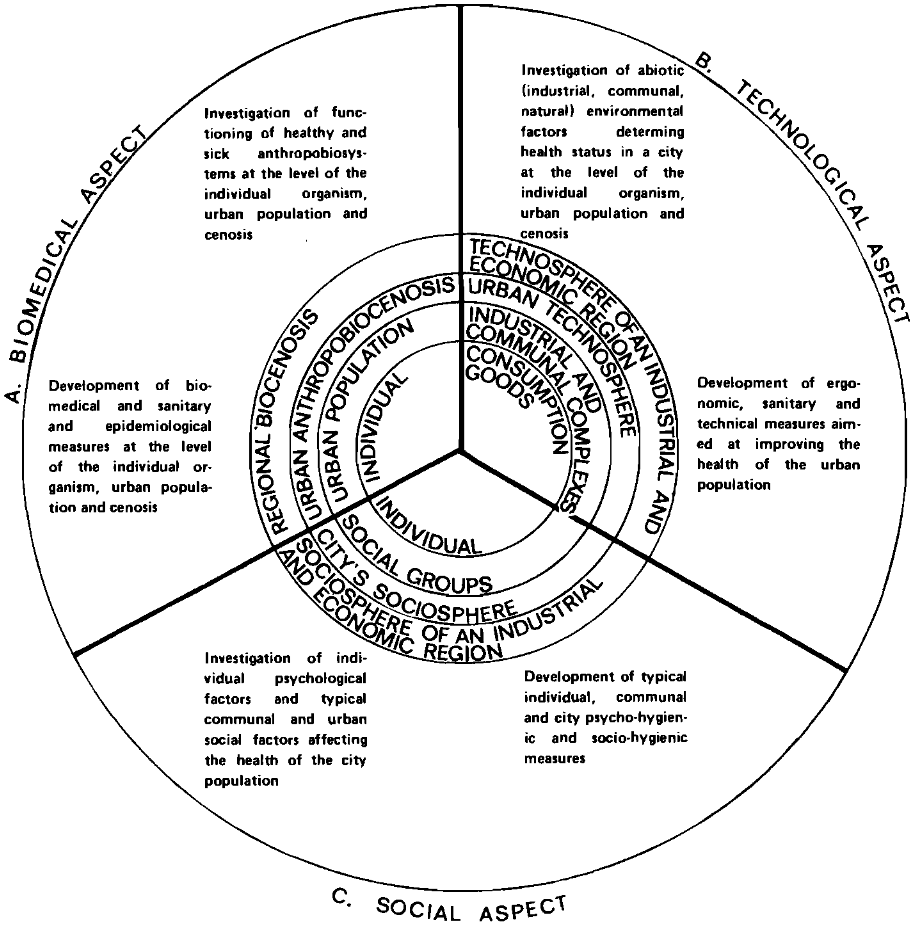

Figure 1. Diagram of a set of measures to optimize the health care system matching the various levels of the population's life activities.

This problem requires solution because it is not proving possible to cope with the increased demands for the examination of hospitalized patients by modern comprehensive techniques, among which biochemical, clinical and hematological investigations play an important part.

In addition, the diversity of structure among large hospitals compelled us to take a hypothetical hospital as a simulation object so that, by specifying the initial parameters of the model, it would be possible to use the results under the conditions obtained in any large multiprofile hospital.

The model was constructed in the following stages:

- Study of the composition of the hospitalized patients as a group;

- Checking on structure and types of diagnostic investigations;

- Study of "technology" of diagnostic investigation;

- Development of a mathematical model of optimal operations in diagnostic subunits;

- Preparation of recommendations for the application of this model to the conditions of any large multiprofile hospital.

First of all, representative bases were selected, account being taken of their capacity, spectrum of specialization, number of treatment and diagnostic subunits, range of staff, adequacy of treatment and diagnostic equipment. The organizational structure of a hypothetical hospital was derived from an analysis of a representative sample from a group of large multiprofile hospitals by using the "primary classification" method.

While studying the composition of the in-patient group and checking the structure and types of diagnostic investigations, plus a study of the "technology" of these investigations, we also processed data taken from 2700 case records; this demonstrated that the functioning of a hospital's diagnostic subunits could be described in terms of the mass servicing theory. Statistical investigation of the basic parameters of servicing--the distribution of the incoming flow of requests, distribution of request holding time, throughput capacity of diagnostic subunits and mean length of queues--led to the conclusion that it was impossible to optimize by analysis the structure of a hospital's diagnostic subunits.

We therefore used simulation. The optimization criterion was stated to be that the mean servicing time for each request should be the shortest necessary if the throughput capacity of diagnostic subunits over a simulated time interval was taken to be not less than the influx of requests over the same period of time. The mean time of servicing for each request is optimal when the throughput capacity equals the influx of demands.

The structural flow chart of the model is shown in Figure 2. It consists of two blocks: a block representing external events, and a servicing block.

The first of these blocks simulates a time-ordered sequence of requests from the main treatment subunits and shapes the net inflow of requests, which is then transmitted to the servicing block.

The second block simulates the distribution of the workload among the various diagnostic subunits, as determined by the algorithm of their functioning. The basic characteristics of the model are also estimated in the same block.

In order to find the steady-state characteristics of request servicing, the process must be repeatedly rerun on a computer and the results obtained must undergo statistical processing.

Since we were required to make repeated calculations to determine the values of the main parameters of the model, we worked out an algorithm which makes it possible to reproduce the original process in terms of its time sequence with acceptable accuracy.

The simulation algorithm consists of two subalgorithms. The first of them simulates the elementary processes and the second takes into account their interaction, combining them in a single process, and ensuring they are matched when played on the computer. The effects of random factors were simulated by means of a random numbers generator.

The second algorithm works as follows:

1. The initial parameters, namely constants and variables, are decided;

2. Variants are modeled;

3. The probable distribution of diagnoses is checked by simulation using Kolmogorov's conformity criterion;

4. The results are analyzed. If the model is loaded to capacity, but there are cases of the holding time for requests exceeding 24 hours, go to step 1; or if the model is idle and diagnostic subunits are underutilized, go to step 1; but if the model is functioning normally, and no cases of overloading or underutilization are observed, go to step 5;

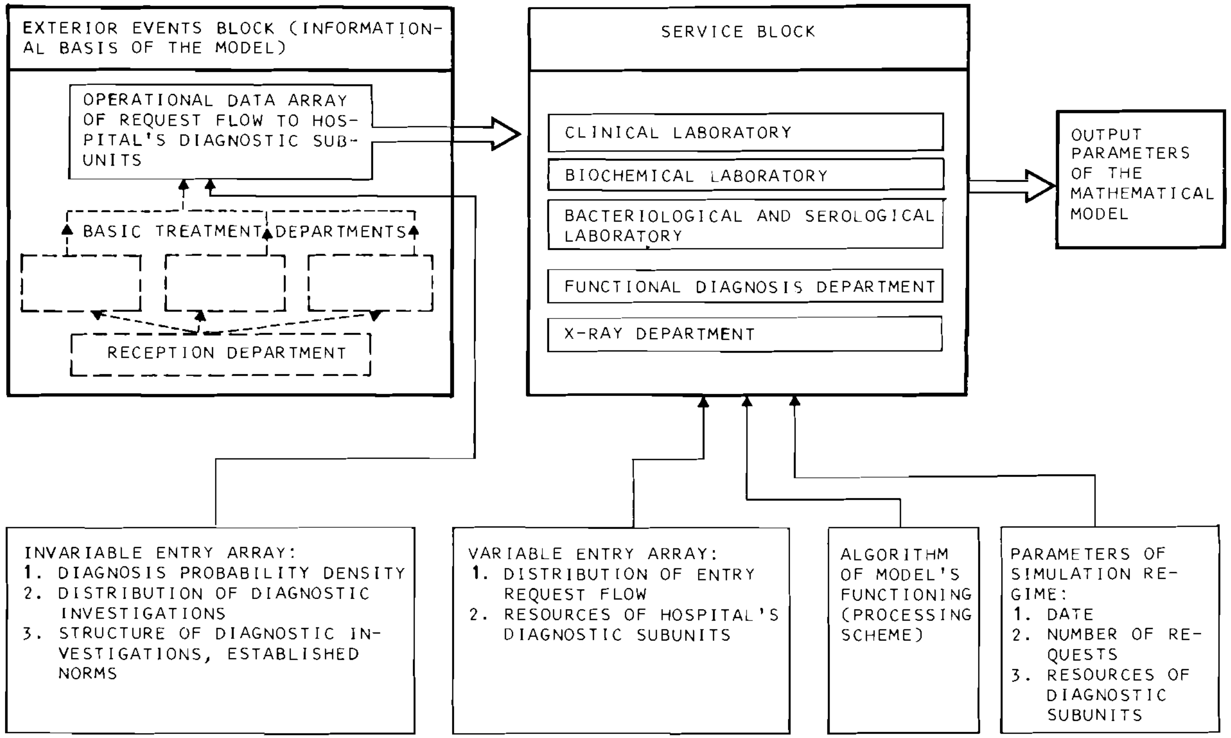

Figure 2. Diagram of the structure of a mathematical model for a large multiprofile hospital.

5. The variant is chosen in which the diagnostic subunits have the optimal throughput capacity.

The model is loaded uniformly throughout the whole simulation, and satisfies the optimization criterion, namely that the request holding time should not exceed 24 hours.

The program of this algorithm consists of nine modules carrying out certain functions in succession.

Module I: Prepares the input of the initial data arrays, starts up the random numbers generator, and gets the model ready to function.

Module II: Covers the final preparations before starting the model. Working fields of the internal and external memories of the computer are cleared.

Module III: Simulates the distribution of requests over the different types of diagnosis (Monte-Carlo method).

Module IV: Shapes the data array. This module produces the array of distribution of diagnostic investigations according to diagnoses; the array of distribution of diagnostic investigations according to laboratory codes; similar array for codes of specialists; a matrix representing man-hours spent on servicing in all the diagnostic subunits.

Module V: Calculates the workload per specialist in all subunits and the maximum time required to service requests.

Module VI: Calculates mean servicing time for each diagnostic investigation, i.e. per request and mean man-hours spent in servicing diagnostic investigations in all the subunits.

Module VII: Calculates the distribution of diagnostic investigations according to diagnoses.

Module VIII: Calculates the distribution of individuals admitted as in-patients, according to diagnosis.

Module IX: Calculates, by using standard programs, the basic parameters of the servicing process.

A preliminary test calculation on the data array for one week was carried out in order to determine the sensitivity of the model to changes in data. It showed that the model was functional and that the maximum daily workload per specialist in a diagnostic subunit, servicing actual request flow, was much higher than the admissible load. It also indicated that the throughput capacity of the subunits was 17.7 percent of the request inflow and the time taken to service demands was between six and nine days.

It was considered that the process of servicing requests might be improved by employing extensive and intensive optimization methods.

The extensive optimization approach was to increase the amount of equipment while retaining the same type of equipment and the traditional methods of servicing. Three variants were run: with fixed resources, with additional resources up to a stated limit, and with unlimited additional resources. Simulation cycles lasting one week were conducted each month throughout 1974. The increase in the average monthly throughput capacity of the subunits resulted in the time taken to service requests being reduced from seven days to one, with the inflow remaining constant at 1333 requests per month. However, that objective was achieved with the third variant when the resources of diagnostic subunits were increased by a factor of 2.2. Such a solution is not the best one in real hospitals.

The same objective was achieved by the intensive optimization approach which consisted of giving the diagnostic subunits automated equipment to carry out the investigations most frequently required, reducing the number of medical personnel and increasing the throughput capacity of the subunits. The fourth variant on these lines was built by using the initial data obtained in the preceding variants, the calculation formulae and the technical characteristics of the selected automated analyzers. It is an established fact that a considerable part of investigations can be automated up to 66 percent, for example, in the clinical and diagnostic laboratory, which combines the functions of the clinical, biochemical and serological laboratories, and as much as 85 percent in the functional diagnosis department.

One study indicated that of the four variants, the fourth variant is most desirable because it uses a ratio between the numbers of specialists with higher and secondary education which coincides with that currently obtaining, namely one to three. This ratio shows a tendency to increase.

A check on optimality using Kolmogorov's criterion proved that the simulated distribution of classes of disease conformed to the initial empirical distribution. It was concluded, from an estimate of improved efficiency that would result from introducing the proposals underlying the fourth variant, that, in the long run, the costs of introduction would be indirectly compensated by higher quality of medical care for the population.

SIMULATION OF AN EMERGENCY HOSPITAL SERVICE FOR A CITY POPULATION

It is known that organizing the emergency hospitalization of patients under modern urban conditions consists of a succession of operations requiring decisions about the method of servicing calls for emergency medical help, selection of transport routes, functioning of emergency medical care teams, need for hospitalization, etc.

Efficient management of an emergency hospitalization service depends on the supply of relevant information. If the necessary information is lacking, decisions are taken on the basis of experience and intuition, because a man in a control system is motivated, first of all, by the need to avoid mistakes rather than the desire to base his actions on the optimal decision in a particular situation. It is therefore necessary to develop a space-time model with the objective of optimizing decision making under the conditions of uncertainty and stress inherent in an urban emergency health care service; this process must take into account a large number of factors including the need for speed and accuracy within given resource constraints.

This objective may be achieved by covering a number of aspects, among which we would stress the optimization of the informational model; the classification of situations and related solutions into routine and nonroutine ones; the definition of internal and external relationships in the system; an agreed level of accuracy for the primary description and computer calculations, as required for decision making.

Construction of the model began with an analysis of the technical chain of processing calls for emergency health care and the means of controlling this processing. Three levels of control were revealed and built into the model. At the first level, the model solves the problems of delivering emergency care to an individual patient, namely, selecting, on the basis of a set of parameters defining the case, the appropriate emergency team, finding the team nearest to the patient, selecting a convenient hospital and the best route to the patient and thence to the hospital.

At the second level, the model solves the problems of operational control: the compilation of schedules showing calls answered by emergency teams, redistribution of teams among substations, etc.

The third level is represented by the problems of planning the activities of hospitalization on the basis of the known distribution of emergency calls over different periods of time and over the city grid.

Since the whole set of problems are common to any system or organizing emergency hospitalization in any large city, the model can be used as a prototype.

THE SIMULATION OF A HEALTH CARE SYSTEM FOR THE POPULATION OF A LARGE INDUSTRIAL CITY

A city is an elementary unit of human society common to all existing socio-economic structures. The objective of simulating an urban health care system is to ascertain its optimal structure and composition. The model is based on the results of a systems analysis of the city as a life-sustaining unit.

First of all, it is necessary to define the objectives and development trends of a city within the framework of a wider socio-economic system.

The objectives and development of an individual city are determined, on one hand, by the need to sustain the life cycles of specific populations, and on the other hand, by the demands of some higher ranking system. This becomes clear in an era of industrial urbanization, when a new city may often be built in surroundings uncongenial to habitation, conditioned by objectives exterior to itself.

The growth objects with exterior objectives, as, for example, large industrial complexes, conditions the growth of life-sustaining objects such as community facilities in the city's health care system, municipal food supplies, transportation, etc.

Human life activities in urban conditions appear to be determined by the degree to which the composition and structure of these systems and the types of relationships between·them ensure a man's complete physical, mental and social well-being.

As a functional approach, the health care system at the city level must include, in addition to health care proper, other elements functionally related to preserving the health of the population. According to this concept, health care is not confined to organizing a public health system; it includes other life-sustaining systems (LSS) and requires their activities to be coordinated in order to preserve public health.

According to the principle of stratified description, a city must be analyzed from three main aspects, namely, biomedical, technological and social.

According to the hierarchical principle, a study is made of the different levels within each aspect; these are shown in Figure 1.

Thus, the biomedical aspect must be studied at the level of an individual organism, the urban population, urban anthropobiocenosis, regional biocenosis. In this way, the data obtained will reflect the complicated relationships which link biosystems at these levels.

Obviously, the characteristic processes at each level have their own rhythm and the time scales required for studying and simulating them cannot be the same in all cases.

The objective of simulation must be to put forward, in the light of the given socio-economic constraints, recommendations about the composition and structure of the optimal health care system to achieve the physical and mental well-being of the individual.

The simulation procedure is based on the axiomatic assumption that the structure of life-sustaining activities of biosystems at various levels (a combination of temporal, spatial, information and resource relationships) determines the composition and structure of the corresponding life-sustaining systems and hence of health care.

In this case, simulation, as a method of acquiring knowledge about life activities and finding optimal LSS must start with information which classifies the factors determining the characteristics of man's life-sustaining activities and covers both their different qualities (illness, health) and different degrees of intensity. Simulation directed at finding a better organization of the health care system (HCS) within the structure of LSS must, in its turn, propose structures of such a nature that phenomena of LSS which are harmful, according to biomedical and socio-hygienic criteria, are neutralized for a minimum period and with minimum expenditure.

The second axiomatic assumption states that the simulation process may begin the study of the life-sustaining activities of biosystems at any level. However, the study must cover at least three contiguous levels, namely, the level under investigation and those immediately above and below it.

Figure 3 shows a diagram of the stages in constructing a HCS at city level.

Studies of life-sustaining activities of biosystems and of the existing LSS and HCS are conducted in parallel.

At the first stage, we classify the abiotic, biotic and social factors of life-sustaining activities and the HCS. This is carried out in conjunction with an investigation of functional objective of the city as an element of an exterior socioeconomic system together with the classification of its interrelationships.

At the second stage, we classify the life-sustaining activities of people at the level of the individual, group and population. At the same stage, the city LSS and HCS are broken down and the types of activities they include are classified. These two sets of classifications are mutually supplementary. For example, classifying the activities of particular objects in the city facilitates the classification of social components in the life activities of various population groups by type of employment within the working community. At the same time, we can estimate the similarity between the functional cycles of LSS objects in the city and biological cycles in the life activities of an individual, group, and population; the methods of eliminating dissimilarities can also be evaluated.

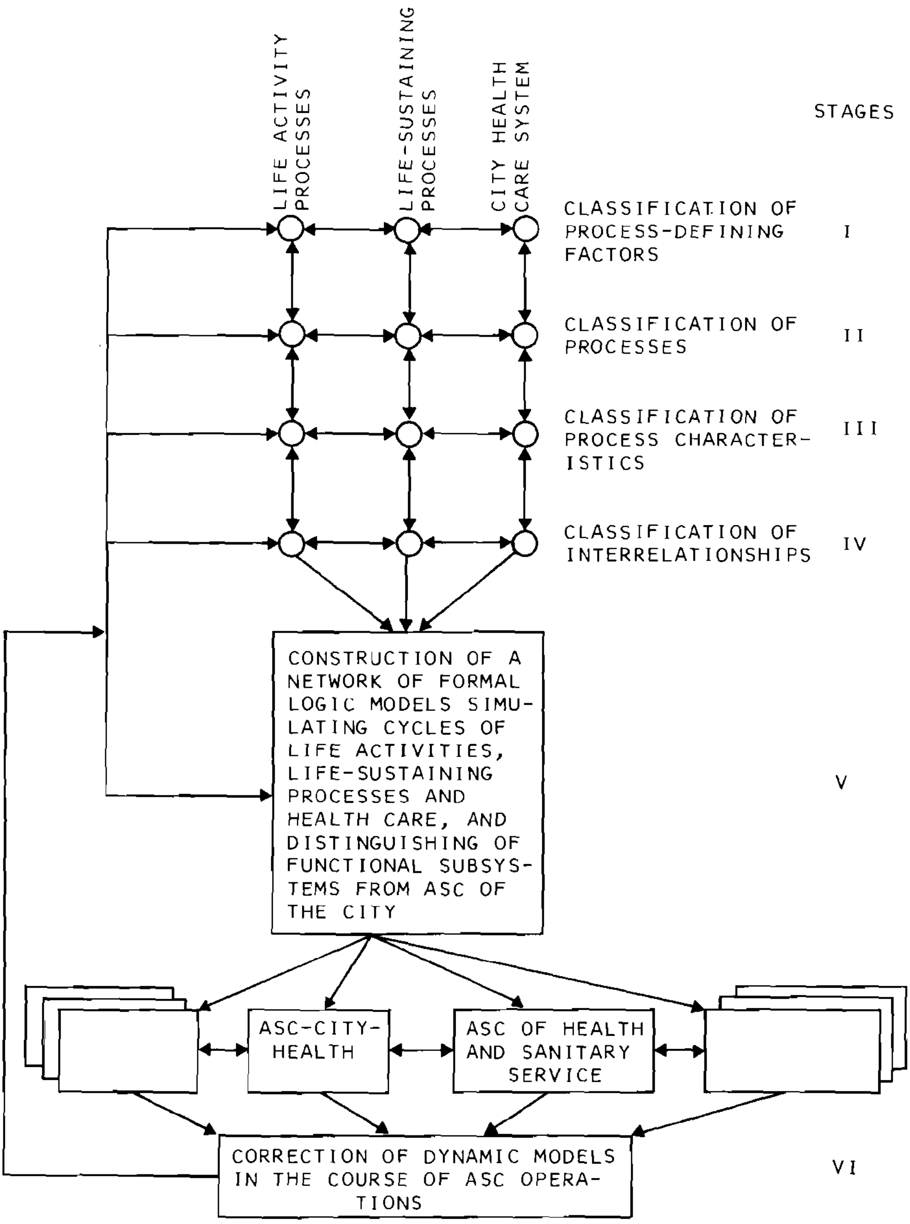

Figure 3. Flow diagram of stages of systems research and construction of dynamic models of the health care system at the city level.

The third stage is devoted to describing the life activities and functioning of LSS and HCS, in qualitative and quantitative terms.

The fourth stage is concerned with the classification by logic and meaning (LM classification) of possible relationships between various components of life activities at all levels and the investigation of relationships (in time, space, resources, etc.) between the types of activities occurring in LSS and HCS.

The third and fourth stages provide the necessary information for constructing formal logic models to describe the dynamic processes in the systems concerned.

The most complicated stage is that of constructing a dynamic model which describes LSS as controlled processes and the activities of LSS and HCS as controlling actions. In constructing the separate elements of such model it becomes evident that it must be a network of more elementary formal logic models. Each of them describes a separate cycle of life activities at each level and the corresponding activity cycle of LSS and HCS. The network of models must reflect the differences in types of control, time and resource correspondence (such as "objective-means", "producer-product", "controlling-controlled", etc.) established at the preceding stages. Naturally, anthropogenetic and social factors of the internal and external media of the city must enter this network of models as disturbances.

This stage is carried out using techniques of multivariate statistical analysis, information approach, and the queuing theory to obtain quantitative estimates of conformity between the states of interacting objects.

Our experience shows that such a network cannot be constructed without using modern means of collecting and processing information.

For instance, investigation of the correspondence between meteorological conditions, atmospheric pollution and morbidity of the population was carried out by the first stage of an automated systems control of the city's HCS (ASC-Cityhealth). It showed that automated systems control of objects in industrial and nonindustrial spheres, in addition to its main purpose of increasing the efficiency of human activities, can and should be used as a tool in working out proposals for optimal LSS and HCS. Therefore, at the fifth stage, the construction of the network of models, distinguishing between the functional subsystems of the city's ASC take place in one block.

The efficiency of such an approach is illustrated by the results obtained by one of the developed subsystems of HCS--the epidemiological service for city populations, included in ASC-Cityhealth [9].

The system is designed in such manner that the activities of the epidemiological service bring together LSS belonging to different administrative branches (municipal food supplies, water supply, etc.).

Development of subsystems to protect the environment and population from industrial pollution is carried out in a similar manner. It involves interrelating studies and practical application in three fields: biomedical, technological and social.

The biomedical aspect involves studying the harmful effects of pollution on man and on the flora and fauna in the city, and proposing a set of medical and ecological measures to protect biosystems from industrial wastes.

The technological aspect involves monitoring the water, atmosphere and soil conditions in the city and its surroundings, detection of sources of harmful wastes and proposing measures to change technology and organize industrial processes with a view to reducing pollution.

The social aspect involves finding social and material resources to carry out the measures listed above, as well as studying the influence of social factors on public health.

The main organizations responsible were assigned to deal with each aspect, namely, scientific and practical institutions of various types, including health care institutions, industrial plants, and social organizations. The need to have within LSS a permanently functioning subsystem for environmental control, bringing together organizations from different administrative branches, made it necessary to establish a special organ to control this system within the Executive Committee of the Soviet of Working People's Deputies.

The subsystem is developed at the city level, by inclusion in ASC-Cityhealth and at the level of individual plants through the automated system of medical and sanitary servicing of the population (ASC-Health). We regard these subsystems as the first subsystems of a future City ASC [9,10].

ASC-Cityhealth is being developed in order to increase the efficiency of health care services by automating the activities controlling health care and coordinating all the organizations in the city responsible for it. ASC-Health works on the assumption that the efficiency of health and sanitary services for the employees of individual organizations is increased by automating both the processes of the service and the methods of controlling them.

ASC-Health is one of the lower-level subsystems of ASC-Cityhealth; at the same time it is one of the central subsystems of ASC-Plant. It is therefore a subsystem that couples ASC of objects in the industrial sphere to that of objects in the non-industrial sphere [10].

Clear-cut information channels are defined for all objectives of these systems. Thus, one subsystem in ASC-Health supplies information to a subsystem "SES" of ASC-Cityhealth on blowouts from spatially distributed sources of pollution, for the purpose of monitoring the state of the atmosphere.

Another subsystem of ASC-Health plans the optimal resource consumption rate, after it has been fixed for longer periods of time by the "Planfin" subsystem of ASC-Cityhealth. Subsystems to coordinate ASC operations in plants provide the requisite advance information to the environment control subsystem to enable it to predict pollution of working spaces and blowouts into the sanitary protected zone, to plan optimal preventive repairs of sewage treatment units, etc.

The use of automated systems control will not only facilitate the process of constructing the network of formal logic models, but will also make it possible to correct models, on a continuing basis and increase their adequacy (stage VI). It should be mentioned that the development of ASC is based on some initial models of self-control by a social organization and of the processes whereby it interacts with other objects. The adequacy of these models therefore determines the degree of possible automation of control processes and the future role of technical methods.

AN EXAMPLE OF MODEL CONSTRUCTION AT THE LEVEL OF THE PUBLIC HEALTH CARE SERVICE OF A REPUBLIC

An attempt was made at the level of the public health care service of a Republic to solve the problem of optimal locations of hospitals in agricultural regions when the optimality criterion is the time of patients' transportation [11].

In selecting the factors determining the geographical distribution of hospitals, the following points were taken into account: the size of population to be served, the standard number of beds per 1000 of population, the area covered by hospital services, the capacity to build hospitals and the average time taken to transport a patient to the hospital; this last factor depends, in its turn, on the distances between settlements, road conditions and the speed of medical transport.

The mathematical model of the problem and the method of solving it are as follows:

if n is the number of settlements in the region where

$$i \in I = 1,2,\ldots,n \quad ,$$

a_i is population of ith settlement and b is the standard number of beds per 1000 of population, then the required number of beds for the ith settlement is

$$b_i = \frac{a_i}{b} \quad .$$

Let $j \in J$, $J \subset I$ be the number of the settlement where a hospital will possibly be built. We define a quantity x_{ij} as follows:

$$x_{ij} = \begin{cases} 0, \text{ if ith settlement is not assigned to} \\ \text{jth hospital,} \\ 1 \text{ otherwise.} \end{cases}$$

Each settlement being assigned to one hospital,

$$\sum_{j \in J} x_{ij} = 1, \qquad (i = 1,2,\ldots,n) \quad . \tag{1}$$

Owing to the limited capacity of hospitals in each settlement having a hospital, the folliwing must hold:

$$100x_{ij} \leq \sum_{i=1}^{n} b_i x_{ij} \leq 250x_{ij} \quad . \tag{2}$$

Let c_{ij} be the time of transportation from ith settlement to jth hospital.

The total time required to transport patients to the hospitals from the settlements assigned to those hospitals is

$$\sum_{j \in J} \sum_{i=1}^{n} c_{ij} x_{ij} b_i \quad .$$

According to the optimality criterion, this expression must be minimized. Instead of c_{ij}, we can introduce the variables $s_{ij} \times v_{av}$, where s_{ij} is the distance from ith settlement to jth hospital, and v_{av} is the average speed at which a patient is transported.

Hence, we arrive at the following numerical linear programming problem

find such values of x_{ij} that the function

$$f = \sum_{i=1}^{n} \sum_{j \in J} s_{ij} x_{ij} b_i$$

assumes minimum value subject to the restrictions

$$\sum_{j\in J} x_{ij} = 1, \qquad (i=1,2,\ldots,n); \; 100x_{ij} \leq \sum_{i=1}^{n} b_i x_{ij} \leq 250x_{ij} \quad .$$

Since with this formulation the model did not include certain necessary economic indices, it was "tuned" at the next stage in accordance with the requirements of integrated regional planning. Corrections were also made for the administrative and economic importance of population centers, and the geographical distribution of industrial plants and agricultural complexes, as well as for the traditional gravitation of people to medical institutions. The optimal version of the plan was compared by means of the reduced expenditures formula with the projects of agricultural regions as developed by traditonal, intuitive methods.

Other criteria of economic expediency were also used, among them specific capital investments, average expenditure per hospital bed per year and the costs of health care transport allocated to a hospital on the basis of standards relating to its capacity.

It is unquestionable that humanitarian factors (a better response to people's needs for health care, its quality, availability, specialization, etc.) must predominate when such problems are being solved, but it appears that economic efficiency in using labor, material and financial resources must not be overlooked either. This is especially true of capital investment in the construction of health care buildings, with their slow rate of amortization.

In conclusion, it should be noted that the principles of systems research and the specific models described in this paper help to increase the efficiency of health care at various organizational levels.

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Systems Analysis and Systems Approach In WHO's Managerial Assistance to Countries

Guido J. Deboeck

INTRODUCTION

Systems analysis is concerned with producing an accurate representation of system elements and their interrelationships, within the precisely defined boundary of a system. This definition has, however, been subjected to a number of interpretations. First of all, it may refer to a descriptive process of analyzing and explaining interrelated elements that constitute a systematic whole, without necessarily using quantitative methods (for example, a descriptive statement of the functioning of the health system). In this interpretation, concepts and conventions of systems theory can be used to gain an understanding of how the structure and processes of smaller and larger systems are built up and interrelated. Secondly, systems analysis may refer to a group of methods to resolve operational problems, using a variety of quantitative techniques, including those of operations research and economic analysis (for example, a cost-benefit analysis of malaria eradication). Finally, systems analysis in its most restricted sense may refer to one or other technique for solving specific and limited problems (for example, an inventory control study of a hospital).

The International Institute for Applied Systems Analysis has inclined towards the second interpretation of systems analysis. In *IIASA: Background Information* it is stated: "Institute interprets Applied Systems Analysis not as a technique or even a set of techniques but as an embracing rational approach to the resolution of complex problems. Applied systems analysis is a framework of thought designed to help decision makers choose the desirable (or in some cases a "best") course of action".

Over the last couple of years, WHO has adopted a similar attitude towards systems analysis and its potential role. Through a process of what might be called planned incrementalism, WHO has developed its own systems approach to health planning and management. Over the last five years, this approach has been applied, with the support of WHO, in numerous countries to various problems. These applications of systems analysis have led to concrete program or project proposals useful in the particular situations, as well as to improved planning or management capability both among nationals and WHO staff members.

The purpose of this paper is broadly to outline the systems approach developed by WHO and to review the applications of systems analysis in WHO's managerial assistance to countries. Furthermore, some experimental applications of systems analysis, which are currently being made in WHO to enhance the systems approach will briefly be discussed.

Although this paper covers a great many of the applications of systems analysis in WHO's activities, it cannot, obviously, present a comprehensive review. Various other applications of systems analysis are being applied within both substantive program areas of WHO, such as environmental health, family health, etc., and its support activities, such as health statistical methodology. The scope of this paper is limited to those applications of systems analysis which, as IIASA defines it, are "designed to help decision makers choose desirable courses of action".

WHO'S SYSTEMS APPROACH TO HEALTH PLANNING AND MANAGEMENT

If systems analysis is not merely a systematic procedure for making choices, but a body of concepts, methods and techniques, then it may be asked in what respects the systems approach evolved in WHO exemplifies the application of systems analysis to health planning and management. In order to answer this question, I shall briefly review the major attributes, concepts and procedures for health planning and management promoted by WHO.

The *major attributes* of the systems approach to health planning and management, as developed in WHO, are the following:

- The health sector is perceived as a system, i.e., its internal organization and processes are perceived as system elements; its relationships with the larger social system are defined and its interrelationships with other sectors are viewed as interactions among subsystems of society;

- Health is seen as a variable subject to multiple-causation; in consequence, health planning and management requires an interdisciplinary approach;

- This interdisciplinary approach to health planning and management has been procedurized, i.e., broken down, into a series of steps, each containing a number of sub-steps that lead logically from a felt need or a discerned opportunity for a planned change in a health system to the preparation of a program and/or project proposal, the implementation of which would accomplish that change;

- The entire process is conceived as an iterative one: processing progressively through the steps, planners and decision makers will need to loop back to earlier steps in order to reconsider earlier assumptions and/or decisions, on the basis of new information entering the planning/management process;

- The procedures for health planning/management employ such techniques as matrix analysis, input-output analysis, scheduling (for example, GANTT and PERT), linear programming, dual programming or shadow pricing, cost benefit/effectiveness analysis, etc.;

- The systems approach developed in WHO incorporates various models of health/disease problems, health services demand and utilization, etc., some of which can be given parameters for computer use. (I shall expand on this attribute later in reviewing some experimental applications of systems analysis in WHO.)

The *key concepts* incorporated in the systems approach to health planning and management, as developed in WHO, are:

- Hierarchy of goals;

- Phases of planning, for example, health policy, program and project planning;

- Management by objectives;

- Economy of resources;

- "National" character of health development; and

- Self-learning by objectives.

In general, the advent of systems analysis and the development of quantitative methods have increased the demand for explicit and meticulously defined goals. A goal is a general term signifying a desired end, which may be the change or the maintenance of a given system. A desired end or direction which implies a space and time dimension, is the first attribute of a goal. A second attribute of a goal is specificity. The term objective commonly denotes desired ends that can be stated more specifically than goals and that contribute to broad goals. A quantified expression of a goal or objective is a target. Measurability is thus the third attribute of goals. In the literature, the terms goals, objectives and targets are often used interchangeably and, unfortunately, inconsistently. In addition to having the attributes of specificity, directionality and measurability, goals should be structured in a hierarchy. In this way, unwritten values and norms may form the peak of the pyramid. Society's aspirations may be stated as goals, while government objectives can be identified as specific intents and directions for action. For each value, there may be many goals and for each goal, several objectives: the whole may be referred to as the *hierarchy of goals*. Adoption of this concept allows both specificity and directionality to be incorporated at any objective level.

More importantly, the measurability of the whole hierarchy is improved since objectives are to be defined in strictly measurable terms. Within each tier of the hierarchy, the goals or objectives may be weighted according to the relative priority derived from higher level values and norms. The result is a clear statement which may be used directly in planning methodologies.

On the basis of a hierarchy of goals, planning emerges as a process containing three logical yet interrelated phases: policy, program and project planning.

- *Health policy planning* consists primarily in developing long- and medium-term goals and parameters. From a consideration of alternative states of future health development in a society, and taking into account the limitations in terms of financial and implementation capacity, a health policy planning process produces regulating principles for a health system, seen as part of a dynamic social system. These regulating principles attempt to optimize the outcome of many conflicting factors without wrecking the health system or its broader social framework in the process. The outcome of a health policy planning process, that is a policy plan, provides the premises and assumptions for health program planning.

- *Health program planning* is that part of the planning process which aims at selecting among alternative health strategies those that can achieve medium-term or strategic objectives, consistent with the values and norms of society and, in case a policy plan exists, with the overall development and health goals of the society as expressed in that plan. Health strategies can be defined as courses of action specifying a selected mix of technology and resources which allow the achievement of one or more strategic objectives. An analysis of the feasibility of these alternative courses of action would then allow the planners to determine those that are compatible with the overall development objectives of a society. The selection of feasible health strategies allows the structuring of health programs. A health program is a schedule of service and development activities requiring physical, human and financial resources for the implementation of a health strategy. Health program planning is therefore primarily the process of choosing between alternative health strategies, and formulating them in one or more health programs, which might identify development projects requiring further detailed planning.

- *Health project planning* is more specific and localized than health program planning. It is closest to implementation and thus focuses on the specification of implementation objectives, implementation activities, a schedule for such activities and a detailed design and format for implementation. Implementation objectives are the desired outcomes of the implementation. Often they are an operational capacity which needs to be built up (for example, additional training of manpower, construction of new facilities, etc.) in order to produce the services considered necessary for the achievement of the strategic objectives. Implementation activities are the specific detailed work that needs to be performed for the achievement of the implementation objectives. The sequencing and estimation of the duration of each implementation activity is necessary to obtain an implementation schedule. The detailed design for implementation is then completed with an estimation of the resource requirements and the selection of an implementation format. Implementation formats can vary from making use of the organization structure of an existing institution for implementation to establishing a new additional organizational entity that alone is responsible for achieving the objectives and undertaking all implementation activities. Between these two extremes there is an organizational format called the health development project which can be defined as a temporary intensive effort to set up and put into operation a new or revised program that will result in the reduction of specific health and/or health-related problems. This intensive effort takes the form of a coordinated set of activities with well-defined objectives and target dates for their achievement. Once the implementation objectives have been achieved, that is, once the operational capacity is set up, the project disbands, leaving the program or service to operate on its own.

These three phases of health planning which are a vehicle for accomplishing change in a health system, can in their turn be considered as a system in which feedback interaction exists between each phase. Each phase of health planning works through intermeshed feedback loops, one reaching upward and one reaching downward, so that phases of planning do not only touch each other but also share feedback loops with adjacent phases.

WHO's approach to health planning and management, which I have outlined, is directed to outcomes, products or results. This may or may not be adequately described as *management by objectives*. Key steps in the entire process are, however, to define policy, strategic and operational objectives and targets. Such an explication of objectives provides the criteria for carrying out evaluation of various results at various stages in the implementation of programs and projects.

Another key concept is *economy of resources*. Indeed, not only the definition of objectives at various levels, but also an analysis of the obstacles or constraints, and the optimization, or selection of the most cost-effective, courses of action, is of crucial importance in the systems approach promoted by WHO.

In this entire process of defining hierarchy of goals, planning in phases, managing by objectives and economizing on resources, WHO has given high prominence to the *national character of health development.* The ultimate aim of WHO's activities on health planning and management is to develop the capacities *within* countries to clarify for themselves the reasons for their own health underdevelopment and to decide themselves, through a process that is both rational and consonant with their own culture, on the most appropriate policies, programs and projects for developing the health of all the people.

Complementary to this, is the concept of *self-learning by objectives* which is the key element of the approach WHO is adopting for the transfer of its systems approach to health planning and management. Self-learning by objectives is a concept of the systems approach to education, whereby each participant in a teaching-learning process sets his (her) own objectives in terms of cognitive understanding and affective and/or psycho-motor behavior he/she would like to achieve. These educational objectives are then used to evaluate performance and further enhance the teaching-learning process.

To date, WHO has developed procedures for the formulating and implementation of health projects (Bainbridge and Sapirie, 1974). Working guidelines have also been prepared for country health programming. These guidelines have further been explicated into procedures for health program planning and project selection (Deboeck and Piot, 1975). No formal set of procedures has yet been developed for health policy formulation. However, such development is mentioned in the current draft of the Sixth General Program of Work of WHO for the period 1978-83, which is being prepared by the Executive Board for presentation to the 29th World Health Assembly in 1976. An outline of the major steps in the existing set of procedures is given below.

The *major steps of health program planning and project selection* are (see Figure 1):

- Collection and analysis of information;
- Definition and selection of priority health problems in the overall socio-economic development context of a country;
- Setting medium-term strategic health objectives;
- Formation of alternative health strategies or courses of action by specifying activities, resource and organization requirements for the attainment of the selected objectives;
- Testing the technical, institutional and financial feasibility of the alternative health strategies;
- Formulation of health programs and selection of health development projects, including their economic, social and political appraisal.

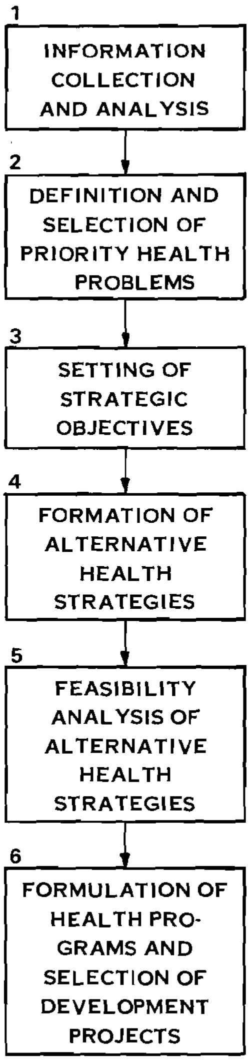

Figure 1. Major steps in health program planning.

The *main steps of project formulation* (see Figure 2) and its rationale can be summarized as follows:* A chartering entity, customarily at high governmental level, organizes a formulation team and provides its terms of reference, including time frames, expected products, resource and problem parameters, and authorizations necessary for the accomplishment of its work. The formulation team plans its schedule and work methods and arranges to obtain needed data in the course of step 1. Situation analysis, steps 2 and 3, may be accomplished sequentially or in parallel, both being concerned with the collection and organization of data on specific subjects, the difference between the steps being in the nature of the data, whether they are descriptive of the community situation or descriptive of the organization, policies, programs, procedures, resources and applied technology that constitute the social response to that situation. From these data, the procedures in step 4 lead to a definition of problem(s) and a future projection of the situation, on the assumption that existing trends would continue without changes in the relevant systems and their policies. Step 5 consists essentially in defining immediate objectives and translating these into the types and amount of services (operational targets) that would have to be provided at various future times in order to reach the objectives. Before moving on to define strategies, step 6 calls for the identification, analysis and ranking of deficiencies in the health and supporting systems and the obstacles to be overcome in repairing these deficiencies. The key sub-steps in designing strategies (step 7) are to make the criteria for strategy design explicit, to outline and select feasible strategies, to assess their implications in costs and resource requirements and to revise either or both the targets and the strategies under consideration in the light of the assessment. From this point, the process moves to defining the project (step 8) its objectives, activities, expected outcomes, schedules and implementation approaches, and required resources aimed at improving the capability of the health system to reach the objectives of reducing the identified problems. In the final step (step 9) the products of earlier steps are reassessed, synthesized and documented in the form of a project proposal.

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*One key assumption underlies the project formulation procedures as they are currently presented in *Health Project Management*. The assumption is that if the national setting is one in which neither detailed policy formulation nor health program planning has taken place, the early steps of the method are so designed as to enable the formulators (and decision makers) to fill these gaps. The implications of the assumption are two-fold: (1) In situations where such planning has *not* taken place, the formulation procedures provide useful guidance and support to such planning *as part of* project formulation. (2) In situations in which such higher-level planning *has* taken place, the analytical and general design steps would be considerably shortened, and more focused and specific in content than the procedures now indicate.

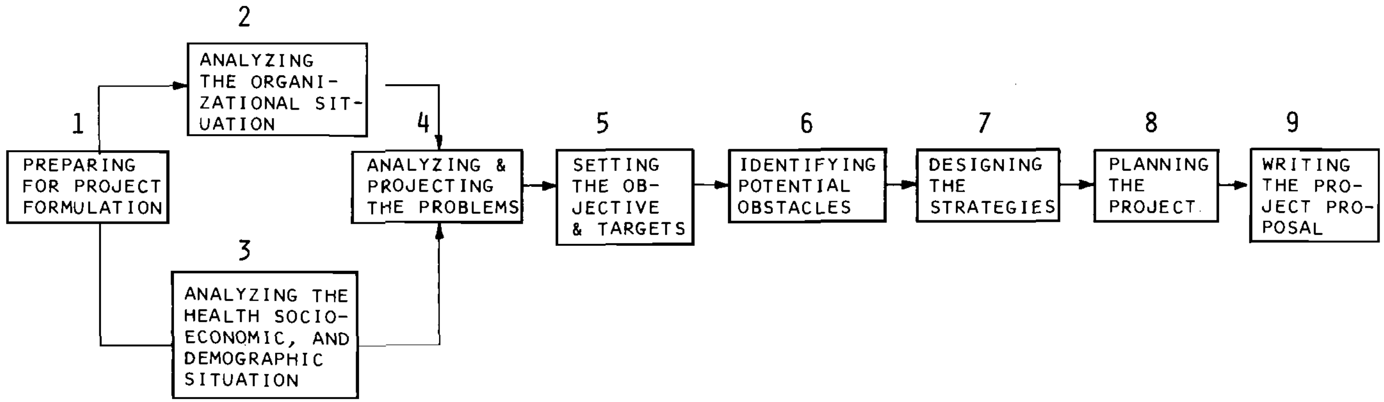

Figure 2. Project formulation steps.

The *procedures for project implementation* (see Figure 3) are based on the assumption that the project has been, or will be, approved, but that, during or after the decision process, changes--whether of time, resource factors or sequence--will require adjustments to the project plan. Such adjustments, along with the selection of key personnel, making of necessary agreements and approval of short-term budgets constitute the project initiation, step 10. Prior to settling an organization, step 12, and obtaining a full complement of resources, step 13, the implementation scenario calls, in step 11, for detailed and specific analysis of the work to be done, the relationship of the roles undertaken by the people who are to carry it out, and a definitive schedule based on work analysis. As these three latter steps are being accomplished, the project's control system can also be designed and put into effect, step 14. Controlled execution of project activities follows, step 15, with prompt identification of hitches, the taking of action to remedy deviations by adjusting resources, methods and schedules and provision for necessary communications. The final procedures specified, at step 16, pertain to the termination of the project, including specification of responsibilities for future action by those in the ongoing organization.

APPLICATIONS OF SYSTEMS ANALYSIS IN WHO MANAGERIAL ASSISTANCE TO COUNTRIES

In the early seventies, WHO concentrated on the analysis of existing health projects in countries. An in-depth review of WHO project experience indicated that the primary factor contributing to the success of a project was the existence of a well-planned *national* undertaking. This was considered so significant that the highest priority was given to the realization of improved project formulation techniques in the form of a set of procedures suitable for use, first, by national health administrators. In the course of reviewing project experience, WHO attempted to identify the characteristics of a well-planned project. Procedures were then developed and tested that were felt to be capable of reproducing these characteristics.

Since 1970, the project formulation procedures have been formally applied in a number of countries, as shown in Table 1.

The essence of the approach adopted for application has been to develop and test successively refined versions of the project formulation procedures in actual project planning situations, chartered by the national authorities in various countries. Each experience produced a real product of use to an interested national health administration. Furthermore, each such experience helped bring the procedures closer to reality, and what was learned was fed into the procedural documentation.

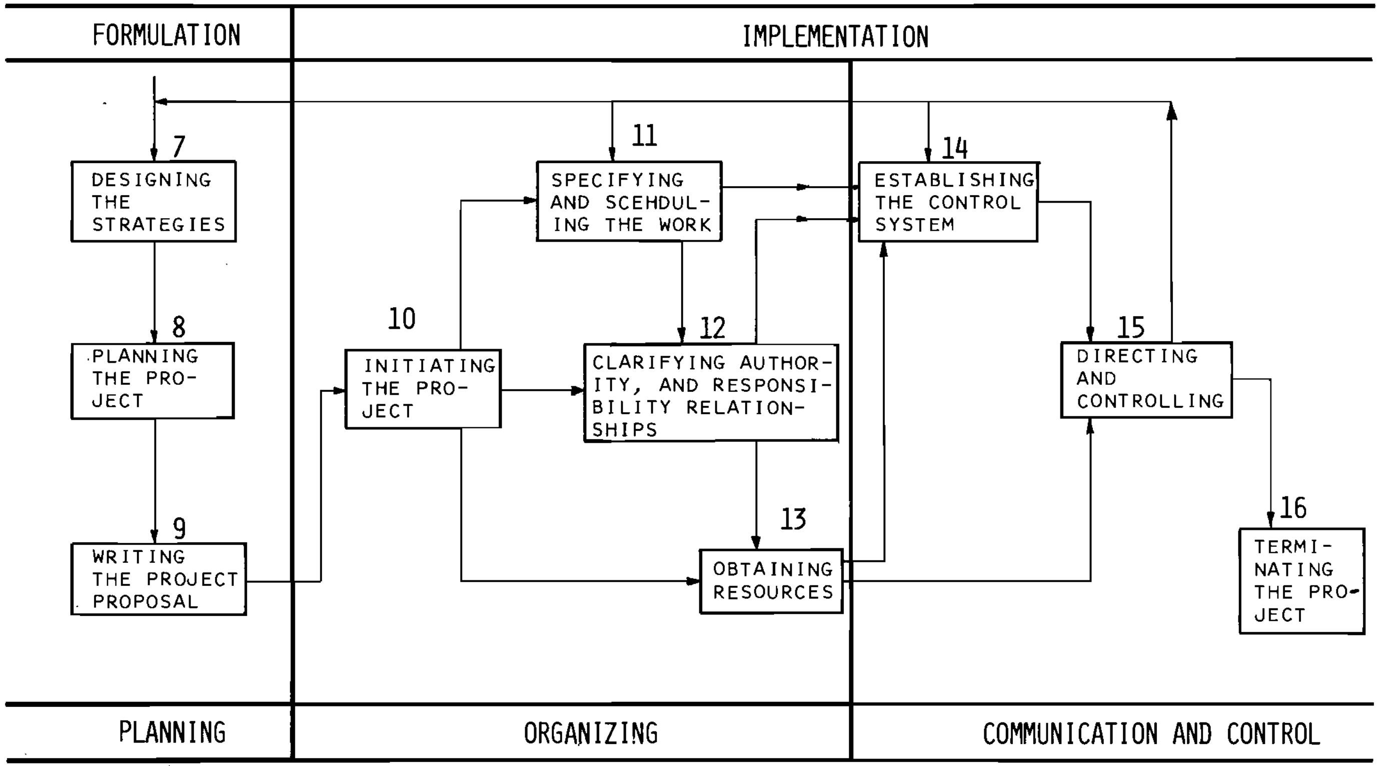

Figure 3. Project management steps.

Table 1. Application of project formulation procedures 1970-73.

Country	Date of Application	Subject
1. Malaysia	October-November 1970	Rural Health Services in Land Development Area
2. Costa Rica	May-June 1971	National Maternal and Child Health Program
3. Philippines	November-December 1971	Medical Care Development in Rizal Province
4. Singapore	January-February 1972	Health Information System Development
5. Malaysia	March-April 1972	Rural Health Services in Land Development Area
6. Kenya	June-July 1972	National Improvement of Rural Health Services and Training Program for Rural Health Service Staff
7. Thailand	October-November 1972	Health Services Development in Chonburi Province and Establishment of Provincial Health Planning System
8. Indonesia	January-February 1973	Rural Water Supply Development in West Java
9. Nigeria	July-August 1973	Sokotu State Maternal and Child Health Project
10. Scotland	September-October 1973	National Child Health Program

Evaluation of the application of project formulation methodology in ten country situations showed the need for, on the one hand, more systematic selection of health development projects and on the other hand, better project implementation.

Development of procedures for project implementation was started early in 1973. As compared with the project formulation procedures, those for implementation are presented in less prescriptive, more conditional terms. Project implementation is indeed more constrained and shaped by ongoing country administrative practices and conditions, than project planning. The procedures for project implementation have been tested in Malaysia, Kenya and Thailand.

Since health development projects are of limited duration, undertakings intended to build up a capacity for the delivery of services through programs, the development of systematic methodology for project selection could not be separated from the development of a methodology for the formulation of health programs. An approach similar to that discussed above was adopted and working guidelines for Country Health Programming were developed and tested successively in various countries, as shown in Table 2. These applications lead next to the development of procedures for health program planning and project selection.

Table 2. Applications of country health programming 1973-75.

Country	Date of Application
1. Bangladesh	August-September 1973
2. Nepal	March-April 1974
3. Pakistan	January-February 1975
4. Thailand	January-February 1975
5. Sudan	March 1975
6. Congo	April 1975
7. Algeria	April 1975
8. Laos	April-May 1975

As a result of the application of Country Health Programming, health development projects were identified which required detailed formulation. Some countries have subsequently applied WHO's project formulation procedures to produce the required detailed project proposals. The most recent applications of project formulation procedures are summarized in Table 3.

OTHER EXPERIMENTAL APPLICATIONS OF SYSTEMS ANALYSIS IN WHO

It is important to stress that in all of the programming, project formulation and implementation efforts discussed earlier, *national* participants played the major role. The role of WHO staff members supporting each of these efforts has been to provide methodological assistance in planning and management. Furthermore, their role has been to further develop managerial skills in national public health administrations. In order for WHO to fulfill this function effectively, both the procedural documentation and the workshop material prepared for training have played

Table 3. Applications of project formulation in follow-up to country health program.

Country	Date of Application	Outcome/Proposals
1. Pakistan	May-June 1975	National Population Planning
2. Thailand	May-September 1975	Among others: - Provincial Health Care - Health Manpower Development - Rural Environmental Development - Management Information System
3. Nepal	May-September 1975	Among others: - Health Information - Nutrition and Goitre - Water Supply and Sewerage - Integration of Basic Health Services
4. Sudan	November-December 1975	- Primary Health Care, Southern Region

down systems, concepts and jargon. In order to make them more intelligible and reduce the use of unfamiliar terminology, the systems concepts and techniques I discussed earlier are now embedded in the procedures. Management games, simulations and the use of heuristic techniques are implicitly included in workshops and actual applications. However, at the same time, more sophisticated applications of systems analysis are being pursued in WHO in order to develop further procedures and training materials. Two examples of such experimental applications, which are relevant to health planning and management, are the development of an intersectoral model and of interactive modeling capability for health care systems.

The development of an *intersectoral model on health and socio-economic development* was started in WHO to aid the planning process, and in particular to explore simultaneously the intersectoral and intrasectoral aspects of the health system. This model consists of a population model, a simplified economic model, some selected social indicators and a health sector model. The different components of the model are represented by selected indices and structural relations between them. Some relationships have been obtained from literature and some from analyzing cross-national data; others are from national or regional data. The model is aggregated in scope and is addressed to the development of basic health services on a regional basis for developing countries. The model can be used for medium- and long-term planning of health services. It provides a demographic projection of a country, taking into account the changes in fertility and mortality rates due to changes in social and economic conditions; on this basis, it projects the population to be served by the health system. In addition, it relates the growth of resources in the health system to the growth of resources in the economy. Considerable work remains to be done in order to make the model more flexible and specific. This, however, refers less to modifications of the structure of the model than to the exploration and incorporation of additional relationships between socio-economic and health problem indicators, between health objectives and interventions in the health system, and relationships between interventions in the system and health resource constraints. Furthermore, an approach has still to be devised to make this model easily accessible to national public health administrators and adaptable to any particular national situation. The work on this intersectoral model of health and socio-economic development is in abeyance pending a policy decision on modeling.

Another experimental application of systems analysis in WHO is the *development of an interactive computer modeling capability for health care systems.* Initial steps towards creating such a capability in WHO have been based on Conversational Modeling Language (CML). CML permits the definition of interactive computer languages which allow mathematical and simulation modeling to be split into two phases. In the first phase, a decision maker and a CML programmer analyze a given problem and determine the general class of models into which the problem can be fitted. The programmer than creates a CML program to simulate this general class of models and extends the CML language to include new statements that the decision maker may use to specify a particular model within the general class. In the second phase, the decision maker, now a programmer in this special purpose language, can specify alternative structures *and* parameters and simulate or optimize the results for each. In WHO's first experimental application of CML, a general class of resource allocation models for health program planning, called HPMOD, was developed. HPMOD is a model primarily designed for the simulation of alternative allocations of resources and their optimal allocation among health programs and development projects. The basic logic of the model considers a set of health and health-related conditions described by incidence rates with respect to each of several described populations. These give rise to discrete classes of eligibles to whom service activities may be delivered. Service activities utilize existing resources and might require additional resources. The additional required resources absorb the outcome of development activities (for example, training of manpower). The service and development activities generate, respectively, recurrent and development expenditures. The effects of delivering service activities on population growth and/or future incidence of any condition can be taken into account explicitly. Two solution modes are available for dealing with HMPOD. In simulation mode, the user specifies the level at which each service activity and development activity is to be carried out. The model computes the consequences over some specified time horizon. In this way, the effect on population, mortality, births, incidence of any condition, resource consumption, facility utilization and the like can all be predicted, given complete specification of the coverage and distribution among facilities of the various activities considered within the model. In optimization mode, the service and development activities are left free to vary. Measures of effectiveness can be specified as a function of the service activities delivered. The selection of service activities and resultant development activities is motivated by the objective function based on values specified by the user and constraints such as budgets, minimum and maximum coverage with health services to be achieved, etc. The model then computes as in simulation mode, the consequences over time of delivering an optimal number of health services. Other experimental applications of systems analysis are at present being made in the Regional Office of the Americas/PAHO, which recently obtained an interactive conversational modeling capability. In WHO Headquarters, further experimentation with CML is in abeyance, pending a policy decision on modeling.

CONCLUSIONS

I shall make no attempt to assess at this stage the systems approach developed by WHO for support of health planning and management nor shall I express my personal opinion about the applications of systems analysis in WHO's management assistance to countries in view of the fact that such an assessment is contained in the terms of reference of a WHO Expert Committee on the Application of Systems Analysis to Health Management, held in Geneva from 16-22 December, 1975. Furthermore, this Expert Committee was requested, on the basis of past experience, to "advise WHO and its member countries on the possible fruitful directions for the future, in relation to whatever potential the application of systems analysis may have for national health development".

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Methodological Approaches to Mathematical Modeling of Health Care Management in a Large City

V.M. Timonin

From the viewpoint of cybernetics, the health care service of a large city is a complex multidimensional dynamic and probabilistic system comprising many interconnected objects of management. The main structural element of this complex system is the medical institution, either therapeutic and preventive or hygienic and preventive [1,2]. There are numerous types of medical institutions corresponding to a variety of functions (Figure 1).

A tentative analysis of various studies carried out both at home and abroad, e.g. [2,3,4], shows that use of modern management methods, econometric methods, systems analysis and computer technology in the planning and management of a city health care service is considerably more difficult than using such methods for diagnostics, medical experiments, social hygiene and medical statistics.

This can be partly explained by the fact that management of a city health care service encounters such difficulties as high population density, migration of population, existence of large-scale industries and institutions, existence of various specialized medical institutions, heavy traffic, large areas to be serviced, etc.

From the systems analysis viewpoint, a city is a structured set of externally-oriented subsystems, the city population and life-sustaining subsystems.

A city health care service is a complex set of medical institutions with a complicated network of interconnections at the horizontal level but at the same time it is a subsystem of the higher-ranking regional, Republic and All-Union health care systems (the vertical functional interconnections). This fact accounts for the diversity and number of problems to be solved at the city level.

Moreover, it is very difficult to formulate mathematically the problems encountered in health care planning and management.

Hence, it can be stated that in the immediate future the task is to develop and apply standard systems of city health

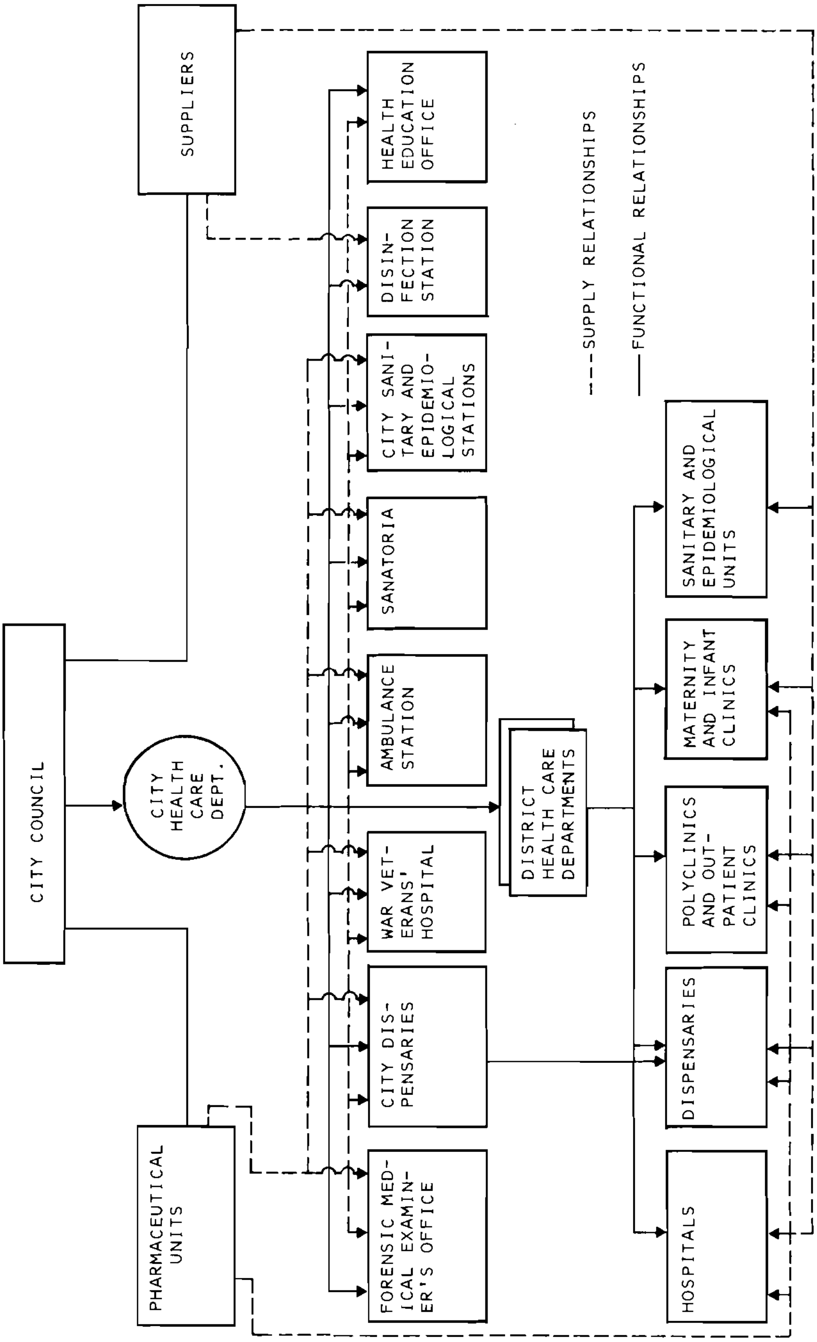


Figure 1. Supply and functional relationships of medical institutions.

care. The first step is to develop standard functional modules, such as modules for the management of patient hospitalization, the sanitary and epidemiological service, hospitals, transport, and medical and technical centers. For large cities with a population of a million or more, a set of interconnected models and algorithms for the planning and management of the health care service should be developed. This will eventually lead to the development of an automated system of control.

When developing the above mentioned set of models and algorithms, planners must take into account possible future changes in the structure and functions of the system due to fundamental discoveries in the field of social hygiene and biomedicine to ensure that certain activities will not become obsolete during the period covered by the plan. Adherence to the concept of preventive medicine is essential in long-range planning.

Analytical and synthetical methods have been developed within the framework of operations and systems analysis which are widely used to carry out complex projects in various industries [5,6,7]. Most of the problems solved with these methods and techniques are similar in form to the problems of a city health care system.

If we consider the management of a city health care service in terms of systems analysis, we should take into account the relationships between the medical institutions and other medical services in order to analyze all the problems encountered. Attempts to divide the system into its constituent parts without taking into account the dynamic relationships between them will yield detailed solutions for individual aspects of the problem rather than for the problem as a whole. Management of the system consists, essentially, in purposefully bringing all its modules into a state which contributes to the overall goal of the system.

The following are the fundamental concepts employed in development of a set of optimum management algorithms (Figure 2):

- Application of the concepts of systems analysis to the analysis and synthesis of the multistage system of health care management;

- Setting up an integrated information base by using medical statistics and economic data and the norms of the entire system for a one-time input of data and by grouping data according to date and management level, for repeated subsequent use, i.e., an automated data bank (Figure 3). An integrated information base is required owing to the interrelationship between all the management problems in the health care system. Hence, the results obtained in the solution of certain problems must be used for solving other problems without additional data input or changes of data;

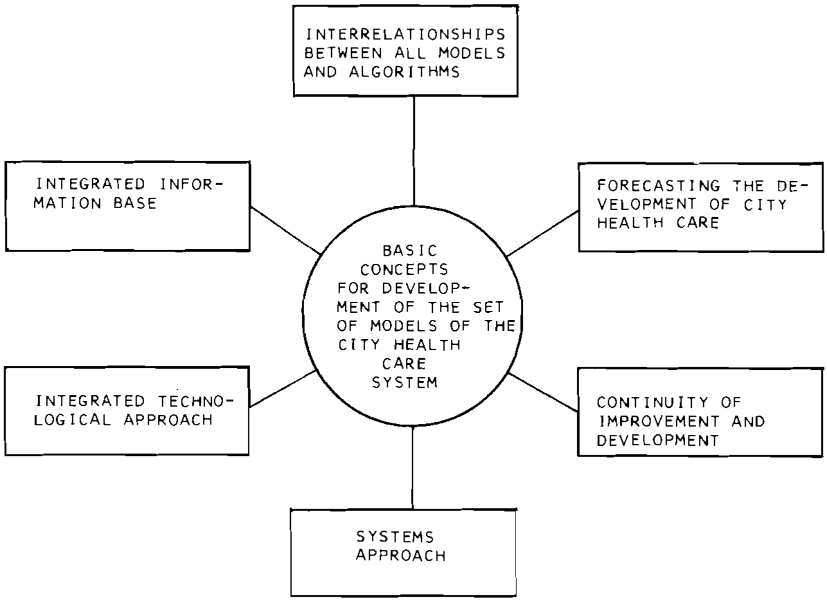


Figure 2. Basic concepts for modeling city health care.

- An integrated software system which allows for the interdependence between all the algorithms and models of the system;

- Use of standardized, compatible modular blocks;

- Development of models which make provision for future trends and developments in community health and medical science. Thus, the planners must take into account morbidity forecasts, estimates of future demand for basic health care, existing trends in hospital construction, the likelihood of general medical screening of the entire population, etc.

- Continuous improvement and development of the system in response to new health care problems.

The system should evolve in two directions:

- Continuous improvement of the methods and means of management;

- Continuous renewal of the elements and equipment of the system.

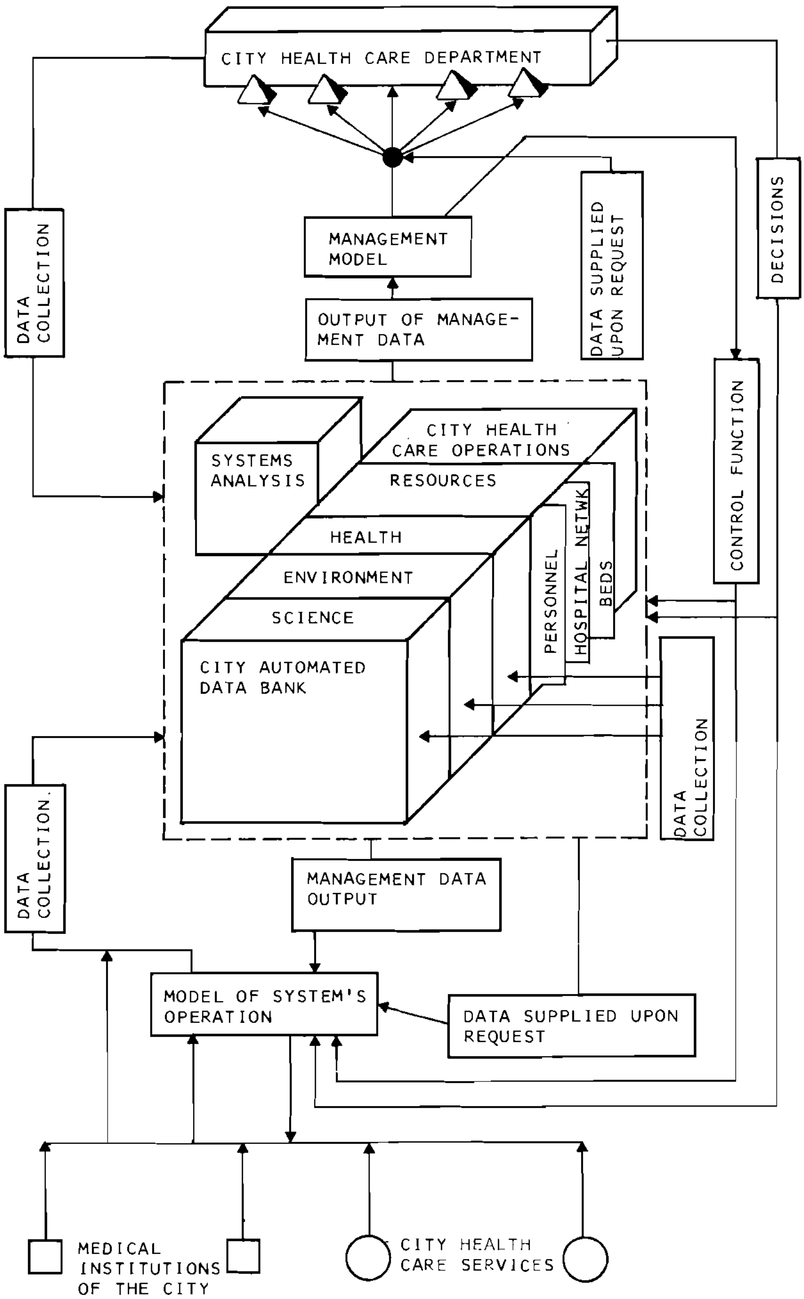


Figure 3. Automated data bank.

Thus, the final model of the system should provide for the possibility of future additions to its functional modules and of its adaptation to systems of management at other levels or in other fields.

There are two possible approaches to simulation of city health care management as for any health care system: 1) development and analysis of a global model of the city health care system reflecting its primary purpose, that is, to regulate the system in order to ensure its optimum operation under urban conditions; 2) development and analysis of the functional models in order to solve specific problems and subsequently to synthesize them to produce an integrated system of management.

The first approach makes it possible to construct a model of optimum structure and operation since it eliminates the contradictions between local criteria and the criterion of the global model. As has been demonstrated by experiments, this approach is impracticable at present, especially in the case of a city system with three management levels and a number of functions at each level. It should be added that each function of the system comprises a set of tasks and each of the tasks requires its own algorithm. However, a general model must be developed since it will contribute to shaping the general development strategy of the system and to integrating it as a structural unit into the system of management of the All-Union health care service.

The second approach consists in developing partial models and subsequently synthesizing them into a comprehensive global model; such partial models can be developed for the three management levels, namely, medical institutions (polyclinics, hospitals, etc.), medical services (ambulance service, epidemiological service, etc.) and health care administration (district health department, city health department), but this is also a complicated matter.

Moreover, the second approach is not without drawbacks. For each model there is a considerable array of input data; at the same time, the output is very specific. Moreover, stage-by-stage optimization does not guarantee that the optimum will be achieved for a global model. It is also difficult to maintain the interrelationships between the models, that is, in some cases the results obtained while solving certain problems can hardly be utilized for solving other problems. In such cases the data services should be centralized; this can be achieved by developing a system of time-space indicators which can be substantiated on economic grounds to facilitate a more efficient management of the city health care service.

Clearly, the system of indicators cannot be the same for all the three levels of management in both the horizontal and vertical direction [1].

Hence, to develop a global model, we have to design a set of partial specific models to yield the optimum indicators presenting a comprehensive description of a city health care system (Figure 4).

The principal features of a global model of the health care system are the following:

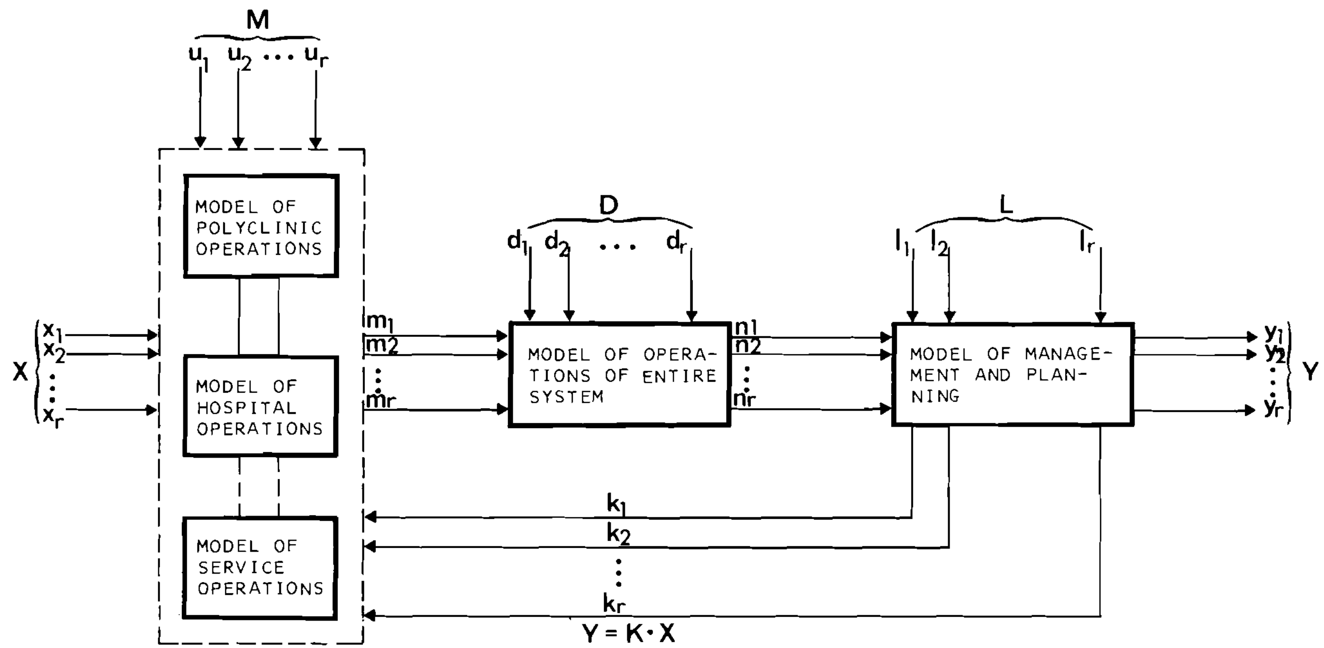
- Identification of the main factors determining the state of the objects of management (input);
- Identification of the principal indicators describing the state of the objects of management (output);
- Development of techniques establishing the formal interrelationships between input (m_r) and output (n_r) for the objects of management;
- Development of techniques for finding the optimum version of health care structure.

The model is difficult to develop for lack of sufficient accurate data to substantiate the above concepts and of clear-cut criteria to evaluate the efficiency of medical institutions and the quality of medical care.

The system must provide high quality and prompt health care which means that its structure and operation must be optimal. The main criteria of quality should be mathematically formulated.

The description of the management system of a city health service in terms of the Markovian processes and the queuing theory proves to be complicated owing to the following factors:

- The random nature of requests, the frequency of which varies in time and space (the frequency is the number of requests for service per unit of time); though the variations in time are random, taken as a whole they reveal an objective pattern;
- The random and nonuniform distribution of requests for service over the urban area;
- The random distribution of time spent by various medical specialists in servicing patients, each servicing being a multiphase process;
- Each phase of servicing proceeds through various stages and the combination of these stages is random for different requests;
- The service route of the request is determined by the states of various elements of the system at the time of request;



X – INPUT VARIABLES (INPUT FLOWS: HOSPITAL POLYCLINIC, SERVICE, ETC.):

Y – OUTPUT RESULTS (RECOMMENDATIONS FOR DECISION MAKING)

M – OUTSIDE DISTURBANCES

D – OUTSIDE DISTURBANCES

L – CONSTRAINTS (PERSONNEL, FINANCE, TECHNOLOGY, ETC);

m,n – OUTPUT VARIABLES (COORDINATES) WHICH CHARACTERIZE THE STATES OF THE OBJECTS (DYNAMIC STATE);

K – OPERATOR WHICH CHARACTERIZES THE CONDITIONS OF A GIVEN SITUATION (TRANSFORMATION COEFFICIENT).

Figure 4. Partial models for operation of city health care system.

- Certain channels of servicing which are free at the time of a request cannot be allocated to that request owing to long distances and other reasons--that is, the queuing system is not fully applicable;

- The conditions governing the transition of various elements from one state to another are difficult to simulate.

The following must be formulated at this stage in developing mathematical models of medical services and institutions:

- The main functions carried out by individual services and institutions as well as by the system as a whole;

- The list of initial data and characteristics required for simulation;

- The list of optimization criteria.

At this stage of model development, complete and reliable data on the parameters and characteristics of the information flows coming into the system and on the technological stages of servicing (particularly, for polyclinics), are lacking. Account must be taken, also, of the current reorganization and improvement of the system. This necessitates the collection of additional data and further analysis of the objects of study.

The model must be based on the tentative analysis of initial data, the relevant mathematical methods and working hypotheses on the structure and characteristics of the objects of the system.

The following must be identified in order to develop mathematical models:

- The structure of the network, geographical distribution, its typical elements, composition of medical personnel and optimum technological resources;

- The standard set of tasks to be carried out;

- The probability function of the distribution of servicing time for all phases of servicing;

- The distribution function of the incoming flows of requests and their parameters (for hospitals and polyclinics);

- The parameters and characteristics of the typical set of tasks to be carried out;

- The quantitative characteristics of the redistribution of request flows among various channels and phases of servicing;

- The priorities of servicing and distribution of requests among various servicing channels;

- The management algorithms of the operations of the servicing process;

- Algorithms and search programs to optimize the organization of servicing;

- Algorithms and programs for forecasting future states of the entire system.

The computer model of our system includes experimental partial mathematical models describing the clinical, administrative and economic activities of medical institutions (management models of hospitals, hospitalization service, etc.), some management functions and the network of urban medical institutions.

These partial mathematical models include analysis of the operations of individual units and prepartion of recommendations for their optimization.

Methods using the statistical theory of pattern recognition can yield promising results. These methods assist with the following problems:

- Selection of the essential aspects of the operation of a unit and arranging them in order of importance;

- Grouping of indicators describing the operation of the unit to develop complex indicators;

- Analysis of the effects exerted by various factors on the efficiency indicators of its operation;

- Standardization of objects to constitute groups of objects with uniform characteristics which, typically, enhances the accuracy of the model.

In order to apply the statistical theory of pattern recognition, indicators are classified into two groups:

- Indicators that describe the conditions governing the operation of the unit (morbidity, resources, etc.);

- The efficiency indicators (for instance, the average stay in hospital, bed occupancy rate, etc.).

Each object (module) can be represented by a point in the space of factors and a point in the space of indicators. Hence, simulation of the operation of the objects (modules) consists in finding the relationship between the points of these spaces.

At this stage the following problems should also be formulated:

- Estimation of bed occupancy in different hospital units for variable incoming flows and calculation of the optimum number of beds;

- Estimation of the optimum service zones and the number of medical teams in the units to deal with the varying flow of requests, etc.

Efficiency criteria are used partly for simulating management functions. This stage will yield some characteristics of the efficient management and operation of the system.

Detailed simulation of such a complicated system as the management of health care in a large city should be based on a vast amount of statistical data that is hardly likely to be available in the immediate future.

In this connection, it seems advisable at the first stage of analysis to pass from the microcharacteristics of individual elements of the system to the macrocharacteristics of the system as a whole which, as a first approximation, can be represented as the weighted average of the corresponding microcharacteristics.

In particular, this approach may be employed to determine the macrocharacteristics of the spatial distribution of calls for the ambulance service.

For the purposes of making a model of the density of calls over the urban area, this can be divided into a large number of squares in such a way that within each square the density can be assumed to be constant. However, the relevant data are very difficult to obtain. Therefore, the urban area can be divided into the servicing zones of the ambulance stations--a division that greatly facilitates the collection of statistical data.

The above argument is illustrated in the Appendix to this paper by some macrocharacteristics of the service zones.

Evaluation of the present status of the problem suggests that concentrated efforts by physicians, mathematicians, systems analysts and economists are required to develop the theoretical concepts of a management system for health care in general and a city health care service in particular, and to develop interrelated models and algorithms for the planning and management of the various health care units and services (hospitals, polyclinics, maternity clinics, ambulance service). All the research and development work (individual models, functional modules, etc.) should be carried out on the basis of a general methodology integrating information, technology and mathematics which would make it possible to develop a general management model.

The above discussion suggests that planners preparing general urban development plans should pay considerable attention to solving the problem of health care for the population.

The performance of the city health care services will be greatly improved by the efficient distribution of medical institutions over the urban area.

In confirmation of the complexity of the system discussed, it is appropriate to cite here the definition of control given by V.A. Trapeznikov. He said that it is the corrective action applied to the object in response to changes in its material and energy resources. Hence, introduction of an automated management system requires not only consumption of material resources but also alteration of the existing health care system. This, undoubtedly, will necessitate the psychological retraining of personnel, the utilization of new technology, changes in organization of manpower, etc.

The new system being developed should therefore be compatible with the existing system and the change in structure should be effected gradually. This necessity should be borne in mind in city health care zoning and in planning the construction of new medical institutions.

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Appendix: Macrocharacteristics of the Service Zones of The Ambulance Service

1. Servicing characteristics, given nonuniform density of calls and location of the ambulance service

The ambulance station is assumed to be located at the center of the servicing zone, a circle of the radius R.

The density of calls to be serviced is taken to be given by the radial Poisson distribution.

$$\gamma(r) = \gamma_o e^{-br} \quad , \tag{1}$$

where r is the radius vector representing the distance from the center, γ_o is the density of calls at the center of the servicing zone and b is the constant which characterizes the rate of variation of density with distance.

The total number of calls in the circle is given by

$$N = \frac{2\alpha\gamma_o}{b^2}\left[1 - e^{-br}(1+bR) \ldots \right. . \tag{2}$$

The density of distribution of the random radial distance when servicing calls is given by

$$P_r(x) = \frac{b^2 x 1^{-bx}}{1-e^{-bx}(br+1)}; \quad 0 \leq x \leq R \ldots . \tag{3}$$

The mathematical expectation and the variance of the radial distance from the center of the circle to the site of the call, where the call density is defined by Equation (1) are expressed by the following equations:

$$M_r = \frac{2e^{bR} - 2 - 2bR - b^2R^2}{b(e^{bR} - 1 - bR)} \tag{4}$$

$$D_r = \frac{6e^{bR} - (b^3R^3+3b^2R^2+6bR+6)}{b^2(e^{bR} - 1 - bR)} - (M_r)^2 \quad . \tag{5}$$

2. The servicing characteristics in the circle of a given density according to the poisson distribution are found by substituting in equations (2)-(5) the following terms:

$$N = \gamma_o \alpha R^2; \; Pr(x) = 2x/R^2 \;\; ;$$

$$M_r = \frac{2}{3}R; \; D_r = R^2/18 \;\; .$$

3. The mean radial distances if the ambulance station is not located at the center of the circle may be found in the following way:

Let us assume that the service zone is a circle with the uniform call density j and that the ambulance station is located at a distance a $(0 \leq a \leq R)$ from the center of the circle. The respective characteristics are

$$N = \gamma \alpha R^2$$

$$M_r = \frac{4}{9\alpha}R \left\{ \left(7+q^2\right) E(q) + 4\left(q^2-1\right) K(q) \right\}$$

$$q = \alpha/R \quad , \qquad (6)$$

where K(q) and E(q) are the first and second full elliptic integrals, respectively.

As can be shown by Equation (6), location of the ambulance station at the circumference of the servicing circle, instead of at the center, increases by approximately 1.7 times the value of M_r.

The orthogonal distance between two points (M_ρ) will be defined as the distance in the Hamming's space or the distance a motor vehicle travels in the orthogonal network of roads characteristic of modern cities.

Appropriate calculations show that $M_\rho = 1.25 \, M_r$ both for uniform and nonuniform call densities.

The real servicing zone with arbitrary boundaries and density of calls may be replaced by the equivalent circular servicing zone with constant call density according to the Poisson distribution so that the total number of calls and the mean radial distances in the two zones are equal. In this case, the equivalent zone will have the following parameters

$$R^E = \frac{3}{2} \frac{\sum_{i=1}^{I} \gamma_i \Delta S_i r_{ij}}{\sum_{i=1}^{I} \gamma_i \Delta S_i} \quad ; \quad \gamma^E = \frac{\sum_{i=1}^{I} \gamma_i \Delta S_i}{\alpha (R^E)^2} \quad ,$$

where r_{ij} is the distance between the ith unit site and the center of the servicing zone j.

Application of Technology to Health Care And Environmental Problems

I.P. Smirnov

I shall discuss some results obtained by using the systems approach to the application of technology to health care.

Literature on systems analysis published in the last decade falls into two categories--"idealistic" and "materialistic".

The "idealistic" category comprises studies that treat systems analysis as an independent theory which does not depend on specific objects of study. These studies widely use modern mathematical methods to substantiate and develop general systems analytical methods.

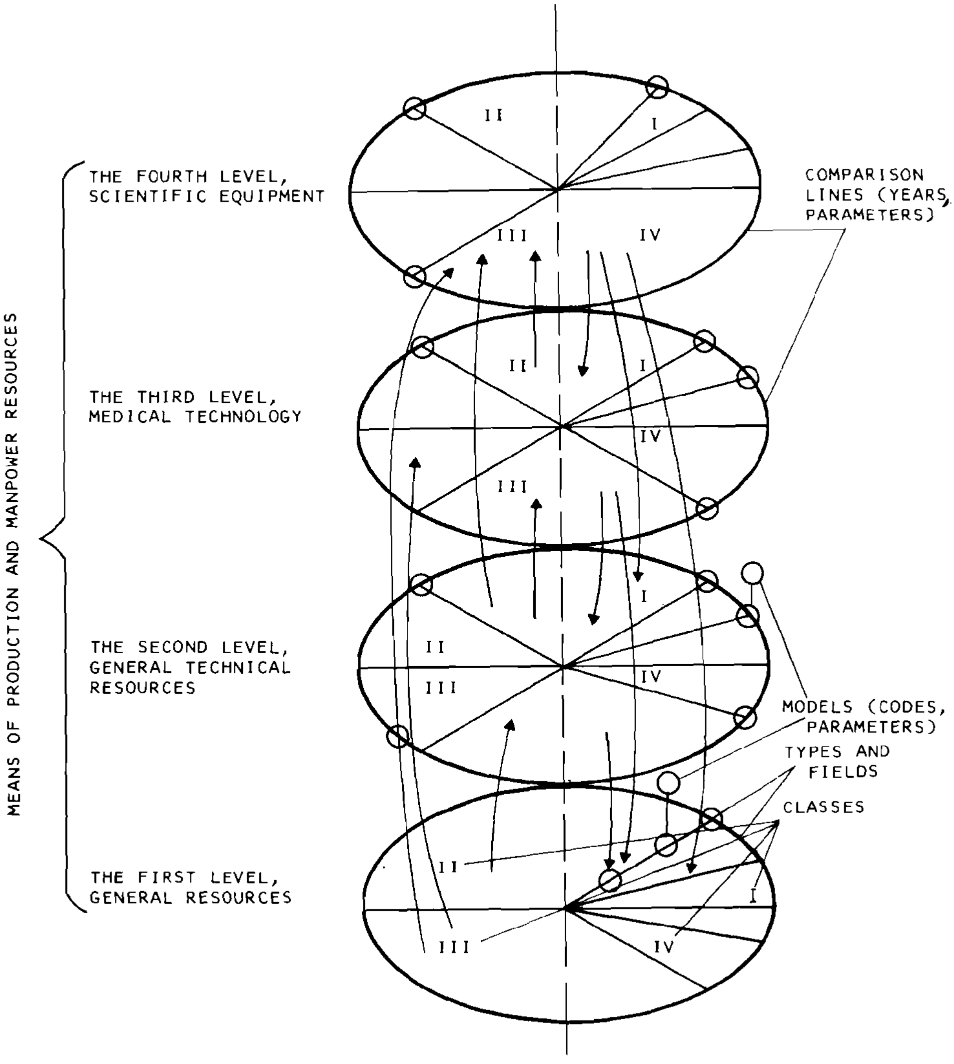
The "materialistic" category comprises studies concerned with systems engineering, design of large systems, developments of the theory used to design and control modern technological and economic automated and semiautomated systems. A typical feature of all these studies is that they deal with large or small, but always complicated, specific "material" objects of study. In these studies, systems analysis is utilized and developed as an analytical instrument.

Typically, a new scientific field is opened and developed by application of the methods of dialectical materialism (with its distinctive logic and systems approach) to a large-scale and complex object of study. Thus, the new research field of medical systems engineering combines the study of health care technology and environmental problems that are inseparable from health care problems.

Medical systems engineering formalizes the problem of managing health care and its subsystems, in particular, managing the production of technological devices. We regard health care management as management of the distribution of flows of limited resources aimed at preserving the maximum number of man-years. The technological resources of the health care system play an important part in maximizing man-years.

The following are the present and future fields of major utilization of technology in the light of the problems currently facing the health care system (Figure 1).

The first field: technological methods to protect air, water and land and to provide better living and working conditions



I PHYSICAL AND ENERGY INSTALLATIONS
II CHEMICAL RESOURCES
III BIOLOGICAL DEVICES
IV CONTROL, MEASURING AND RECORDING DEVICES, MANAGEMENT DEVICES AND DATA PROCESSING EQUIPMENT

Figure 1. Structural model of technological resources of the health care system.

for populations. They include various filters for cleaning effluents and gaseous discharges, disinfecting and decontaminating devices, means of protection from natural and man-made forms of radiation, antinoise and antivibration devices, various technological methods to protect workers' safety, air-conditioning installation, etc.

The second field: technological devices used in health care institutions to increase the productivity and improve the working conditions of medical and supporting personnel. They include various types of lifting and transport equipment, kitchen equipment, feeding devices for patients, equipment to provide patients with changes of bed and personal linen, communication devices, signal systems, etc.

The third field: use of technological methods in career guidance to pick out the men and women who can perform particular technical and professional jobs in modern industries.

The fourth field: use of technological resources in biomedical research.

The fifth field: direct or indirect use of many technological devices by medical personnel in carrying out various preventive, diagnostic and therapeutic processes. Such devices are generally described as medical technology.

The structure of medical technology is shown in Figure 2. Scientists in practically all countries have been paying great attention to the development of medical technology in the recent years. Much has been done and much is being done in this respect but, unfortunately, a marked improvement in the cost effectiveness of health care cannot be expected solely through the development of medical technology; plans should be made to improve the design and increase the production of all types of technological resources used in health care. Such a step would bring not only economical benefits by providing the population with a healthier global and local environment but would also contribute to solving the great social problem of making it possible for human beings to develop harmoniously.

Even at the present time, some international measures could and should be taken to improve the technological resources of health care systems, for example:

- Development and industrial production of internationally standardized technical devices to protect air, water and land from harmful natural and man-made agents;

- Development and industrial production of internationally standardized technological devices to mechanize and automate the work of auxiliary and nonmedical personnel in health care services;

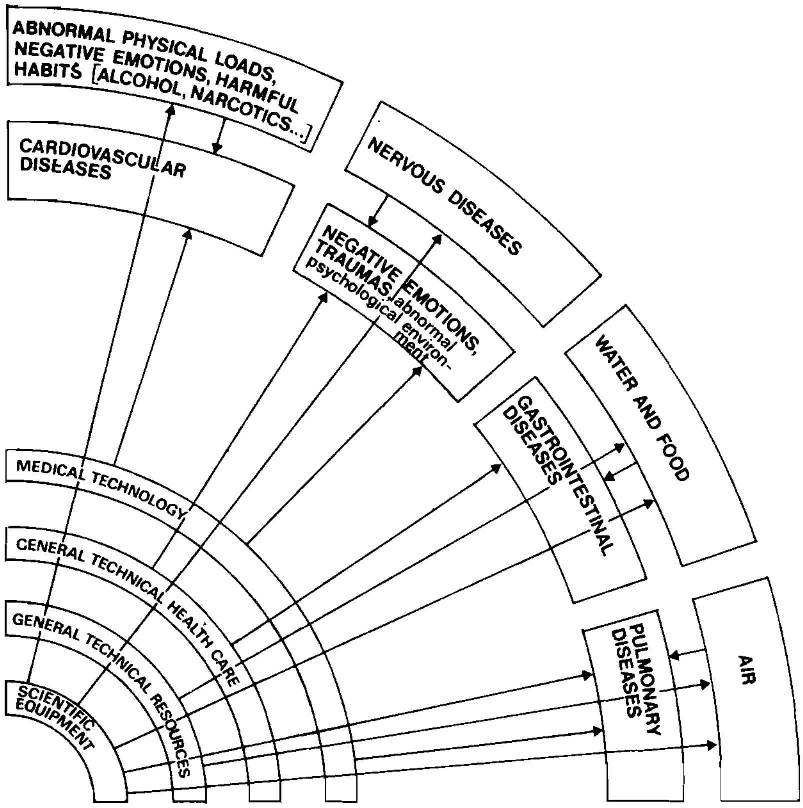


Figure 2. Means of production and manpower resources in the health care system.

- Development and industrial production of standardized medical technology;
- Development and industrial production of standardized technological methods of selecting professional pilots, drivers, sportsmen and candidates for other occupations where fitness is essential to the job and of checking rapidly their capacity to carry out their professional duties; in addition standardized methods of selecting professions for partially disabled persons and sufferers from chronic diseases.

In conclusion, it should be noted that an acceptable model of health care should take into account the status and dynamics of development not only of information and control systems but of all types of technological resources, which, even at present, constitute the material foundation of the health care system.

The Relationship Between Medical Resources and Measures Of Health: Some Additional Evidence

Joseph P. Newhouse and Sharon Yamasaki

INTRODUCTION

One of the most vexing questions in health services research is the relationship between resources devoted to personal health services and the outputs of those services. The prevailing view in the United States on this matter may be described roughly as follows. Additional personal health services do little, if anything, for mortality and/or morbidity. They probably provide relief of anxiety, symptomatic relief, or prognostic information. What the patient does for or to himself (through smoking, drinking, exercise, sleep and the like) has much more to do with explaining varying outcomes in conventional measures of health status than additional personal health services.

This view has been expressed elsewhere by one of the authors of this paper (Newhouse, Phelps, and Schwartz, 1974); it has probably been most forcefully expressed by Victor Fuchs (Fuchs; 1972, 1974a, 1974b). The evidence supporting this view typically comes from regressions of mortality or morbidity rates on medical care resources across regions (for the most part, regions of the USA) (Letourmy, 1975; Auster, Leveson, Sarachek, 1969; Newhouse, 1968; Larmore, 1967). As a general rule, the authors are not able to reject the null hypothesis of no relationship at conventional levels of significance. Moreover, the estimated size of the effect (i.e., the size of the regression coefficient) differs little from zero. At the same time, the effect of education does appear in these studies. The work of Belloc and Breslow showing that "health habits" such as exercise, smoking, drinking, and so forth are predictive of mortality is also consistent with the notion that "life-style" may be more important than purely medical variables (Belloc and Breslow; 1972, 1973).

In this paper, we illustrate a different approach to the problem of assessing the impact of medical care resources on health status, one we feel has some advantages. Rather than look at mortality or morbidity directly, we have chosen to look at physiological measurements taken in the United States Health Examination Survey. We feel this approach potentially has greater power than existing approaches to isolate the contribution that medical care services or other factors can make to health status, because one can focus on diseases or conditions where medical care may make a difference. If, as many believe, most diseases are either self-limiting or irreversible by the time they are diagnosed, the set of diseases for which additional medical services can affect mortality may be small. Additionally, most of the individuals with such diseases may receive treatment even with minimal resources. In this case, if mortality from all causes is aggregated and regressed upon medical care resources and environmental factors, as has been done in the literature to date, the observed effect of medical care will be both small and hard to observe. By contrast, there may be some diseases, such as hypertension or periodontal disease, where additional medical care resources would make a difference. If so, it should be much easier to measure the contribution of medical care by focusing on the variation in the prevalence of such problems rather than variation in mortality or morbidity rates from all causes. The effects of health habits may also be clearer.

The work reported in this paper is preliminary in at least two respects:

- We have chosen to examine only a limited number of physiological indices in order to appraise the usefulness of the approach before proceeding further;

- We have not estimated relationships between the physiological measures and subsequent mortality or morbidity, although one could clearly do so with longitudinal data such as the Framingham Heart Study data. For example, in order to estimate the value of reducing blood pressure, one would estimate a functional relationship between diastolic blood pressure and life expectancy.

METHODOLOGY

We have analyzed data from the United States Health Examination Survey, Cycle I. This Survey, which is discussed in detail below, gave screening examinations to a random sample of the US population during the years 1959 to 1962. In this paper, we have chosen to analyze the results from this examination for diastolic blood pressure, serum cholesterol concentration, electrocardiogram evaluation, chest X-ray evaluation, varicose veins, and a periodontal index. Our reasons for choosing this diverse list of indices are discussed below.

The Health Examination Survey was conducted among the population of 39 areas of the USA selected at random (using a stratified nationwide probability sample, clustered by city size). Each area consisted of a county or a small group of contiguous counties. Our method of procedure is to regress the physiological indices on measures of the medical resources in an area, as well as demographic and socio-economic characteristics of the person sampled such as age, sex, race, family income and education of the head of household. It is then possible to make statements of the following kind: An incremental amount of medical resources of a specified kind, other factors constant, can be expected to reduce diastolic blood pressure by a given amount. Although we do not do so in this paper, it is also possible to estimate the consequences for mortality and morbidity of a given reduction in diastolic blood pressure.

An objection, based on direction of causality, may be raised about the above procedure. Specifically, it may be asserted that our physiological indices do, in fact, measure the health status of an area, but that demand for medical services is higher in "sicker" areas, and therefore more resources are available in those areas (more physicians have chosen to practice there; more hospital beds have been built there, etc.). Hence, the estimated regression coefficients in our procedure are biased upward.

Two responses may be offered to this objection. First, the problem is much less with specific health indices than with overall mortality and morbidity rates because the specific indices are not very highly correlated. Table 1 shows the simple correlation coefficients between the six indices (the scaling of the measures is explained below). Although many of these correlations are statistically significant, they are all rather small, indicating that there is considerable independent variation. As a result, it is unlikely that variation in any one of these indices plays a large role in attracting medical care resources to an area. If so, this is an additional advantage of using specific indices, rather than an overall mortality rate or morbidity rate.

Despite the apparent protection against simultaneity that working with many nearly independent indices gives, we have also estimated the relationships with a simultaneous equation estimator. To implement this approach, we must assume that there are certain variables (instrumental variables) in our data base that affect the quantity of medical care resources in an area, but do not affect the health status levels of the individual observations (more precisely, that are independent of the error term in our equations).

We next describe the Health Examination Survey, discuss the list of physiological indices that we have chosen to study, and describe our list of explanatory variables and instrumental variables.

THE HEALTH EXAMINATION SURVEY

The Health Examination Survey is described at length in a publication of the United States National Center for Health Statistics (1965). The Survey examined 6672 individuals (of a sample of 7710 individuals) from civilian, noninstitutionalized

TABLE 1

	Presence of Varicose Veins	Electrocardiogram Abnormality	Chest X-ray Abnormality	Serum Cholesterol Abnormality	Periodontal Index
Diastolic Blood Pressure	0.117	0.121	0.003	0.224	0.186
Presence of Varicose Veins		0.083	0.106	0.119	0.099
Electrocardiogram Abnormality			0.055	0.075	0.150
Chest X-ray Abnormality				0.075	0.060
Serum Cholesterol Concentration					0.102

N= 4664

population in 39 areas from October 1959 to December 1962. The exact areas involved are shown in the Appendix to this paper; they included both urban and rural areas. The design called for individuals between the ages of 18 and 72 to be sampled, but in fact individuals between the ages of 18 and 79 actually were included in the sample.

The data collected included both physiological measurements and demographic and socio-economic information based on responses given at an interview. The physiological measures collected included: X-rays of the chest, hands and feet; height; weight; air conduction; body measurements such as skinfold; blood tests (including serum cholesterol, microhematocrit and a modified glucose tolerance test); electrocardiogram; a dental examination; and a vision examination. The data collected through an interview included: household composition, age, sex, education and income.

THE PHYSIOLOGICAL MEASUREMENTS

The six physiological measures we selected were the same six used by Abrahamse and Kisch (1975) from the Health Examination Survey data to define their Health Status Age index of health. Abrahamse and Kisch selected these six measures because they were all significantly related to age and because they all appeared related to various aspects of an individual's health status. Abrahamse and Kisch made the following comments on their reasons for choosing these particular measures:

- Diastolic blood pressure was chosen because of its demonstrated relationship to the risk of stroke and myocardial infarction;

- Serum cholesterol concentration was chosen for two reasons: It is related to risk of heart disease, and it may well reflect a body's general metabolic health. Abnormal serum cholesterol levels may, in fact, be as much a total system disorder as are abnormal blood glucose levels in diabetics;

- Electrocardiogram abnormalities and abnormal chest X-rays have a strong association with diminished health;

- The presence of varicose veins in the legs (varicosities) was included in the index because these veins may reflect on the general status of the body's connective tissues;

- A periodontal index was included as one of the few (if not only) physical parameters that reflect, in a graduated manner, preventive-care practices.

While the clinical significance of some of the measures chosen (e.g., varicose veins) is arguable, we have treated each component individually, which permits the reader to ignore results for those measures he feels are of little or no significance. Retaining all six of the Abrahamse and Kisch measures, however, has the additional benefit of permitting an assessment of medical care resources using their Health Status Age measure. This measure is the linear combination of the six measures that result when age is regressed upon the measures. Thus, the Health Status Age variable is scaled in terms of years; when compared with an individual's actual age, it yields the statement: "Such an individual is young (old) for his age".

In scaling the physiological data, we followed the procedures employed by Abrahamse and Kisch. What follows is taken from their description of the data.

Diastolic Blood Pressure

Documentation provided with the Health Examination Survey data contains the following description of the manner in which diastolic blood pressure readings were made:

> The average systolic and diastolic blood pressure readings were computed from the three blood pressure measurements that were taken. The first measurement was taken just after the physician met the examinee. The second was taken midway in the examination, after completing the auscultation of the heart in the sitting position. The third measurement was taken at the end of the physical examination.
>
> Blood pressures were taken while the examinee was sitting on the examining table. The nurse placed the middle of the cuff over the bulge in the upper left arm. The cuff was left on the arm between the first and second measurements, was removed after the second, and returned for the third. The physician held the arm at the level of the atrium, with the nurse raising the Baumanometer to the physician's eye level. Using the bell of his stethoscope, the physician noted the pressure when the sound first was heard, when it first became muffled, and when it disappeared. All three measurements were recorded. The point at which the Korotkov sounds disappeared was taken as the diastolic pressure. If the sounds did not disappear, the point of muffling, if distinctly heard, was used. Since the Baumanometer is scaled in intervals of 2mm., measurements were so recorded.
>
> The average of three readings only was used.

Serum Cholesterol Concentration

Documentation provided with the Health Examination Survey data contains the following description of how serum cholesterol concentrations were obtained:

> A blood specimen was collected from each examinee in a 15 cc. Sheppard-Keidel tube. The tube was kept at room temperature for a minimum of one hour following venipuncture, then refrigerated for a minimum of six hours to assure a good clot. The blood clot was freed gently from the tube, and the tube was centrifuged for twenty minutes.
>
> Determination of total serum cholesterol concentration was made by a modified ferric chloride procedure. The values were then converted to comparable Abell-Kendall values.

For some reason, the mg % values were recoded to integers (1,2,...) in the Health Examination Survey data. We reconverted these codes back into mg % values, but the code-recode procedure, by its nature, left each value rounded off to an odd 10--i.e., values taken in our data are 90, 110, 130,... mg %. Out of the 6672 records, 170 contained unknown serum cholesterol levels, and one was coded above 520 mg %. These 171 cases were eliminated.

Electrocardiogram Readings

According to documentation provided with the Health Examination Survey data,

> The electrocardiogram was read independently by three cardiologists according to certain criteria they developed. ... The three electrocardiographic readings were compared. Where they all agreed, the unanimous decision was used for subsequent diagnosis. In the event that there was any disagreement, the three readers met with a coordinator and came to a final decision.

For our purposes, a single dummy variable was created in the following way: If the final summary reading agreed to by the three cardiologists indicated a normal electrocardiogram, a variable EKG (the dependent variable) was set equal to zero. If any abnormality was noted, EKG was set equal to one.

Chest X-Ray Reading

X-ray films taken by the Health Examination Survey were interpreted by "three radiologists with a special interest in pulmonary disease". Unlike the EKG readings, no attempt to reconcile different readings was recorded in the data base. We defined a variable called XRAY equal to the number of radiologists who indicated anything abnormal in a specific X-ray interpretation. XRAY thus takes on the range of values 0,1,2,3.

Varicosities

Varicosities were checked for in both legs. We coded a variable VARICOSE equal to one if either leg was other than normal. Otherwise, VARICOSE was set equal to zero.

Peridontal Index

The following definition of the periodontal index is provided with the Health Examination Survey data:

> A periodontal score is recorded for each tooth in the mouth, and the arithmetic average of all scores is the individual's Periodontal Index.
>
> Scoring:
>
> 0--*Negative.* There is neither overt inflammations in the investing tissues nor loss of function due to destruction of supporting tissues.
>
> 1--*Mild Gingivitis.* There is an overt area of inflammation in the free gingival, but this area does not circumscribe the tooth.
>
> 2--*Gingivitis.* Inflammation completely circumscribes the tooth, but there is no apparent break in the epithelial attachment.
>
> 6--*Gingivitis with Pocket Formations.* The epithelial attachment has been broken, and there is a pocket (not merely a deepened gingival crevice due to swelling in the free gingival). There is no interference with normal masticatory function, the tooth is firm in its socket, and has not drifted.
>
> 8--*Advanced Destruction with Loss of Masticatory Function.* The tooth may be loose; may have drifted; may sound dull on percussion with a metallic instrument; may be depressible in its socket.

Scores on the index for patients examined ranged from 0 to 8. Nineteen cases were not examined; 1201 cases were assigned the score 9.8. While this score was not explained, we believe it to represent people who were examined but had no teeth. We eliminated from our study the 1220 cases who either were not examined or who were examined and given a score of 9.8.

THE EXPLANATORY VARIABLES

The variables used in the equations reported below fall into three categories: biological; medical resources; and socio-economic.

The *biological* variables include age in years, age squared, and sex (0=male, 1=female). These variables are included because of biological processes that relate them to the physiological measures, and indeed they are practically without exception strongly related to the measures. Because our interest in including these variables is only to control for the variation attributable to them, we report the results for these variables only in the Appendix to this paper.

The *medical resource* variables include primary care physicians/100,00 population, other practicing physicians/100,000 population, and short-term general hospital beds/1000 population. In the case of the periodontal measure, dentists/100,000 population is used in the place of all three of the above variables.

Primary care physicians are defined as physicians engaged in patient care who are in general practice, family practice, internal medicine or obstetrics and gynecology. (Pediatricians are excluded because we are dealing with an adult population.) The hospital beds variable excludes federal hospitals because of the way the data are collected; however, since federal hospitals are a quite small proportion of the total, this omission is of little significance. (For example, in 1960, births in federal hospitals were four percent of total births in hospitals.) Dentists are not divided into general practice dentists and periodontists, because over 90 percent of all dentists are general practice dentists. These medical resource variables are measured for the year 1964, because that was the earliest year found; the error this introduces should be negligible.

The *socio-economic* variables included in the regressions reported below are: education of the family head; family income; race (0=white, 1=nonwhite); and the percentage of the sampling area that is classified as urban. Education is measured as the highest grade completed in school (to a maximum of five or more years of college), and is measured in intervals of none, 1 to 4 years, 5 to 8 years, 9 to 12 years, 1 to 2 years college, 3 to 4 years college, and over 4 years college; we have used the midpoint of the interval, except at the upper interval, where 5 years of college was used.* The education of the male is used in two-parent families. Education of family heads is highly correlated with that of the individual (r=.69), so a person-specific education measure would give similar results. Income is measured in intervals: less than $500, 500 to 999, 1000 to 1999, 2000 to 2999, 3000 to 3999, 4000 to 4999, 5000 to 6999, 7000 to 9999, greater than 9999; we have again used the midpoint of the interval, except for the open-ended intervals where $250 and $10,000 were used.** Persons with missing values for education and income were removed; 602 due to missing income, and 297 due to missing education. These along with previous deletions reduced the sample size to 4664. Some persons were deleted from the sample for multiple reasons. The definition of an urban area is complex, but approximates a city or town of 2500 individuals or more.***

A measure of education is included as the best measure available of the "knowledge" available to produce "health" (Grossman, 1972). Beneficial effects on health are expected. Income is included as a measure of resources available to the family. It perhaps would be preferable to include a measure of income adjusted for family size, but we have not done so in this work. In Fuchs' work, the effect of income on mortality has essentially vanished over time, perhaps because greater income engenders a less healthy life-style which offsets greater ability to purchase medical care. Therefore, no strong effect of income is expected. Race is included partially for biological reasons, and partially because it may reflect access to medical care resources and socio-economic variables that are not measured by other variables. Nonwhites are expected to have poorer health. The percentage of the sample living in urban areas is included partially as a measure of access to medical care resources, partially to control for the supposed "unhealthiness" of the urban environment. Because these two effects go in opposite directions, no prediction is made concerning the sign of this variable.

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*The distribution of the sample by eduction interval is none 1.4%, 1 to 4 years 6.2%, 5 to 8 years 25.0%, 9 to 12 years 45.5%, 1 to 2 years college 7.4%, 3 to 4 years college 9.2%, and over 4 years college 5.3%.

**The distribution of the sample by income interval is less then $500 2.0%, 500 to 900 4.5%, 1000 to 1999 7.7%, 2000 to 2999 8.4%, 3000 to 3999 11.3%, 4000 to 4999 11.8%, 5000 to 6999 22.6%, 7000 to 9999 17.7%, greater than 9999 14.0%.

***For the complete definition, see any publication of the United States 1960 Census of Population, for example, U.S. Bureau of the Census, *U.S. Census of Population: 1960, Subject Reports: Socioeconomic Status*, Final Report PC(2)-5C, U.S. Government Printing Office, Washington, D.C., 1967, p. XIII.

A number of other variables included in computations are not reported here. These included ten dummy variables for occupation, ten dummy variables for industry, two marital stasus variables (formerly married and currently married), family size and whether the individual was self-employed (which, among other things, affects the amount of medical insurance held in the USA; see Phelps, 1973). None of these variables proved to have much explanatory power, nor did the results reported below change with their inclusion. In the interests of simplicity, we have not reported results from the estimated equations which included these variables.

Table 2 presents the means, standard deviations, range, and number of zeros for the variables that were included.

METHODS OF ESTIMATION

Below we report results using three methods of estimation: ordinary least squares (OLS), two-stage least squares (TSLS), and logit. Logit equations were used for the two dichotomous dependent variables: presence or absence of varicose veins and presence or absence of an abnormal electrocardiogram (EKG) reading. Polytomous methods (Nerlove and Press, 1973) would have been appropriate in the case of abnormal chest X-rays and the periodontal index, but the cost of computation precluded their use, so OLS and TSLS were used.

The continuous variables, diastolic blood pressure and serum cholesterol concentration, were treated using a two-stage process. Simply using a continuous measure as a dependent variable will not yield good estimates of the effect of an explanatory variable on mortality and/or morbidity, if mortality and/or morbidity are nonlinearly related to diastolic blood pressure or serum cholesterol concentration (which is certainly the case). Moreover, the medical care process may treat only those with "abnormal" blood pressures or serum cholesterol values (i.e., those at elevated risk).

A simple model would be

$$\text{Diastolic BP} = Zb + e, \tag{1}$$

if the individual did not have his blood pressure taken by a physician, or if he had his blood pressure taken but it was less than or equal to some critical value;

$$\text{Diastolic BP} = Zb - \text{Treatment Effect } (BP_o) + e, \tag{2}$$

if the individual had his blood pressure taken by a physician and it was greater than some critical value, where Diastolic BP is diastolic blood pressure observed in the survey, Z is a vector of demographic characteristics, e is a random error term

TABLE 2

SUMMARY STATISTICS

Variable	Mean	Standard Deviation	Maximum	Minimum	Number of Zeros
Presence of Hypertension	.11	.32	1	0	4130
Prevalence of Cholesterol >300	.049	.22	1	0	4435
Prevalence of Abnormal Chest X-Ray	1.66	.99	3	0	551
Prevalence of Abnormal EKG	.22	.41	1	0	3644
Prevalence of Varicose Veins	.16	.37	1	0	3902
Periodontal Disease Scale	1.12	1.65	8	0	1276
Abrahamse-Kisch Health Status Age Index	40.05	8.67	73.39	15.94	0
Age	38.95	13.81	79	18	0
Sex (1=female)	.52	.50	1	0	2226
Race (1=nonwhite)	.13	.34	1	0	4036
Income ($)	5464	2850	10,000	250	0
Education of Head	9.80	3.76	16	0	67
Percentage of Population Urban	80.98	28.87	100	0	87
Primary Care Physicians/100,000	55.05	18.12	89.39	14.49	0
Other Physicians/100,000	83.17	54.76	196.41	4.73	0
Beds/1000	3.67	1.01	6.09	0.97	0
Dentists/100,000	56.91	29.74	128.45	8.62	0

with zero mean, and the Treatment Effect is the effect on blood pressure of any antihypertensive regimen the physician uses. The Treatment Effect is written as a function of the blood pressure observed by the physican BP_o, on the assumption that the effect may be greater for those who begin with higher initial diastolic blood pressures.

One may assume that the quantity of medical resources, especially physicians, in an area affects the probability that an individual will have his blood pressure taken by a physician. If one could measure this probability, one could predict the number of hypertensives who would be found, and from this number, the number of hypertensives who could be controlled. Unfortunately, however, one cannot compute the probability from these data.

Therefore, one cannot straightforwardly estimate Equations (1) and (2), and so we have used the following procedure to estimate the effect of additional resources on the distribution of blood pressure. We have assumed that individuals are at elevated risk when their blood pressure is greater than 90 if they are under 40 years of age, 95 if aged between 40 and 60, and 100 if over 60 (and with serum cholesterol concentration greater than 300). In the first stage of our estimation process, we estimated how medical resources and other explanatory variables affect the probability of being at elevated risk. This stage uses logit methods. In the second stage, we estimated the effect of our explanatory variables applied to individuals at elevated risk and used OLS and TSLS.* In this second stage of estimation, we have assumed for simplicity that the effect of additional resources is a simple shift in the location parameter within the subset of the population that is at elevated risk. We further assume that the probability of any individual at elevated risk seeing a physician and the physician managing him is independent of diastolic blood pressure (plausible, since the individual will not know in general that he is at elevated risk until he sees the physician), but that this probability of seeing the physician is dependent upon the number of medical resources in the area. In this preliminary work, we have assumed that the relationship between the probability that a physician sees a patient and manages him and the number of resources is linear.

Note that the first stage of this process is all that is necessary in the case of the other physiological measures examined, which are dichotomous (or in the cases of periodontal disease and chest X-ray already scaled in approximate units).

*It would be slightly better to use Tobit with a lower limit at the critical value. However, so few observations are exactly equal to the critical value that the gain from Tobit is not worth the computational cost.

In the case of the continuous variables, the second stage estimates the effect of medical resources on the mean of the subset of the population that is at elevated risk. This second step allows for the possibility that medical treatment may for some of the population only mitigate the problem, not eliminate it; if medical treatment eliminates the problem, then coefficients on medical resources will be zero in the second stage.

The two-stage procedure is an approximation; one could do better by defining additional intervals and estimating the probability of an individual being in any particular interval as a function of an area's medical resources (using polytomous methods); if the intervals were sufficiently numerous (i.e., sufficiently small in size), one could omit the second step of estimating a within-interval effect. In this preliminary work, we have not pursued the problem to this level of detail.

One other loose end remains to be tied up before we present our results. In the two-stage estimation process, we require instrumental variables that affect the quantity of medical resources in an area but do not affect (or affect negligibly) the physiological measures. The three variables used are the median income of the area, the percentage of the adult population that completed high school (recall that both household specific income and education variables are included as explanatory variables), and a dummy variable indicating the presence or absence of a medical school in an area. The latter variable could arguably affect the quality of medical care and through that the observed physiological measures; however, we have assumed that this effect is small. In any event, we do not rely strongly upon the two-stage least squares results in supporting our conclusions.

THE RESULTS

Table 3 shows results for the medical resource variables; complete equations may be found in the Appendix. The only substantial beneficial effect is that of additional hospital beds on the prevalence of varicose veins; the elasticity is -0.43, and the coefficient is significant in every specification and estimation method used. Another measure of the impact is the coefficient itself; each increment of 0.6 in beds per thousand reduces the probability of varicose veins by about one percentage point. The only other apparent beneficial effect of medical care resources is that more nonprimary care physicians in an area are associated with a lower prevalence of abnormal chest X-rays. However, the effect is small; the elasticity is a low -.08. There are two statistically significant coefficients with a positive (i.e., "wrong") sign, nonprimary care physicians in the case of the prevalence of hypertension and hospital beds in the case of abnormal chest X-rays. However, neither coefficient is significant in the two-stage least squares results, suggesting that simultaneity may be present in the OLS results.

TABLE 3

EFFECTS OF MEDICAL CARE RESOURCES — ELASTICITY AT MEAN (e), t-STATISTIC, AND COEFFICIENT (c)[a]

Dependent Variable and Estimation Method

		Prevalence of Hypertension, Logit	Diastolic Blood Pressure, Subset of Hypertensives, OLS	Prevalence of Serum Cholesterol >300, Logit	Serum Cholesterol Levels, Subset of >300, OLS	Prevalence of Abnormal EKG, Logit	Prevalence of Abnormal Chest X-Ray, OLS	Prevalence of Varicose Veins, Logit	Perio-dontal Scale, OLS	Abrahamse-Kisch Health Status Age Measure, OLS
Primary Care Physicians/ 100,000	e =	-.12	-.02	.36	-.002	.02	-.03	.13	—	-.004
	t =	.64	1.11	1.21	.06	.19	.70	.82		.37
	c =	-.00024	-.040	.00031	-.013	.000088	-.00081	.00034		-.0031
Other Physicians/ 100,000	e =	.23	-.003	-.04	.01	-.08	-.08	-.04	—	-.002
	t =	2.31	.37	.28	.83	1.16	4.19	.47		.28
	c =	.00030	-.0042	-.000025	.061	.00019	-.0017	.000068		-.00082
Beds/ 1000	e =	.20	.005	-.12	.02	.05	.09	-.43	—	.007
	t =	1.16	.30	.45	.49	.43	2.63	2.91		.70
	c =	.0060	.14	-.0016	1.54	.0028	.042	-.017		.081
Dentists/ 100,000	e =	—	—	—	—	—	—	—	.001	—
	t =								.02	
	c =								.000019	

[a]Coefficient is always from OLS equation for ease of interpretation; t-statistic always is absolute value.

Table 4 shows results from selected equations for the education and income variables. Education has large and statistically significant beneficial effects for the prevalence of hypertension and the prevalence of periodontal disease. In the case of hypertension, the elasticity with respect to education is -.44, and in the case of the periodontal scale, it is -.59. The periodontal scale has no natural units, so the elasticity is the best measure of the size of the effect; in the case of hypertension, each additional two years of education reduces the probability of hypertension by about one percentage point. There is also a statistically significant effect of education on the prevalence of abnormal chest X-rays, but the elasticity is relatively small, -.06. The summary measure of all six indices, Abrahamse and Kisch's health status age index, is significantly reduced by additional education, although the effect is not large; an additional five years of education makes an individual roughly one year "healthier" than is average for his age group.

Income has significant effects only on the periodontal disease scale, where the elasticity is -0.34 and the health status age measure; however, the effect of income on this latter measure is small. The elasticity is -.02; an additional US $8000 of income (1960 US dollars) would make an individual roughly one year healthier than his age group.

Table 5 shows the effects of the percentage of the population living in an urban area and the effect of race. In both cases, the effects are mixed. There is a beneficial effect from urbanization in the case of hypertension and negative effects in the case of chest X-rays and varicose veins. Nonwhites have a much higher probability of having hypertension and abnormal electrocardiogram readings than whites, .13 in the case of hypertension, and .16 in the case of the electrocardiogram. However, nonwhites do better than whites in the case of abnormal chest X-rays and varicose veins; they have a ten percentage point smaller likelihood of having an abnormal chest X-ray, and a five percentage point smaller likelihood of having varicose veins. This finding was unexpected, but appears robust against changes in specification and estimation method.

DISCUSSION

The results reported are consistent with the view that--in the USA at least--what an individual does for himself is probably more important to his health than the quantity of medical care resources, while the beneficial effect of additional education is quite noticeable in the case of hypertension and periodontal disease.

The lack of effect of medical care resources on physiological measures of health must be qualified because the data are from 1960, and medical technology has progressed in the intervening 15 years, especially in the area of antihypertensive drugs. However, particularly noteworthy from the viewpoint of the lack of efficacy of additional medical care resources is

TABLE 4

EFFECTS OF EDUCATION AND INCOME, ELASTICITY AT MEAN (e), t-STATISTIC, AND COEFFICIENT (c)[a]

Dependent Variable and Estimation Method

		Prevalence of Hypertension, Logit	Diastolic Blood Pressure, Subset of Hypertensives, OLS	Prevalence of Serum Cholesterol >300, Logit	Serum Cholesterol Levels, Subset >300, OLS	Prevalence of Abnormal EKG, Logit	Prevalence of Abnormal Cheat X-Ray, OLS	Prevalence of Varicose Veins, Logit	Perio-dontal Scale, OLS	Abrahamse-Kisch Health Status Age Measure, OLS
Education of Head Years	e =	-.44	-.002	.25	.01	.05	-.06	-.17	-.59	-.05
	t =	3.53	.18	1.26	.56	.61	2.53	1.62	10.06	6.15
	c =	-.0049	-.021	.0012	.47	.0011	-.011	-.0025	-.068	-.19
Income ($)	e =	.06	-.007	-.03	-.02	-.07	-.03	-.04	-.34	-.02
	t =	.63	.79	.17	1.35	1.08	1.56	.51	7.55	2.70
	c =	.0000012	-.00014	.00000022	-.0014	-.0000026	-.0000094	-.0000011	-.000070	-.00012

[a]Coefficient is always from OLS equation for ease of interpretation; t-statistic always is absolute value.

TABLE 5

EFFECTS OF RACE AND URBANIZATION ESTIMATED USING OLS COEFFICIENT AND t-STATISTICS[a]

Dependent Variable

		Prevalence of Hypertension	Diastolic Blood Pressure, Subset of Hypertensives	Prevalence of Serum Cholesterol >300	Serum Cholesterol Levels, Subset >300	Prevalence of Abnormal EKG	Prevalence of Abnormal Chest X-Ray	Prevalence of Varicose Veins	Perio-dontal Scale	Abrahamse-Kisch Health Status Age Measure
Percentage of Population in Urban Area	c =	-.00069	.0053	-.0000089	-.18	-.0000026	.0030	.00049	-.0010	.0047
	t =	3.20	.28	.06	1.36	1.08	4.49	2.05	1.11	.98
Race (1=Nonwhite)	c =	.13	1.93	-.018	-1.18	.16	-.096	-.050	.10	.033
	t =	8.95	1.84	1.76	.12	8.88	2.12	3.11	1.45	.10

[a]t-Statistic always is absolute value.

the lack of association between the prevalence of periodontal disease and the number of dentists in an area. Since periodontal disease can be prevented by regular cleaning of the teeth, it is surprising that there is no association between the number of dentists and periodontal disease. It might be argued that the number of dentists in an area reflects demand for services and that the income and education variables are measuring this variation in demand. However, there will be variation in supply that is independent of demand (due to variation in location preferences, for example); furthermore, education and income will not completely explain demand. Thus, this argument cannot explain the lack of association. It might also be argued that where there are few dentists there are many dental hygienists, so that there is less variation in total dental manpower than in dentists. This hypothesis is being investigated further; however, it is unlikely that the number of hygienists employed in 1960 was large enough, especially in areas with few dentists, to account for these results. It is more likely that simply increasing the supply of dentists does relatively little to the fraction of the population that utilizes preventive dentistry.

In contrast to the effect of dentists on periondontal disease, the effects of education and income on periodontal disease are marked. It is hypothesized that those with higher education do utilize preventive dental care; it is also well known that in the United States visit rates to dentists are strongly correlated with income. Seeing the dentist more frequently would thus appear to reduce periodontal disease.

The contrasting lack of association between income and the other five physiological measures is also suggestive. In 1960 visit rates to a physician rose steadily with income (this is no longer true). Yet there is no noticeable effect on the five physiological measures from those additional visits. It is quite possible, of course, that additional income induced changes in life-style inimical to health (e.g., more smoking), but the results are consistent with the view that preventive medical care, at least in 1960, was not very efficacious for adults.

CONCLUSION

Several studies of mortality and a few studies of morbidity have concluded that the effect of additional medical care resources on mortality and morbidity was small, if it existed at all. However, this conclusion was suspect because mortality appears to be a relatively insensitive measure of outcome; in other words, the power of statistical tests when mortality is used as a dependent variable might not be great. As a result, this study utilized physiological measures of health status, at least some of which (e.g., hypertension) are known to be predictive of mortality. It was thought that effects of medical care resources that might be concealed in the variation of an aggregate mortality rate would appear if one looked at particular physiological measures; additionally, the simultaneity problem (i.e., more resources locating where "health status" is poorer) should be much less severe when looking at individual measures.

Our results support the conclusions of the studies of mortality and morbidity; the effect of additional medical care resources appears small to vanishing point. It is possible that this conclusion would need to be modified if data from more recent years were used; data from a similar survey made roughly a decade after the survey used in this paper will be available soon and will permit testing for the effects of technological change in medicine.

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APPENDIX TABLE A-1

COMPLETE EQUATIONS
HYPERTENSION, COEFFICIENTS AND ABSOLUTE VALUES OF t-STATISTICS

	Dependent Variable and Estimation Method							
	Prevalence of Hypertension, Logit		Prevalence of Hypertenaion, OLS		Pervalence of Hypertension, TSLS[a]		Diastolic Blood Pressure, Subset of Hypertensives, OLS	
Primary Care Physicians/100,000	-.0025 (.64)	.0035 (1.16)	.00034 (1.16)	.00024 (.64)	-.0066 (1.25)	.00061 (.91)	-.040 (1.11)	-.040 (1.51)
Other Physicians/ 100,000	.0031 (2.31)	—	—	.00030 (2.31)	.0024 (1.20)	—	-.0042 (.37)	—
Beds/1000	.062 (1.16)	—	—	.0060 (1.16)	-.025 (.44)	—	.14 (.30)	—
Education of Head, Years	-.051 (3.53)	-.051 (3.50)	-.0049 (3.50)	-.0049 (3.53)	-.0043 (2.84)	-.0049 (3.53)	-.021 (.18)	-.023 (.20)
Income ($)	.000013 (.63)	.000013 (.67)	.0000013 (.67)	.0000012 (.63)	.00000053 (.22)	.0000012 (.62)	.00014 (.79)	.00016 (.91)
Race (1=Nonwhite)	1.35 (8.95)	1.35 (8.99)	.13 (8.99)	.13 (8.95)	.12 (5.32)	.13 (8.96)	1.93 (1.84)	1.88 (1.80)
Percentage of Population Urban	-.0072 (3.20)	-.0049 (2.51)	-.00047 (2.51)	-.00069 (3.20)	-.0012 (1.76)	-.00055 (2.11)	.0053 (.28)	.0018 (.10)
Age	.14 (7.48)	.14 (7.41)	.013 (7.41)	.014 (7.48)	.014 (7.12)	.013 (7.39)	.62 (3.21)	.63 (3.25)
$(Age)^2$	-.0013 (5.99)	-.0013 (5.91)	-.00013 (5.91)	-.00013 (5.99)	-.00013 (5.80)	-.00012 (5.90)	-.0031 (1.50)	-.0032 (1.55)
Sex (1=Female)	-.26 (2.77)	-.26 (2.76)	-.025 (2.76)	-.025 (2.77)	-.019 (1.60)	-.025 (2.78)	-.12 (.14)	-.16 (.20)
Constant	-4.94 (11.02)	-4.95 (11.85)	-.14 (3.56)	-.14 (3.29)	.16 (.47)	-.15 (3.51)	83.11 (18.06)	83.60 (18.64)
R^2	.06	.06	.06	.06	.02	.05	.20	.20
F	27.64	33.67	33.67	27.64	—	—	12.78	16.00
d.f.	10,4653	8,4655	8,4655	10,4653			10,523	8,525

[a]In case of TSLS, values given beneath coefficienta are asymptotically normal variates. R^2 is between actual and estimated dependent variable.

APPENDIX TABLE A-2

COMPLETE EQUATIONS, SERUM CHOLESTEROL, COEFFICIENTS AND ABSOLUTE VALUE OF t-STATISTICS

	Dependent Variable and Estimation Method				
	Prevalence of Cholesterol >300, Logit		Prevalence of Cholesterol >300, OLS		Subset with Cholesterol >300, OLS
Primary Physicians/100,000	.0068 (1.21)	.0051 (1.14)	.00031 (1.21)	.00023 (1.14)	-.013 (.06)
Other Physicians/100,000	-.00055 (.28)	—	-.000025 (.28)	—	.061 (.83)
Beds/1000	-.035 (.45)	—	-.0016 (.45)	—	1.54 (.49)
Education of Head (Years)	.027 (1.26)	.027 (1.26)	.0012 (1.26)	.0012 (1.26)	.47 (.56)
Income ($)	-.0000048 (.17)	-.0000044 (.15)	.00000022 (.17)	.00000020 (.15)	-.0014 (1.35)
Race (1=Nonwhite)	-.39 (1.76)	-.38 (1.75)	-.018 (1.76)	-.017 (1.75)	-1.18 (.12)
Percentage of Population Urban	-.00020 (.06)	-.00052 (.18)	.0000089 (.06)	.000023 (.18)	-.18 (1.36)
Age	.050 (1.81)	.050 (1.83)	.0023 (1.81)	.0023 (1.83)	-.19 (.15)
$(Age)^2$	.000089 (.28)	.000084 (.27)	.0000040 (.28)	.0000038 (.27)	-.0013 (.10)
Sex (1=Female)	.27 (1.93)	.27 (1.92)	.012 (1.93)	.012 (1.92)	-5.98 (1.03)
Constant	-5.86 (8.99)	-5.92 (9.76)	-.069 (2.33)	-.072 (2.61)	373.31 (11.38)
R^2	.030	.030	.030	.030	.064
F	14.18	17.70	14.18	17.70	0.76
d.f.	10,4653	8,4655	10,4653	8,4655	10,111

APPENDIX TABLE A-3

COMPLETE EQUATIONS,
PREVALENCE OF ABNORMAL EKG
COEFFICIENTS AND ABSOLUTE VALUES OF t-STATISTICS

	Estimation Method			
	Logit	Logit	OLS	TSLS[a]
Primary Care Physicians/ 100,000	.00057 (.19)	-.00056 (.23)	.000088 (.19)	.013 (1.89)
Other Physicians/ 100,000	-.0012 (1.16)	——	-.00019 (1.16)	-.0045 (1.65)
Beds/1000	.018 (.43)	——	.0028 (.43)	.033 (.43)
Education of Head (Years)	.0070 (.61)	.0066 (.58)	.0011 (.61)	.000052 (.03)
Income ($)	-.000017 (1.08)	-.000018 (1.16)	-.0000026 (1.08)	.0000019 (.56)
Race (1=Nonwhite)	1.06 (8.88)	1.05 (8.83)	.16 (8.88)	.18 (5.99)
Percentage of Population Urban	-.00090 (.51)	-.0020 (1.27)	-.00014 (.51)	.00085 (.94)
Age	-.083 (5.59)	-.083 (5.58)	-.013 (5.59)	-.015 (5.39)
$(Age)^2$	.0014 (8.41)	.0014 (8.39)	.00022 (8.41)	.00024 (7.78)
Sex (1=Female)	-.64 (8.54)	-.64 (8.52)	-.099 (8.54)	-.11 (6.80)
Constant	-.37 (1.05)	-.25 (.77)	.38 (7.05)	-.14 (.28)
R^2	.094	.094	.094	.029
F	48.43	60.35	48.43	——
d.f.	10,4653	8,4655	10,4653	——

[a]In case of TSLS, values given beneath coefficients are asymptotically normal variates. R^2 is between actual and estimated dependent variable.

APPENDIX TABLE A-4

COMPLETE EQUATIONS,
PREVALENCE OF ABNORMAL CHEST X-RAY
COEFFICIENTS AND ABSOLUTE VALUES OF t-STATISTICS

	Estimation Method			
	OLS	TSLS[a]	OLS	OLS
Primary Care Physicians/ 100,000	-.00081 (.70)	.055 (2.57)	-.0019 (2.03)	——
Other Physicians/ 100,000	-.0017 (4.19)	-.019 (2.40)	——	-.0016 (4.59)
Beds/1000	.042 (2.63)	.30 (1.32)	——	——
Education of Head (Years)	-.011 (2.53)	-.016 (2.63)	-.011 (2.64)	-.011 (2.55)
Income ($)	-.0000094 (1.56)	-.0000044 (.44)	-.000012 (1.93)	-.000010 (1.73)
Race (1=Nonwhite)	-.096 (2.12)	-.0030 (.03)	-.11 (2.49)	-.10 (2.32)
Percentage of Population Urban	.0030 (4.49)	.0064 (2.36)	.0015 (2.56)	.0029 (4.32)
Age	-.037 (6.47)	-.044 (5.36)	-.036 (6.41)	-.037 (6.51)
$(Age)^2$	.00053 (8.06)	.00060 (6.39)	.00052 (7.98)	.00053 (8.09)
Sex (1=Female)	.15 (5.37)	.099 (2.06)	.16 (5.49)	.16 (5.46)
Constant	2:07 (15.43)	-.55 (.39)	2.28 (18.18)	2.20 (17.75)
R^2	.046	.006	.041	.045
F	22.64	——	25.17	27.38
d.f.	10,4653	——	8,4655	8,4655

[a]In case of TSLS, values given beneath coefficients are asymptotically normal variates. R^2 is between actual and estimated dependent variable.

APPENDIX TABLE A-5

COMPLETE EQUATIONS,
PREVALENCE OF VARICOSE VEINS
COEFFICIENTS AND ABSOLUTE VALUES OF t-STATISTICS

	Estimation Method				
	Logit	Logit	OLS	OLS	TSLS[a]
Primary Care Physicians/ 100,000	.0028 (.82)	——	——	.00034 (.82)	.0037 (.58)
Other Physicians/ 100,000	-.00058 (.47)	——	——	-.000068 (.47)	.0031 (1.28)
Beds/1000	-.14 (2.91)	-.13 (2.94)	-.015 (2.94)	-.017 (2.91)	-.18 (2.59)
Education of Head (Years)	-.021 (1.62)	-.021 (1.59)	-.0024 (1.59)	-.0025 (1.62)	-.0025 (1.38)
Income ($)	-.0000092 (.51)	-.0000087 (.48)	-.0000010 (.48)	-.0000011 (.51)	-.0000056 (1.90)
Race (1=Nonwhite)	-.42 (3.11)	-.42 (3.10)	-.050 (3.10)	-.050 (3.11)	-.093 (3.46)
Percentage of Population Urban	.0042 (2.05)	.0042 (2.70)	.00050 (2.70)	.00049 (2.05)	-.0013 (1.60)
Age	-.012 (.72)	-.012 (.70)	-.0014 (.70)	-.0015 (.72)	-.0011 (.45)
$(Age)^2$	.0010 (5.22)	.0010 (5.20)	.00012 (5.20)	.00012 (5.22)	.00012 (4.24)
Sex (1=Female)	.81 (9.49)	.81 (9.51)	.096 (9.51)	.096 (9.49)	.11 (7.67)
Constant	-3.34 (8.26)	-3.30 (8.32)	.012 (.26)	.0083 (.17)	.72 (1.71)
R^2	.14	.14	.14	.14	.05
F	73.74	92.11	92.11	73.74	——
d.f.	10,4653	8,4655	8,4655	10,4653	——

[a]In case of TSLS, values given beneath coefficients are asymptotically normal variates. R^2 is between actual and estimated dependent variable.

Appendix Table A-6

COMPLETE EQUATIONS, PERIODONTAL DISEASE, COEFFICIENTS, AND ABSOLUTE VALUE OF t-STATISTICS

	Estimation Method	
	OLS	TSLS[a]
Dentists/100,000	.000019 (.02)	.0017 (1.19)
Education of Head (Years)	-.068 (10.06)	-.068 (10.12)
Income ($)	-.000070 (7.55)	.000071 (7.65)
Race (1=nonwhite)	.10 (1.45)	.10 (1.47)
Percentage of Population Urban	-.0010 (1.11)	-.0020 (1.75)
Age	.040 (4.50)	.040 (4.49)
$(Age)^2$	.000087 (.86)	.000088 (.86)
Sex (1=female)	-.41 (9.19)	-.41 (9.22)
Constant	1.05 (5.49)	1.05 (5.47)
R^2	.17	.16
F	115.38	—
d.f.	8,4655	—

[a]In case of TSLS, values given beneath coefficients are asymptotically normal variates. R^2 is between actual and estimated dependent variable.

Appendix Table A-7

COMPLETE EQUATIONS
ABRAHAMSE-KISCH HEALTH STATUS AGE INDEX,
COEFFICIENTS AND ABSOLUTE VALUES OF t-STATISTICS

	Estimation Method	
	OLS	TSLS[a]
Primary Case Physicians/ 100,000	-.0031 (.37)	.33 (2.44)
Other Physicians/100,000	-.00082 (.28)	-.094 (1.84)
Beds/1000	.081 (.70)	.21 (.14)
Education of Head (Years)	-.19 (6.15)	-.22 (5.73)
Income ($)	-.00012 (2.70)	-.00012 (1.92)
Race (1=nonwhite)	.033 (.10)	.27 (.47)
Percentage of Population Urban	.0047 (.98)	.017 (1.02)
Age	.55 (13.63)	.51 (9.82)
$(Age)^2$	.0022 (4.76)	-.0018 (3.07)
Sex (1=female)	.40 (1.94)	.18 (.59)
Constant	24.14 (25.11)	13.65 (1.53)
R^2	.36	.20
F	263.04	—
d.f.	10,4653	—

[a]In case of TSLS, values given beneath coefficients are asymptotically normal variates. R^2 is between actual and estimated dependent variable.

APPENDIX TABLE A-8

AREAS IN THE HEALTH EXAMINATION SURVEY'S SAMPLE*

Caravan I	Caravan II
1. Philadelphia, Pennsylvania	(During the early part of the Health Examination Survey only one Mobile Examination Center was used.)
2. Valdosta, Georgia	
3. Akron, Ohio	
4. Muskegon, Michigan	
5. Chicago, Illinois	
6. Butler, Missouri	
7. Midland, Texas	
8. Los Angeles, California	
9. San Jose, California	
10. San Francisco, California	
11. Grand Coulee, Washington	12. Washburn, Wisconsin
13. Minneapolis, Minnesota	13. Minneapolis, Minnesota
14. Chicago, Illinois	14. Chicago, Illinois
15. Detroit, Michigan	15. Detroit, Michigan
16. Fort Wayne, Indiana	17. Auburn, New York
18. York, Pennsylvania	19. Biddeford, Maine
21. New York, New York	20. New York, New York
22. New York, New York	23. Baltimore, Maryland
23. Baltimore, Maryland	25. Oxford, Mississippi
24. Nashville, Tennesse	26. Savannah, Georgia
27. Eufaula, Alabama	29. San Antonio, Texas
28. Clinton, Louisiana	31. Kennett, Missouri
30. Newport, Arkansas	33. Louisville, Kentucky
32. Topeka, Kansas	34. Providence, Rhode Island
35. Boston, Massachusetts	36. Carbondale, Illinois
37. Conway, South Carolina	38. Columbus, Ohio
39. Winslow, Arizona	40. Pittsburgh, Pennsylvania
	41. Newport News, Virginia
	42. Rocky Mount, North Carolina

Source: US National Center for Health Statistics (1965).

*Three separate samples were drawn in New York City, and two were drawn in Chicago; thus the actual number of distinct areas involved in the survey was 39.

Mathematical Modeling and the Goal of Health Care System

A.A. Blyusin and M.A. Schnepps-Schneppe

The simulation model of the health care system has one drawback, namely, that it is not clear how to use it for decision making in health care management. It will produce indicators by the hundred. If we simulate two versions of the same measure we shall obtain two sets of output indicators. Typically, one version will give a better performance over some of the indicators and the other version will be better over other indicators. Such difficulties will arise when comparing a mere two versions but health care management faces problems which involve selecting from a set of versions that present a continuum. Thus, we get into the situation which the well-known expert in operations analysis Professor T.C. Koopmans (USA) called "the procedural stupidity" when "the analyst delivers the mountain of results to the customer leaving him in profound confusion before a mass of equivalent decisions".

To help the customer--in our case a health care administrator--we must develop a single comprehensive indicator (criterion, index) whereby one version of a health care measure could be judged preferable to the other versions; and use computers to select from the multitude of available versions the version for which that indicator reaches its extreme value.

In recent years, the World Health Organization has devoted considerable efforts to finding such a comprehensive criterion for measuring the efficiency of health care programs. At the opening of the technical discussion commemorating WHO's 25th anniversary in 1972, Professor E. Amundsen stressed the need to define the primary objective which must be taken into account at all the stages of public health planning and which must guarantee that the public health system should make an optimum contribution to the development of society. The summary of this discussion points out that the indicators used at present in the public health (such as the ratio of physicians to the population, the number of the hospital beds per 1000 population, the availability of medical personnel) show only the potentialities but do not describe the results.

The participants in the discussion were right in criticizing the above indicators but they came to the conclusion that "the universal indicator seems to be impossible to develop".

We cannot accept such a pessimistic conclusion and the aim of this paper is to formulate an objective of public health and a single criterion of health care management stemming from it, in addition to an indicator of the relative efficiency of the measures and functions of the health care system.

It is suggested that the main objective of health care is the maximization of man-years weighted by their value for society taking into account humanitarian principles and other limitations accepted in any given country.

Figure 1 illustrates our concept of the health care objective. The resources allocated by society for health care are distributed among the individual functions and measures of the system. These influence the rate of flows (transitions) between various groups based on health status and hence, the number of individuals who are at any moment in one of the following groups: "healthy individuals", "latent sick", "patients and incapacitated individuals" and "dead". Individuals are assumed to enter the group of "dead" at the moment of death and to remain in it during their unlived years.

In any group, except that of healthy individuals, there is a loss of man-years:

- Death involves unlived years;
- Disease and incapacity involves wasted periods; (it may be assumed that all or part of the period of illness is completely lost for the individual and society);
- General fatigue typical of a considerable number of the latent sick leads to a decrease in working capacity and creative activity, which is equivalent to the loss of part of their life span.

Every unit of time has its value for the individual and society. This value depends not only on the age and the social position of the individual but also on his health. The more severe the disease, the greater the fraction of human time that is assumed to be lost and hence, the smaller the fraction of time that is regarded as being usefully spent for the individual and society. These concepts are used in selecting the weighting factors for the different man-years. The fraction of time usefully spent depends on health care measures and part of it is directly due to the health care measures. In fact, health care activities aim at increasing this part.

A few words about the mathematical side of the problem. The objective we have formulated can be treated as to achieve the extreme value which is the optimum in management of the health care system. The criterion of optimum is the sum of weighted man-years for society while the limitations are not only those on resources but also those that arise from the health care concepts prevailing in any country.

It may seem that a comparison of health care programs on the basis of our objective would require either information that is not available or elaborate and impractical computations. However, this is not so, to obtain the mathematical solution to the problem of optimum management, we have to calculate, not the sum of weighted man-years but the partial derivative of this sum with respect to the expenditures on the measures being compared. In other words, we have to calculate the ratio between the increase in the criterion for optimization and the corresponding increase in expenditures on each of the measures under consideration and this task is considerably simpler than a calculation of the criterion's absolute value.

The efficiency of every health care measure or set of measures may be evaluated with the following formula:

$$\Delta Q = \sum_{ijk} \Delta A_{ijk} q_{ijk} \quad , \qquad (1)$$

where the subscript i indicates the age; j indicates the health group; k indicates the social position; q_{ijk} is the weighting factor which reflects the usefulness (value) of a time unit for society as a whole and for the individual who is at state i, j, k; ΔA_{ijk} is the change in the number of individuals at state i, j, k as a result of health care measures.

The factors q_{ijk} are often measured in points, but money/time units should be used in justifying the allocation of funds to health care measures. For the group of "dead", the value of q_{ijk} is zero. The data available from current medical, economic and demographical statistics are sufficient for calculating ΔQ if the classification of the population into categories is not very detailed.

To calculate the effects of individual health care measures, ΔA_{ijk} can be expressed in terms of changes in the flow μ_{ijk} into the state i, j, k and in the time t_{ijk} spent in this state. Denoting these changes by $\Delta\mu_{ijk}$ and Δt_{ijk} respectively, we obtain

$$\Delta A_{ijk} = \mu_{ijk} \Delta t_{ijk} + (t_{ijk} + \Delta t_{ijk}) \Delta\mu_{ijk} \quad . \qquad (2)$$

The ergodicity concept suggests here that the change in unlived years due to death as a function of the age at death is given by the following expression

$$\sum_{i,j,k} \frac{\Delta\mu_{ijk}}{A_{ijk}} \sum_{n=i+1}^{N} \sum_{l,m} A(nlm/ijk) q_{nlm} (1+E)^{i-n} \quad ,$$

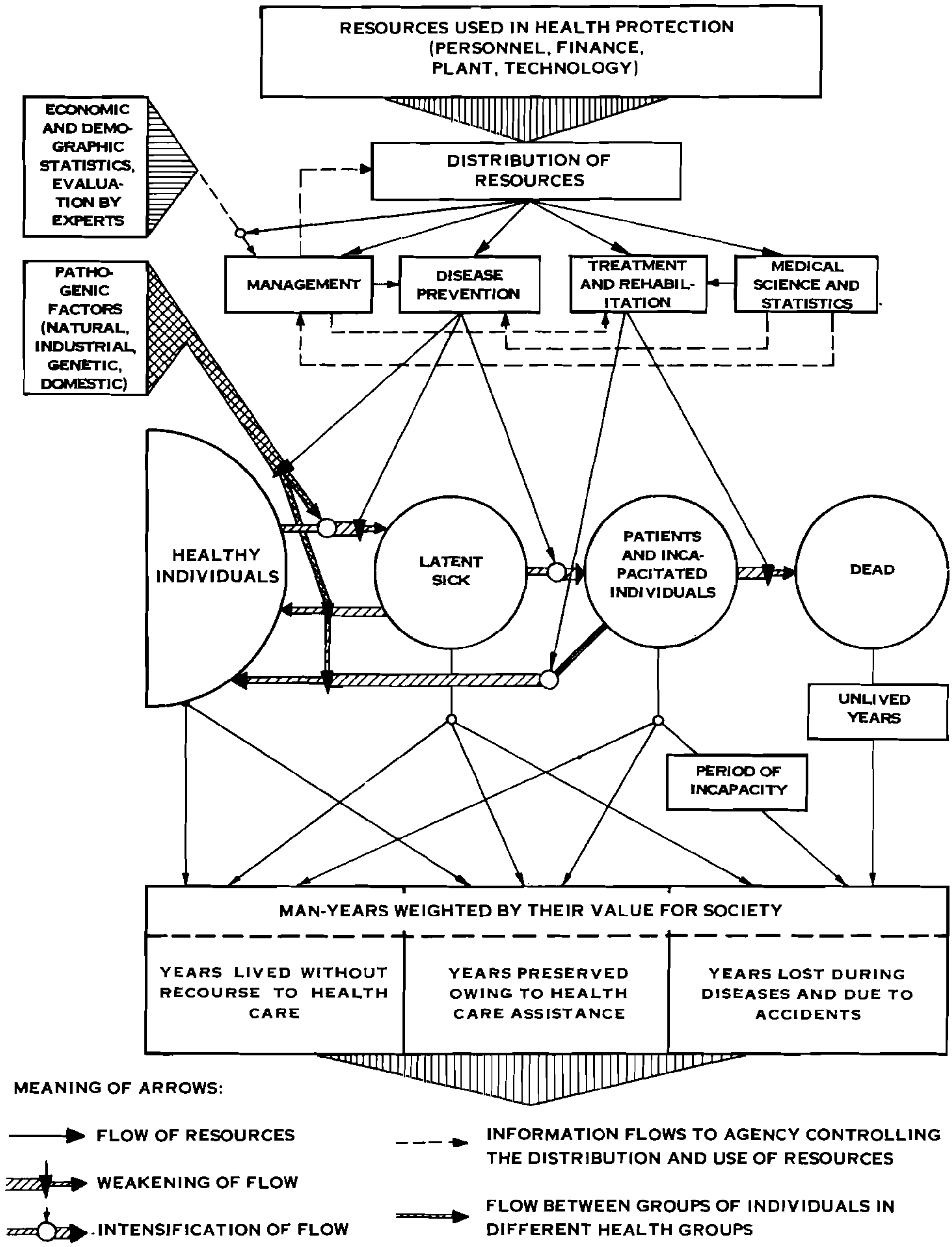

Figure 1. General diagram showing operation of the health health care system.

where i is the age at death, N is the maximum lifespan, A(nlm/ijk) is the expected number of individuals who would enter state n, l, m from state i, j, k, that is, who had at the moment of death the indicators j, k, E is the standard efficiency factor, and $\Delta\mu_{ijk}$ is now the change in mortality at state i, j, k.

It should be noted, by the way, that the common drawback to the indices suggested by Miller, Chayang, Fanshell, Bush and others is the incorrect evaluation of losses caused by premature death. This problem was mentioned in the WHO technical report on statistical indicators [1].

Our formulation of the health care objective makes it possible to solve the problems of the optimum operation and development of the health care system. Computations for individual health care measures will not be more complicated than computations of the efficiency of poliomyelitis vaccination or anti-tuberculosis programs, etc. which are discussed in the *Handbook on Social Hygiene and Public Health Organization* [2]. In these calculations not only the expenditures but also the effects were computed in money units.

The above concepts are further discussed in [3,4,5].

It should be noted that this health care objective is based on the concept of the social objective as discussed in [6] and in a report submitted to the International Seminar on the Application of Mathematical Methods in Sociology held at Novosibirsk in 1970.

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Some Comments on Aspects of Modeling

G. Rosenthal

G. Rosenthal, the Director of the U.S. National Center for Health Research, said that the Center had for many years enjoyed unique possibilities in that it combined work on research and policy problems, since it was responsible to the Federal Government for the organization, financing and technology of public health services; it was also to a limited extent concerned with problems of biomedical research. Following the recent trend to develop models to assist in formulating policy, the center had started to develop its own model to help determine the general direction of its activities. In his view, a model was indispensable to analyze methodology which should be taken into account prior to decision making.

However, the terms "development of models" and "simulation" required more precise definition since he considered that simulation and thinking were absolutely inseparable processes. Most frequently, models were built for research purposes in order to develop and test hypotheses. Such models were primarily related to a particular discipline and expressed relationships in terms of various general functions. He strongly inclined to the view that in time, these theoretical models would become standard models which would be put to practical use.

Another important type of model were management and control models, associated with operational studies. Such models were used, for example, in space research and commerce to calculate the number of engineering staff needed to solve certain problems. Models of this type were capable of detailed development, but they were generally designed to study microproblems, i.e. problems arising within a narrow research project. There were primarily multidimensional in the sense that they reflect the real situation. The models under discussion at the Conference were of this type.

The National Center made extensive use of such models for practical issues and checked their performance. In this way, the Center was endeavoring to develop models with reliable parameters. In practice, most health care models were models of resource distribution. In the USA, models were used to distribute manpower according to the demand for various public health services. Typically, they proved useful in widely different cases: for instance, the Center achieved reasonably accurate results for the allocation of resources to out-patient clinics.

As a general rule, existing models led to the development of further models. Sometimes the latter were concerned with social, economic, demographic or other characteristics of the population. General models also covered a fairly wide spectrum of data, primarily, related to epidemiology. However, considerable problems were caused by the fact that such data was often inaccurate. To effect an improvement, it would be necessary to achieve a more or less uniform distribution of diagnostics and to standardize epidemiological characteristics. Such matters were associated with problems of modeling technique since any system of observation would produce modifications which should be introduced into the model. But this leads to a decrease in precision.

Both now and at earlier stages of model development and study, it would be easier if the scale of demand was fully known.

The Center is concerned at present with studies on all aspects of the health care services.

Problems arose in different areas but they were essentially one and the same--how to improve the service concerned and the related study. The Center was therefore facing the extensive task of developing models for general research problems; it was hoped that the Center's classification system would be helpful in establishing the nature of relationships.

Finally, he observed that in moving from theoretical concepts to actual operational systems, a change of strategy was necessary. At the present time, many changes in modeling technology were taking place which would affect the course of biomedical studies and the shape of health care services, since it was possible that the selection of indicators of morbidity, mortality and so on had been mistaken.

Simulation Languages and Software Facilities

I.N. Vorontsov and M.M. Greshilov

The paper is concerned with some methodological and technological problems associated with the application of many ideas in the development of fundamental and applied research and in the solution of complex practical problems.

There exist at present considerable difficulties in organizing the use of computers for complex system simulation, particularly on a widescale by many specialists and mathematicians.

The task consists in the development of highly adequate models which permit us to analyze the totality of all the important aspects of a phenomenon. We must develop models to assist us in important decision making. For that purpose, it is necessary to devise computer languages and methods of using them which would increase the efficiency of research and project work, including the development of management methods and evaluation of planning decisions.

The main characteristics required of the simulation languages and software facilities used in such work may be divided into three categories.

The first category comprises characteristics to ensure an efficient development of the description of physical processes.

First, we must be able to interpret formally the concepts used in the description of various types of systems and the concepts of various mathematical disciplines.

Secondly, we must have the possibility to develop the description of structures and parameters of static systems in order to describe dynamic systems.

Thirdly, we must be able to develop the description on a large scale.

The second category of characteristics includes aspects of testing systems models. These involve statistical experiments, integration methods, collection of experimental data, data processing, data input in a readily assimilable form, model check-out, model correction, check-out and analysis of models in the process of experiment.

Most algorithmic and simulation languages and their software are not really adapted to these requirements. At the same time, it is very important to be able to correct errors rapidly and to analyze effectively. The burden of work of this kind is very great.

The third category of characteristics includes the use of dialogue facilities and the capability of development in language systems and software.

The first requirement is model description and methods of applying software facilities which are easy to understand.

The second requirement is the capability for syntactic expansion, development of hierarchical descriptions, capability of developing the languages to solve individual standard problems, e.g. each user should be able to develop in a common language some service or formal concepts convenient for his purpose which can be easily interpreted in terms of the description of certain physical phenomena.

The third requirement is the establishment of libraries and banks of individual standard and specific models.

We cannot build a fresh model for each narrow class of phenomena. We have to develop models for rather broad classes of phenomena and then make them more specific. It is therefore necessary to envisage the establishment of libraries and banks with the data of both types of models.

The fourth requirement is the development of data banks in the form of complicated sets of models that make it possible to cover the totality of some broad systems.

The fifth requiremnt is the capability of interaction with various widely used algorithmical languages and access to libraries of programs based on these languages.

The answer to the question of which algorithmic language is the most convenient is the following: every algorithmical language is designed to solve some specific problems and the whole gamut of languages open up vast possibilities. Therefore it would be incorrect to say one particular language must be used or that this language will be suitable in all the cases. It is necessary to use a variety of languages. Simulation languages must provide a means of combining the capacity of various algorithmical languages for communicating with their libraries. This is one of the most important requirements.

The sixth requirement is the possibility of conducting investigations using a third generation multiple-computer complex and fourth generation computing systems.

Fourth generation computers will make it possible to process very large data files and to simulate a great number of simultaneous processes. Already, with the use of third generation computing systems considerable technical possibilities exist to investigate a number of problems.

The seventh requirement is the availability of a data bank reference service in the shape of compound complex models.

It should be noted that there are two types of automatic reference services. The first type is informational; such data banks are generally built up by using various methods of classification, e.g. descriptive methods. However, this way of systematizing data and its related methods does not as yet make it possible to develop systems models and organize the collection of information in specific areas.

The other type of data bank in the shape of compound complex models permits the systematic collection of information and, very importantly, it permits the development of new methods of organizing collective research. We are referring to the results of analysis and research.

The eighth requirement is the possibility of organizing collective modeling.

The time has passed when models were available only to their builder or user. When we encounter a major model (a model of a living cell, an organism, public health system, a city or country) it usually turns out that the model has been built by many specialists and that many specialists must participate in the evaluation of data, investigation of models and their practical application.

This fact is of considerable importance nowadays.

In conclusion, it is worth mentioning that: simulation languages are a specific class of languages, associated with theoretical concepts. The theories may not always be formulated but nevertheless they constitute the basis of the languages. The conceptual apparatus, the terminology with which these languages operate, make it possible to develop language-mediators or interdisciplinary languages. In this sense, research into the development of simulation languages has something in common with linguistic research associated with the development of language-mediators.

In support of some of the opinions expressed in this paper, mention may be made of some striking examples of the development of simulation languages, such as the well known DINAMO language which is based on the theory of differential equations. It is only because this language is based on such a well established mathematical theory that it has been widely used in spite of many drawbacks and provides a reasonable interpretation of a number of real phenomena.

Another language is SIMULA. An attempt was made in developing this language to provide an answer to many of the problems enumerated in this paper. But this language does not have such a compelling theory as the basis of its conceptual system as has DYNAMO. It is closer to the all-purpose algorithmical languages and requires very skillful specialists to manipulate it. Thus it has the striking disadvantage that it inhibits increased productivity on the part of the many specialists who are non-mathematicians.

Methods of synthesizing and analyzing models, formalized languages and software facilities that meet the requirements described in this paper would make it possible to increase very substantially the efficiency of research, project work, and the development of control methods. In many cases, they would open up completely new possibilities of solving complex scientific and practical problems.

Stochastic Compartmental Modeling, Parameter Estimation, and Analysis of Cancer Treatment Systems

Asha S. Kapadia and Bayliss C. McInnis

INTRODUCTION

Deterministic compartmental modeling has become an established method of studying biomedical systems. Comprehensive reviews of the deterministic compartmental theory have been given by Sheppard (1962), Rescingo and Segree (1965), and by Jacquez (1972).

On the other hand, stochastic compartmental analysis is still in the stage of evolution. The theory of illness-death processes as given by Chiang (1968) provides a basis for stochastic compartmental analysis. Significant results have recently been obtained by Matis and Hartley (1971) for a discrete population of particles in a system of m compartments. These authors have reported on a procedure for identifying the parameters of the model when time series data is available only on the passage of the total quantity of material to the exterior of the model.

In modeling cancer treatment systems, data are generally available from follow-up studies on the total number of patients under treatment or "apparently cured". Data on the number of patients in different stages of treatment and under remission are very seldom available.

In this paper we have designed a stochastic compartmental model to determine the survival of cancer patients at various points in time. Their life expectancies at different points in time after being treated for cancer are also calculated. The data used were from a collaborative study aided by a grant from the National Institute of Cancer and the U.S. Public Health Service. The study covered 17 medical institutions which provided the necessary population of patients. The results of the study were published in the September 1975 issue of *Cancer*.

DESIGN OF THE INVESTIGATION

The investigation was designed as two separate but integrated trials of primary lung cancer as follows:

- Patients with lesions considered operable at the time of diagnosis.

- Patients who were considered potentially operable only after radiotherapy.

Classification of Patients

Each patient was evaluated clinically and classified into one of three groups:

1. Patients with involvement of only one lung and with no evidence of extension of tumor beyond the lung were classified as "clinically operable"; they are referred to as "initially operable patients".

2. Patients with lymph node involvement, chest-well invasion or encroachment of the tumor upon the carina were considered "clinically inoperable without radiotherapy"; these are referred to as "potentially operable patients".

3. Those with more extensive disease or a condition which would preclude either surgery or radiotherapy were excluded from the study.

THERAPY

Initially operable patients. These were randomly assigned to receive surgery (1) after prior radiotherapy--this group received radiotherapy and then surgery after a four to six weeks period if their clinical status indicated surgery to be appropriate, (2) immediately.

Potentially operable. These patients received radiotherapy and, after a four to six weeks waiting period, those considered clinically suitable for surgery were randomly assigned to receive either (1) surgery or (2) no surgery.

To patients receiving surgery, no additional surgery, radiotherapy, or chemotherapy was to be given unless their cancer had proved unresectable or there was evidence of metastasis or recurrence. Patients who did not receive surgery could receive only additional radiotherapy unless the cancer recurred. In that case chemotherapy could be given.

More than 3600 patients with a diagnosis of primary cancer of the lung were registered with the statistical center. Only 568 (16 percent) met the criteria for the initially operable study group. The randomization procedure assigned 289 to receive preparative radiotherapy and 278 to receive immediate surgery. Another 425 (12 percent) were classified as potentially operable after a course of radiotherapy; of these only 152 patients were considered suitable for attempted resection once their course of radiotherapy was completed. Randomization assigned 78 to receive surgery and 74 to recieve no surgery.

RESULTS

Some results of the investigation are shown below in Table 1 and Figures 1-7.

Table 1. Table of life expectancies.

1. Immediately Operable Patients Group 1 (RT + Surgery)

Time	ELE
t = 0	4.3 yrs.
t = 1	8.3 yrs.
t = 2	11.00 yrs.
t = 3	13.02 yrs.
t = 4	17.54 yrs.

2. Immediately Operable Patients Group 2 (Surgery)

Time	ELE
t = 0	6.006
t = 1	12.99
t = 2	17.14
t = 3	22.72

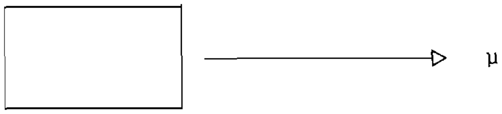
3. Potentially Operable Group 1 (Radiotherapy)

Time	ELE
t = 0	2.02
t = 1	2.25
t = 2	6.32
t = 3	6.66
t = 4	6.66

4. Potentially Operable Group 2 (RT + Surgery)

Time	ELE
t = 0	1.5
t = 1	2.50
t = 2	5.00
t = 4	5.00

One Compartment Model



$$P(n,t) = (N_0/n)\,e^{-n\mu t}(1-e^{-\mu t})^{N_0-n} \tag{1}$$

$$E(n/t) = N_0 e^{-\mu t} \tag{2}$$

$$Var(n/t) = N_0 e^{-\mu t}(1-e^{-\mu t}) \tag{3}$$

$$\begin{aligned} E[n/t] = {} & N_0 e^{-\mu_0 t}[u(t) - u(t-1)] \\ & + N_1 e^{-\mu_1 (t-1)}[u(t-1) - u(t-2)] \\ & + N_2 e^{-\mu_2 (t-2)}[u(t-2) - u(t-3)] \\ & + N_3 e^{-\mu_3 (t-3)}[u(t-3) - u(t-4)] \\ & + N_4 e^{-\mu_4 (t-4)}\,u(t-4) \\ & 0 \le t < \infty \quad . \end{aligned} \tag{4}$$

Average Life Expectancy

$$\begin{aligned} \int_{t=0}^{\infty} \frac{E(n/t)dt}{N_0} & = \text{Average life expectancy at } t = 0 \\ & = \frac{1}{N_0}[N_0(1-e^{-\mu_0})/\mu_0 + N_1(1-e^{-\mu_1})/\mu_1 \\ & + N_2(1-e^{-\mu_2})/\mu_2 + N_3(1-e^{-\mu_3})/\mu_3 \\ & + N_4/\mu_n] \quad . \end{aligned} \tag{5}$$

$$\int_{t=1}^{\infty} \frac{E(n/t)dt}{N_1} = \text{Average life expectancy at } t = 1$$

$$= \frac{1}{N_1}[N_1(1-e^{-\mu_1})/\mu_1 + N_2(1-e^{-\mu_2})/\mu_2$$

$$+ \ldots\ldots + N_4/\mu_4] \quad \text{, etc.} \qquad (6)$$

Estimation of Parameters

The parameters are estimated in stages using a nonlinear regression package. First μ_o is determined such that

$$\sum(Y(t) - N_0 e^{-\mu_0 t})^2$$

for data points in (0,1) is minimized, where N_0 represents the initial number in any group. This value μ_0 is then used to obtain the expected number of individuals surviving at time t=1, which becomes our N_1 and the process is repeated until all the μ's are determined.

The results are as follows.

1. Immediately Operable Patients in Group 1

N_0 = 289	μ_0 = .903
N_1 = 117.11	μ_1 = .466
N_2 = 73.44	μ_2 = .327
N_3 = 52.95	μ_3 = .418
N_4 = 34.84	μ_4 = .057

2. Immediately Operable Patients in Group 2

N_0 = 278	μ_0 = .93
N_1 = 109.66	μ_1 = .400
N_2 = 73.48	μ_2 = .376
N_3 = 50.44	μ_3 = .044

3. Potentially Operable Patients in Group 1

$N_0 = 74$	$\mu_0 = .822$
$N_1 = 32.50$	$\mu_1 = 1.39$
$N_2 = 8.09$	$\mu_2 = .341$
$N_3 = 5.75$	$\mu_3 = .291$
$N_4 = 4.29$	$\mu_4 = .150$

4. Potentially Operable Patients in Group 2

$N_0 = 78$	$\mu_0 = .822$
$N_1 = 34.26$	$\mu_1 = 1.8$
$N_2 = 5.37$	μ_2 = almost zero

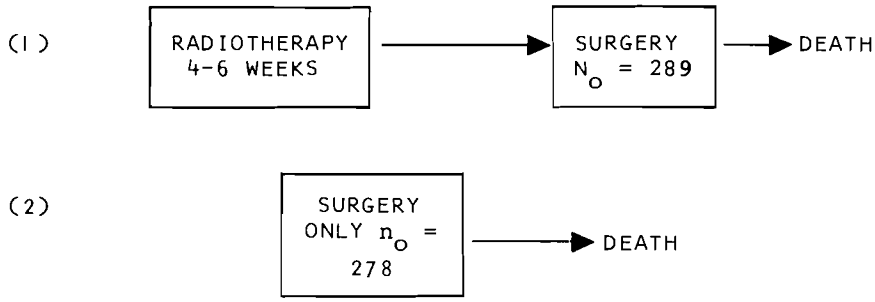


Figure 1. Immediately operable patients.

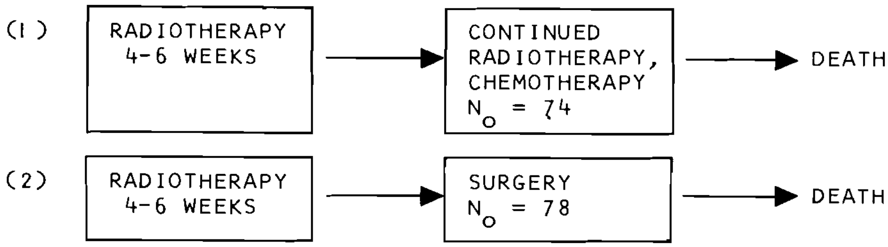


Figure 2. Potentially operable patients.

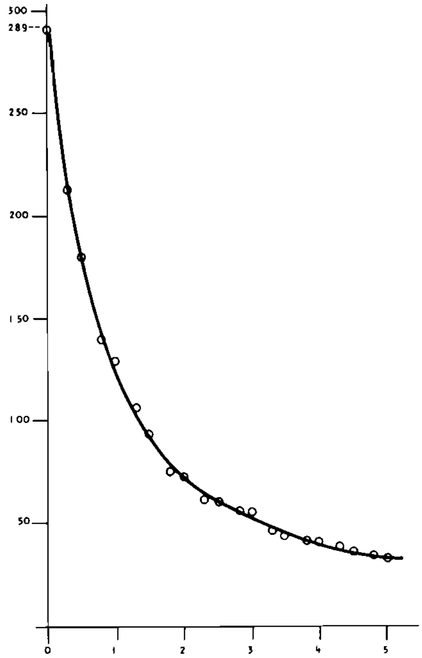


Figure 3. Survival of immediately operable patients in group 1.

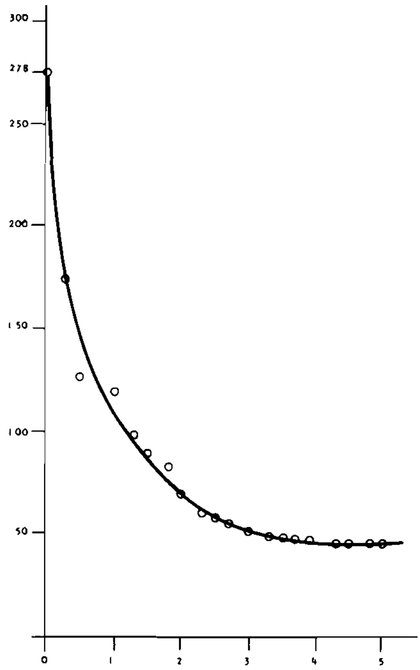


Figure 4. Survival of immediately operable patients in group 2.

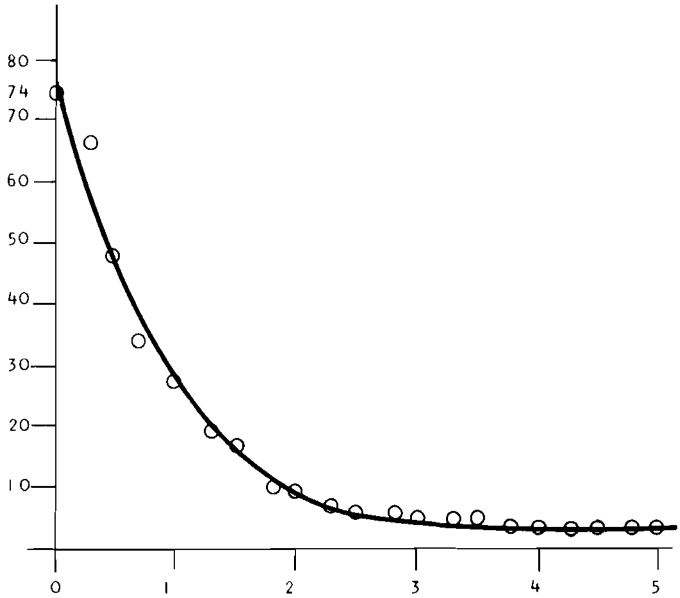


Figure 5. Survival of potentially operable patients in group 1.

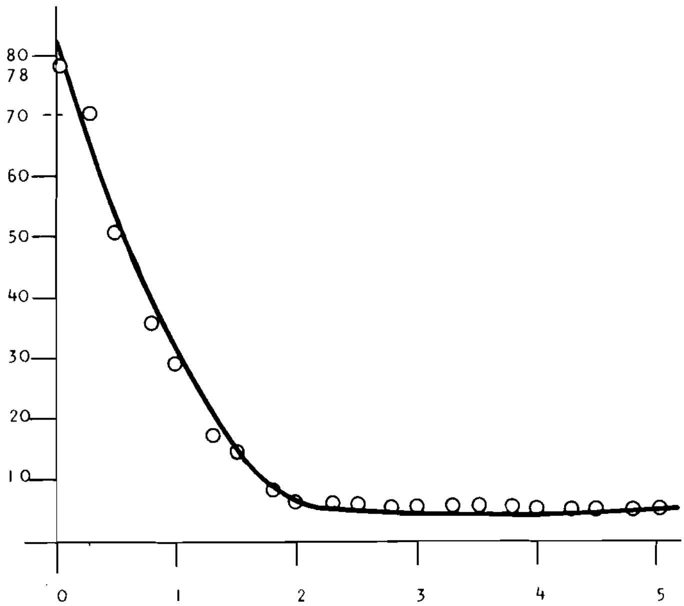


Figure 6. Survival of potentially operable patients in group 2.

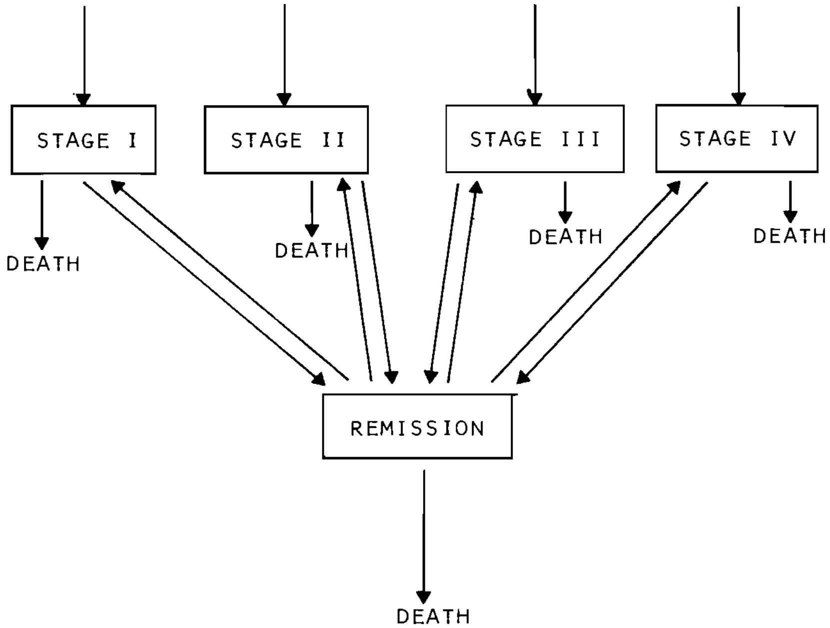


Figure 7. Simplified model of cancer treatment systems.

On Models for Population Health Care

V.K. Kuznetsov

Most investigators dealing with population health care models base their research on the traditional approach of measuring the effectiveness of a public health system by means of the mathematical calculation of cost.

Thus, McDonald and Gibbs discuss a model which involves the factors of detecting and treating cases of illness and also includes the costs.

Soviet investigators have a similar policy of investigating and monitoring results.

A distinguishing feature of the McDonald-Gibbs model was the comparison of costs with yield (i.e. the effect produced by investment) by means of econometric parameters. McDonald and Gibbs present different terms in the form of commensurable addends and calculate the net efficiency in the form of posynomials of arguments. These arguments are the number of patients and expenditures of resources. Among the parameters of these functions are the so-called elasticity parameters. This approach makes it possible to cover nonlinear relationships; this has already been mentioned by Professor Thrall.

McDonald and Gibbs also distinguish between real and ideal costs. In the work by Soviet scientists, costs are presented in the form of established norms.

This short survey of the models demonstrates that there are no objections in principle, and the construction of population health care models can be assigned to that domain of mathematics which is called geometrical programming and which considers the optimization of a system where the optimum is reached by minimization or maximization of the empirically obtained posynomials of the form

$$y(x_1,\ldots,x_m) = \sum_{i=1,2,\ldots,n} C_i x_1^{a_{i1}},\ldots,x_m^{a_{im}} \quad . \tag{1}$$

where y, a function of m arguments, is a sum of terms with subscript i taking on the values from 1 to n. Each term has a scaling factor C_i and is multiplied by a standard function, which is a product of these arguments raised to arbitrary powers, either integer or fractional. When the powers are integers, a posynomial reduces to a polynomial.

The coefficient C and exponent a are found by means of standard methods of mathematical statistics, on the basis of representative data. These data are given, as derived for one microeconomic model, in the paper by Donald Yett, et al. in this volume.

I believe that to ensure that an approach discussed by this conference is realistic, it is necessary to reach a decision on standardizing it. On the basis of the theory of measuring the effectiveness of a health care system in terms of posynomials, it is possible to construct dynamical stochastic models of a higher order than those presented to this conference; this requires an elementary application of this typical solution to various situations under conditions when coefficients of the posynomials (coefficients C and elasticity factors a) vary in time and space.

It is easily demonstrable from the general probability theory that posynomials of cost are variants of statistical distributions very close to the Gaussian distribution. However, models of such order will be realizable only in a remote future, since the econometric programs have not yet been worked out; posynomials are not yet ready for practical application.

Let us consider another interesting investigation of the efficiency of various methods of cancer treatment as discussed in the Conference paper by Kapadia and McInnis. This investigation applied the techniques of stochastic compartmental simulation. Seventeen medical institutes of the USA took part in this study, which was financed by the U.S. National Cancer Institute, by supplying required patients, who were classified into two groups: those who were considered operable at the moment of diagnosis formulation, and those who could be operated after preliminary radiotherapy.

Application of the above mentioned mathematical techniques and exponential equations made it possible to obtain important results concerning after-treatment life expectancy of the patients. It was shown that while in the first class it is expedient to operate on the patients without preliminary radiotherapy, in the second class (patients with the disease in a more serious form) it is preferable that radiotherapy not be followed by the operative treatment (surgery shortens the after-treatment life-span).

In conclusion, the significance of systems analysis lies in the integration of the efforts of the medical profession with those of other specialists organizing the health industry, namely mathematicians, economists, rate fixers, accountants, and quality controllers. In these conditions a doctor becomes a central figure, like an engineer in a plant. A doctor certainly has at his disposal more active means of early diagnosis and prevention of preterminal states and of health education.

It is proposed to inculcate this outlook in future generations of doctors and to restructure the thinking of the present organizers of medical care by means of advanced training.*

The "technical approach" system assumes that phenomena are analyzed in such manner that no subsystems of the total system are used within the monitoring sphere. The operations are assumed to be on such a scale that systems approach to control becomes necessary.

A solution to the fundamental problems of the system as a whole, i.e. increased output and improved quality, is impossible outside the framework of systems engineering and systems management of doctors' activities to integrate medical specialists at the control level in the hierarchical organization of production.

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*See Deboeck in this volume.

A Decade of Health Services in Egypt

Amal S. Ibrahim and Samir G. Botros

INTRODUCTION

In Egypt, the state is responsible for providing health services to its citizens and in pursuance of this objective has defined the following policy [1]:

- The extension of health services to the rural areas. Efforts have been made to combat infectious and endemic diseases, e.g. tuberculosis;
- The extension of already existing free health services in both rural and urban areas;
- The extension of mother and infant welfare centers;
- Medical services available to all citizens in government hospitals at nominal fees;
- The construction of medical institutes specializing in one branch of medicine or surgery to protect citizens from exploitation by private medical services;
- The construction of fully equipped training centers to provide the required personnel;
- The increase of locally produced pharmaceutics to meet the demand for reasonably priced medicines;
- The extension of health insurance to cover all citizens.

Health planning is necessary in any country, irrespective of its political and economic system. It is the only systematic method for dealing with health problems and guaranteeing adequate health care to all citizens.

A prerequisite for health planning is a proper information system and complete statistics. A basic defect in developing countries, is the inavailability of information [2]. Much medical and epidemiological information is collected and then lost because to those who generate it, it is just so much paper. Investigators are inclined to register their data selectively, a practice which does not always yield sufficiently reliable indices and results [3].

DESCRIPTION OF THE EXISTING HEALTH SYSTEM

Before proceeding to an analysis of health service statistics in Egypt, it is useful to describe the health system as it now exists.

Figure 1 gives the overall existing administrative arrangements in health care delivery; i.e. at central and governorate levels; while Figure 2 shows services provided at the governorate level in more detail [4].

Implementation of administrative policies emanating from the Ministry of Health (MOH) in the various governorates is carried out by the Director General of Health Affairs. The follow-up is made through monthly statistical reports and periodic meetings with health authorities in different governorates as well as through occasional visits from higher authorities in the MOH. Various statistics are published periodically by the MOH and by the Central Agency for Public Mobilization and Statistics (CAPMAS). These publications are the basis of the statistics presented in this work.

The following types of existing units are of interest in our work:

- Rural health units;
- Rural health centers and combined units;
- Maternal and child welfare centers;
- Health bureaux;
- School health units;
- Specialized hospital;
- District and governorate hospitals.

A description of these units is given below:

1. Rural health units operating in the villages offering preventive and curative services at the general practitioner level but with no inpatient service or beds.

2. Rural health centers were originally designed to serve about 20,000 people with an outpatient clinic, a laboratory and a pharmacy, and an inpatient department of ten beds, four of which are reserved for maternity and child health (MCH). They were also intended to deal with preventive health, and the control of factors affecting public health. There is an ambulance service and accomodation for a doctor and nursing staff.

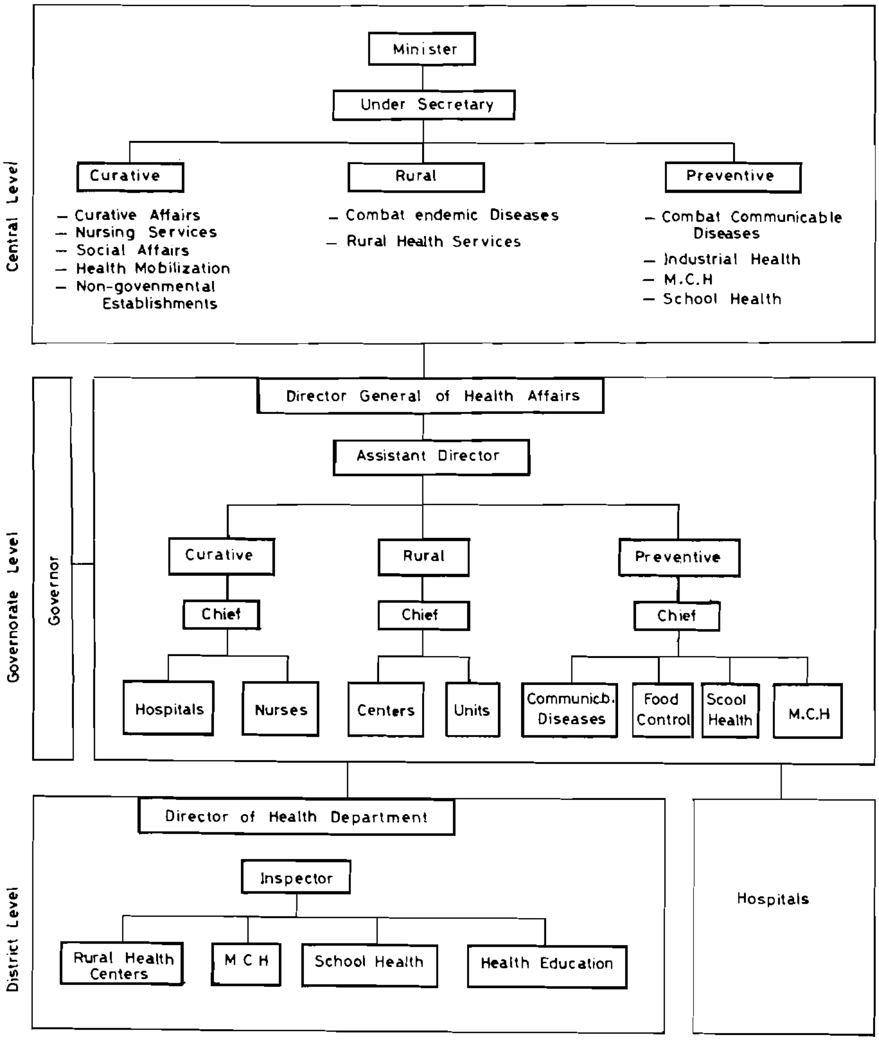

Figure 1. Administrative arrangement of health services.

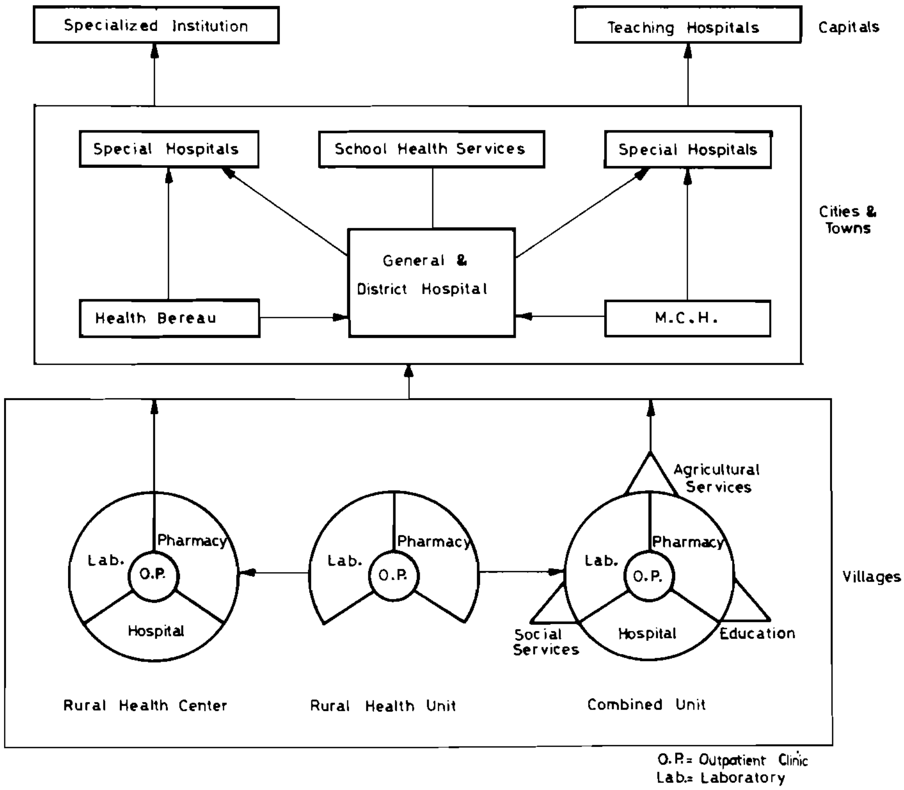

Figure 2. Health services at different levels.

3. Combined units were originally designed to provide comprehensive medical services, health education, agricultural extension and social welfare services for every rural community of about 15,000 persons. The health section was to consist of an outpatient clinic, MCH center, dispensary, laboratory and inpatient service of 14-20 beds--nine for males, three for females and two for maternity cases--and an operating theater. Such centers were also intended to promote school health and provide health education.

4. Maternal and child welfare health centers (MCH) were established in cities and the main towns of administrative districts and were hence considered urban centers but they serve rural populations. They were designed to serve 50,000 people and to be responsible for the care of mothers and infants, with the aim of reducing infancy mortality and minimizing pregnancy-related deaths and accidents. Prenatal, postnatal and infant welfare clinics are held at the center but many services, including delivery, are offered at home.

5. Health bureaux designed as comprehensive health bureaux and including a health office to monitor control of, and vaccination against, communicable diseases.

6. School health services are covered by rural health units and the rural centers as well as by comprehensive school health units. Services offered include physical examinations, vaccinations and curative services. In addition, specialized school health units provide a variety of specialist treatment services.

7. Hospitals: the present system offers several different categories of hospitals, some of which have outpatient as well as inpatient services. Hospitals vary in the number of facilities and beds. District hospitals are located in a "Markaz" (district center) and governorate hospitals are generally located in the capital city of the governorate. In addition to general hospitals, there are hsopitals specializing in the treatment of one disease as well as private and military hospitals which cater for a restricted public.

Population in Egypt

In Egypt, a population census is held every ten years: the last census took place in 1960. Circumstances of war have rendered it inexpedient to carry out a complete census since that date. A sample census was held in 1966.

The size of population in any intervening year was estimated on the assumption of a geometric progression with an annual growth rate between 1960 and 1970 of 2.54 percent which represented the annual rate of increase between the 1960 and the 1966 sample census. Subsequent to 1970, an estimate of the population has been made on the basis of a modified growth rate of 2.24 percent which takes account of the observable decline in the birth rate over the last few years [5].

The age and sex distribution of the population as revealed by the 1960 census is shown in Table 1 [6].

Table 1. Population by age and sex (1960 population census).

Age Group	Population					
	Male	%	Female	%	Total	%
Under 1 year	383,360	2.9	369,203	2.9	752,563	2.9
1 - 4	1,728,100	13.2	1,651,458	12.8	3,379,558	13.0
5 - 9	1,971,927	15.2	1,827,076	14.1	3,799,003	14.6
10 - 14	1,651,421	12.6	1,527,203	11.8	3,178,625	12.2
15 - 19	1,114,149	8.5	1,040,286	8.9	2,154,435	8.3
20 - 24	921,120	7.1	874,228	6.8	1,795,348	6.9
25 - 29	859,806	6.6	1,054,269	8.2	1,914,075	7.4
30 - 34	806,857	6.2	844,111	6.5	1,650,968	6.4
35 - 39	847,447	6.5	879,178	6.8	1,726,625	6.6
40 - 44	660,666	5.0	614,211	4.8	1,274,877	4.9
45 - 49	567,163	4.3	577,145	4.5	1,144,308	4.4
50 - 54	493,799	3.8	503,574	3.9	997,373	3.8
55 - 59	322,936	2.5	315,375	2.4	638,311	2.5
60 - 64	320,796	2.5	353,865	2.7	674,661	2.6
65 - 69	163,876	1.2	169,485	1.3	333,361	1.3
70 - 74	133,531	1.0	167,761	1.3	301,292	1.2
75 & over	120,866	0.9	147,152	1.1	268,018	1.0
Not stated	192	0.0	509	0.0	701	0.0
Total	13,068,012		12,916,059		25,984,101	

Rural Health Services

Sixty percent of the Egyptian population are rural inhabitants. This demonstrates the importance of the role played by rural health services in the health care delivery system in Egypt.

The ultimate goal of the rural health services is to provide four outpatient clinics and one rural hospital of 10-14 beds per 20,000 rural inhabitants. In the last decade, the number of outpatient clinics increased fivefold and rural hospital beds by a third. In 1970, the goal was still far from being achieved, since there was one outpatient clinic per 11,000 persons and one bed per 2500 people.

Endemic Disease Services

The control of endemic disease in Egypt includes both preventive and curative functions.

The preventive function is concerned with vector control and is carried out by bilharziasis inspectorates and centers and malaria inspectorates and stations in addition to medical inspectorates and units for the control of insects. There was an increase in the number of these services, except for the last category whose main function is to combat such quarantinable diseases as yellow fever (Table 2).

Table 2. Preventive services against endemic diseases.

Service	Year	
	1960	1970
Bilharziasis inspectorates	13	39
Bilharziasis centers	71	165
Malaria stations	46	79
Malaria inspectorates	78	166
Medical insect inspectorates	11	13

The curative service covers outpatient treatment and hospitalization of complicated or advanced cases. This function is carried by endemic disease hospitals and units, rural health units and school health units.

As shown in Table 3, the number of endemic disease units is nearly constant, while the number of special beds is diminishing. This is due to the fact that treatment of endemic diseases is becoming simpler and safer and is carried out in outpatient centers, i.e. in nonspecific centers without much need for hospitalization. Complicated cases are treated in general and district hospitals.

Table 3. Curative services for endemic diseases.

Service	Year	
	1960	1970
Endemic disease units		
Number	141	151
Beds	2144	1532
Rural units with beds		
Number	469	578
Beds	6600	8149
Rural units without beds	254	1208

Maternity and Child Welfare Services (MCH)

The care of expectant and nursing mothers and of their babies is one of the most important branches of preventive medicine. Child bearing is a physiological process and maternal morbidity must be regarded fundamentally as preventable by efficient medical and social care. This task is more difficult in the face of preexisting disease or pelvic abnormalities, but even in such cases much can be done to reduce risks. The newly-born infant faces a hostile environment of potential infection and injury which continues to take a heavy toll. At birth, there is also a risk of injury which may be functional or anatomical; before birth, maternal diseases may cause foetal mortality or such damage as impairs life from the outset. Careful nursing and feeding are essential to the health of the baby and mothers often need advice on this subject. The efficiency of the services must therefore be constantly tested.

The services are supplied by urban MCH centers as well as by special sections in the rural health centers and units. Hospitalization is possible in maternity and infant-care hospitals, with the possibility of restricted inpatient care in certain MCH centers. About 40 percent of all deliveries occur under supervision of these governmental centers.

Urban MCH Centers: The number of these centers doubled in ten years, rising from 95 in 1960 to 205 in 1970. The number rose steadily and by 1970, there was an average of two beds per unit for emergency cases.

Rural MCH Services: Unfortunately there are not available statistics on MCH activities in rural areas. However, the number of units corresponds to that of rural health centers and units discussed above.

School Health Services

These services are of major importance in health care delivery in Egypt, since 35 percent of the Egyptian population falls into the age group 5 to 20 years. School children constitute a well-defined group where preventive measures and early detection can be carried out efficiently and through which the health education of the whole family can be achieved.

School health services are carried out by:

- School health hospitals;
- School health centers with specialist services (outpatient clinics);
- School health units with GP services (outpatient clinics);
- Health visitors in individual schools.

The number of school health services increased from 143 in 1960 to 205 in 1970; mainly in centers and units. Beds increased from 246 to 424 in the same period, indicating that many school children are treated in general and district hospitals, especially in areas without school health hospitals.

Table 4. Breakdown of school health services (1963 to 1970).

Item	1963	1970
School enrollment*	3,840,035	4,976,582
Visits	1,244,000	3,973,000
Visits per 1000 students	323	798
Hospitalization	6000	7000
Hospitalization per 1000 students	1.6	1.4

*Comprising primary, preparatory, secondary and training teachers' institutes.

Hospital Services

The total number of beds was 74,596 in 1970. Compared to 1960, that represents an increase of 18,922 beds at an average annual rate of about 1500. The increase was due to the expansion of already existing hospitals as well as to the establishment of new units.

The number of beds per 100,000 of population remained nearly constant (about 220). The main burden in hospital services falls on the outpatient clinics.

Crude statistics show that 12,586,000 visits were made to outpatient clinics in 1970. This means that each hospital had about 72,000 visits in that year, or 1400 visits per week. It has been calculated that 125 people out of every 1000 sought medical advice in these clinics.

Mental Illness

In recent years, there has been an increased demand for psychiatric help among the general population. Consequently, the number of units increased from 13 in 1960 to 36 in 1970 and the number of beds from 3334 to 5868.

In 1970, the total number of visits was 135,000 as compared with 29,000 in 1960, representing one visit per 1000 of population in 1960 and four visits per 1000 in 1970.

The number of hospitalizations was nearly stable at 5000 patients, mainly persons dangerous to themselves and to the community. The average turnover during the period 1960-1970 was about 1.3 patients a year.

Emphasis on Prevention

A basic principle of health services is to stress prevention. This should start during intrauterine life by proper antenatal care followed by labor and postnatal care. This service is offered by MCH centers as well as rural health centers as well as general and special hospitals.

Protection of infants and young children, as well as of the community as a whole, against infectious diseases depends mainly on massive vaccination programs and isolation of patients in special hospitals. Vaccination is obligatory during the first year of life and is administered according to the international scheme. Booster doses are given to school children, to vulnerable groups and as a quarantine measure to international travellers and in circumstances where there is a real danger of the spread of an epidemic. The main responsibility for vaccination falls on health bureaux as well as on rural and school health units.

Screening is used as a measure of early detection mainly for pulmonary tuberculosis through mass radiography; it is followed by the immunization of susceptible individuals and the isolation of active cases in 54 chest disease sanatoria. The number of chest dispensaries has doubled in the last decade, reaching 85 units in 1970. There was an average of 1230 visits per month to each outpatient clinic. Periodic screening for other diseases, specially bilharziases and cancer, is carried out on a limited scale.

HEALTH MANPOWER

CAPMAS classifies manpower working in medical establishments into ten main categories: physicians, pharmacists, technicians, nursing staff, social workers, midwives and assistant midwives, dental technicians, administrators and auxiliaries. Official statistics have been published for the period 1967 to 1970.

Physicians

There is a serious shortage of doctors in medical establishments. The rate of increase in the number of physicians lags far behind the population growth rate. The ration was 2.4 per 1000 of population in 1967; it had dropped to 1.8 per 1000 in 1970. Two thirds of these doctors work in government establishments.

Pharmacists

In contrast to physicians, the number of pharmacists relative to population increased from 1.9 per 100,000 to 2.5 per 100,000 over the period 1967 to 1970. Nearly half of them work in government establishments.

Nursing Staff

The number of nursing staff did not increase in the period under study. Consequently, there has been continuous drop in their numbers relative to practicing physicians, the ratio being 2.2 in 1970. The ratio is better (3.7) in university hospitals than in others.

Midwives and Assistant Midwives

On the assumption that each pregnancy terminated in a live birth, the statistics show that the number of midwives per 1000 deliveries increased from 5.3 to 6.6 during the period 1967 to 1970.

Technicians

The number of technicians was fairly constant during the period 1967 to 1972. Consequently, their number relative to population decreased from 13.2 per 100,000 to 12.1 per 100,000 over the period. Eighty-eight percent of them work in government institutions.

CONCLUSION

The preceding statistics show that deficiencies existed in some of the health services in the period 1960 to 1970. These deficiencies were further aggravated by the regional distribution of services and manpower. Certain areas, e.g. the capital, are much better served than others, specially as far as the private sector of health services in concerned. Budget limitations, lack of personnel, social conditions, etc. are among the factors responsible for these deficiencies.

The availability of correct and reliable statistics is a must. This could be achieved in a developing country, like Egypt, if we can:

- Have a sufficient number of trained personnel;
- Convince medical and nonmedical hospital staff, that statistics are not merely so much paper but of value for proper health care delivery;
- Have standardized definitions of different services and types of manpower. Examination of yearly statistics sometimes shows marked fluctuations which could be explained by the fact that a particular category appears under one heading in a given year and under another heading in a subsequent year;

- Use computer techniques to process the wealth of information obtained;

- Apply control methods to guarantee that information is supplied completely and correctly.

A multistage system is suggested. The first stage would be manual and carried out at the governorate level. Special forms must be designed for this purpose. The second stage would be to send some of the basic information to a central unit to be processed electronically. In addition to this analysis of health service activities, health manpower information should be also computerized centrally and updated at regular intervals. A more detailed study of this information system will be published later.

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Some Systems and Control Concepts for Health Care Planning and Disease Control

A.Y. Bilal and N. Danial

INTRODUCTION

Health has been defined as a state of complete physical, mental and social well-being and not just the absence of disease or infirmity. In these terms, health is an imaginary state; the real situation is that there are different levels of health, from disease or disability at the bottom to optimum health at the top. A man (or mankind) functions in a natural and social environment that contains agents affecting his health. Such effects vary with the individual's resistance, susceptibility or adaptability to these agents. Environmental health programs are undertaken to promote health and to prevent or to limit disease and disability. However, man's health is not only affected by the environment but, especially at the group level, it itself influences the environment. This is a feedback system (Figure 1) [1] which lends itself easily to analysis on the basis of feedback control theory. Such analysis may offer us new directions and methodologies for health planning and control.

Before discussing further the factors outlined in Figure 1, it may be appropriate to consider the operation of a feedback control system as illustrated in Figure 2. The desired reference output determined by some decision-making process, is compared to the actual output or condition, as perceived through some process of information feedback. Any discrepancies between the desired output and the actual output cause the controller to attempt to reduce the discrepancy by manipulating controllable inputs. This is a continuing process. The controller must react to the effects of uncontrolled inputs and counter the effects of anticipated disturbances (i.e. input variables which cannot be controlled), through feed forward information. There are formidable barriers in the way of a full scale application of control concepts to social systems, mainly arising from the impossibility of measuring or even identifying all the variables that affect a given system's operation. There is often a problem in the specification of realizable objectives. Of course, the controller (or administrators) must have a clear idea of how the system operates, i.e. how it responds to changes in input. In particular, among all controllable inputs, those that will achieve the desired results must be identified.

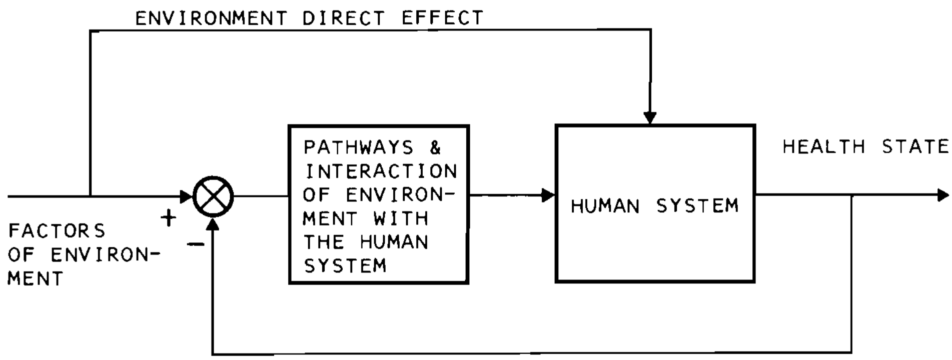

Figure 1. A feedback schematic diagram for the health system.

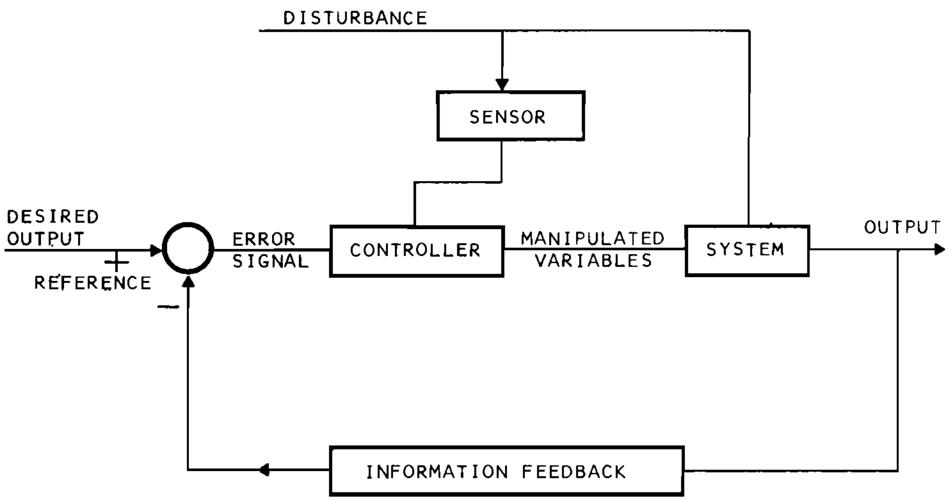

Figure 2. Identification of a generalized feedback control system.

THE ENVIRONMENTAL HEALTH SYSTEM (MAJOR CONCEPTUAL SUBSYSTEMS)

Environmental health is most directly concerned with the well-being of humans living in communities. For this reason Figure 3 is a modified expansion of Figure 1, based on the concepts of Figure 2; it will be our basic model for the health system and will be considered in further studies dealing with the design of optimal programs with the objective of promoting and protecting human health.

In Figure 3, factors within the physical and social environments interact to produce environmental health problems and benefits. In addition to direct effects on man's health, such factors produce significant ecological, economic and aesthetic consequences which interact with and influence human health for better or for worse. The feedback information represents the combined effect upon health and upon other factors which again influence the environmental forces themselves. Figure 4 shows the elements involved in each subsystem in some detail in order to indicate their general relationships [1].

In Figure 4, humans may be exposed to stresses directly at their sources (1A, 1E), or the stresses may reach them through various media (1B) along pathways that can be long, complicated and relatively indirect.

The biological element-set includes "other humans" in the sense that man can be the source of biological agents such as pathogenic microorganisms, in other words, he can be a reservoir or carrier of infection as well as a carrier of potentially hazardous chemical and physical environment. On the other hand, a special set of stresses, diseases, defects and other pathophysiological states may be transmitted genetically or otherwise from humans to their offspring (1A4-4). Food, including drinking water and milk, constitutes a main pathway through which environmental factors can affect man.

In considering the social environment as it affects human health, one finds that the concepts involved are less clear than those describing the physical environment. The factors and their relationships are not accurately or completely defined, as in the case of physical factors. This probably reflects the relative underdevelopment of the social sciences compared with the natural sciences.

However, the social environment may be conceptualized as being composed of general factors (2A) such as demography, economy, education, social organization and culture, on which would depend derived factors (2B) such as occupation and nutrition and the type of health care available in the community. Factors in the social environment would cause the direct exposure of people to psychological and other stresses (2D-4) and to potentially health-promoting factors (2B3-4), as well as the modification of

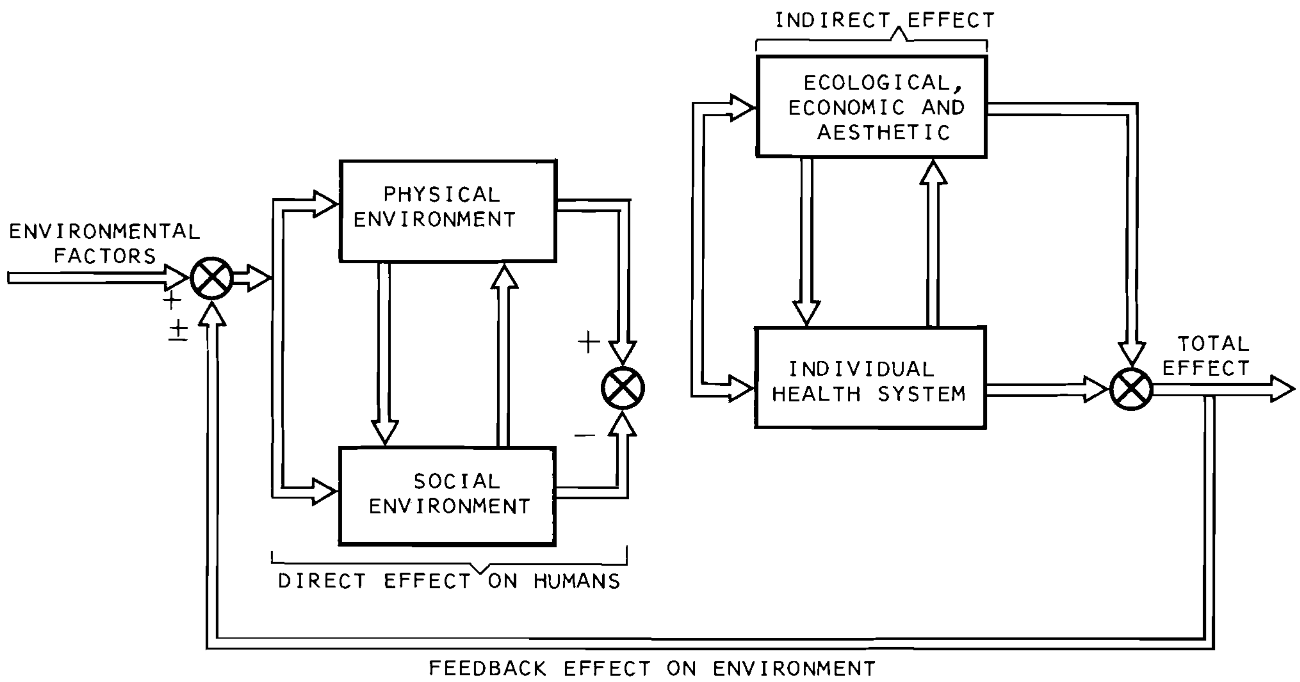

Figure 3. A simplified model to illustrate major subsystems in health systems.

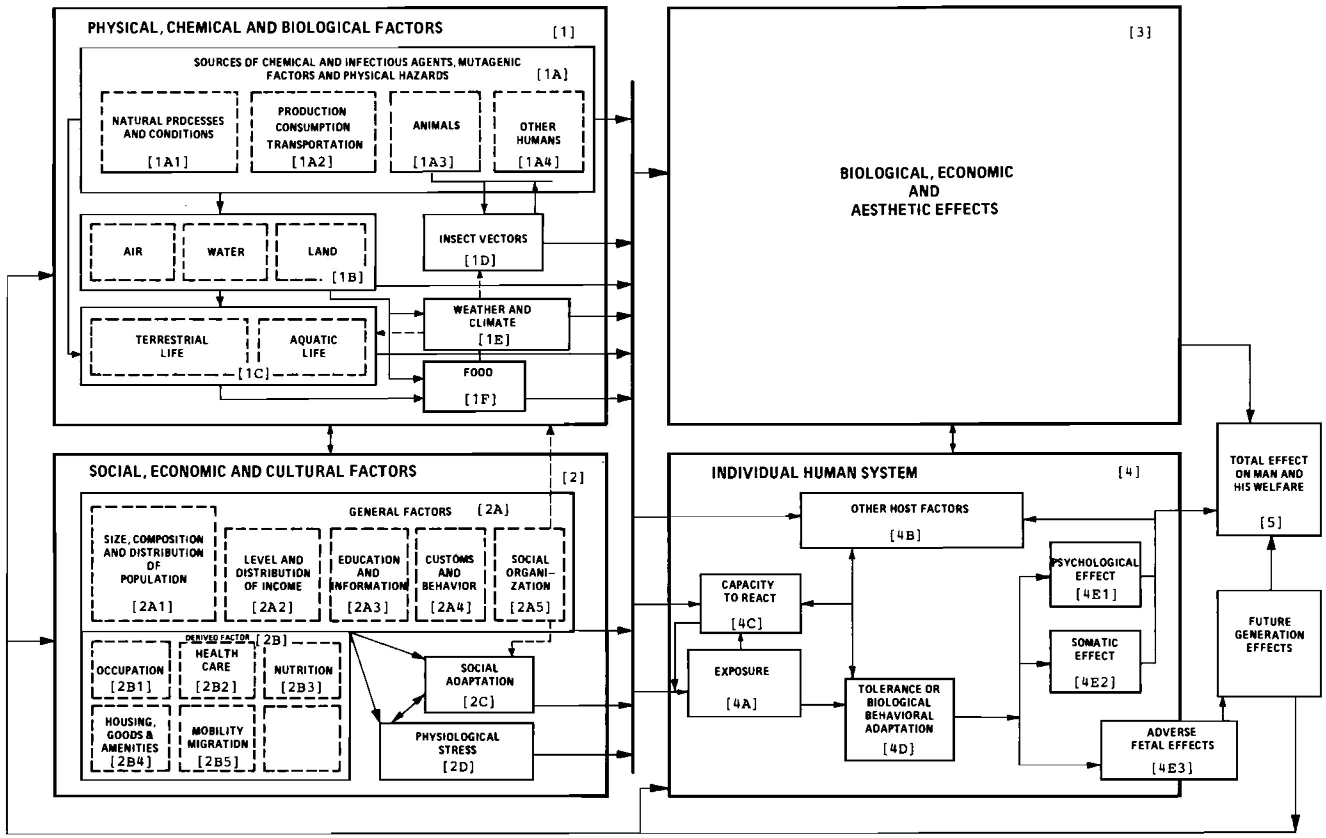

Figure 4. Environmental health as a system.

such exposures through the process of social adaptation (2C-4) by means of welfare programs, changes of attitude, establishment of standards and group ideologies which serve as shields and filters against other stresses.

Forces in the environment bear indirectly on health by producing effects on the ecology, economy and aesthetic milieu (2-3). Such forces act on the immediate environment (e.g., by inducing changes in housing policies) or on the more distant environment (e.g., by controlling water pollution), in ways which may have differing effects on health.

The health status of the individual is affected not only by such host factors (4B) as natural or induced immunity, nutrition and education, but also by his continuous exposure to the environment (1,2-4A). His psychological and somatic reactions (4C) may be stimulated by a combination of these factors and experiences. Exposure to environmental forces may trigger reactions (4A-4C) in the form of protective behavior, that serves to avoid, reduce or terminate exposure. The effects of exposure depend on the relationship between it and the individual's tolerance and adaptability (4D). The latter represents the combination of the state of his host factor (4B) and his reactive capacity (4C). Therefore, feedback may be produced in the individual by modifying somatic and psychological host factors (4E1,4E2-4B) with or without any clinical signs or symptoms being apparent. The results of exposure may not be limited to psychological and somatic effects upon the individual exposed but may extend to genetic and other effects (4E3), placed at the boundary of the "individual human system" and felt only by "future generations".

Finally, effects upon individuals contribute to the "total effect on man and his welfare", changing the state of that element-set and stimulating feedback to other parts of the environmental health system.

METHOD OF CONTROL (INTERVENTION) IN A HEALTH CARE SYSTEM

It is clear from the previous sections, that in a well-designed health program control policies should be directed towards environmental stresses, individual and social behavior in response to such stresses or a combination of both. A rational choice must be made among the alternative control policies which can be implemented in practice including interventions to induce behavioral changes in members of the community, interventions in the form of control and preventive services and interventions to alter or eliminate environmental factors. Figure 5 is a proposed modification of Figure 1 taking into consideration intervention or control actions that could be implemented by the health planning personnel.

The details of the box labeled control or intervention are shown in Figure 6. This figure clearly shows alternative

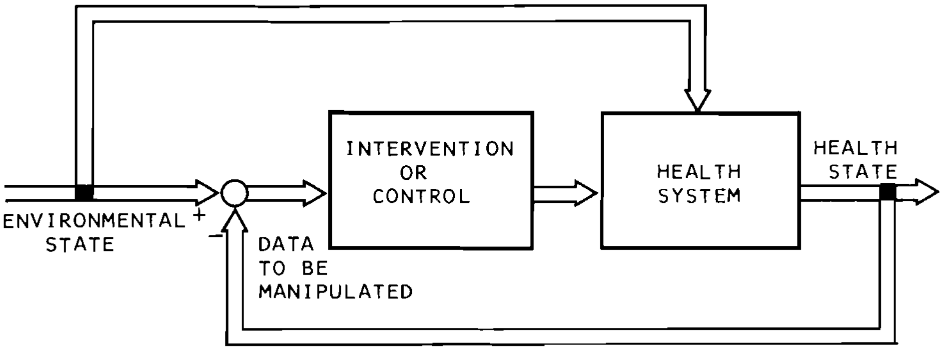

Figure 5. A feedback health system with a controller.

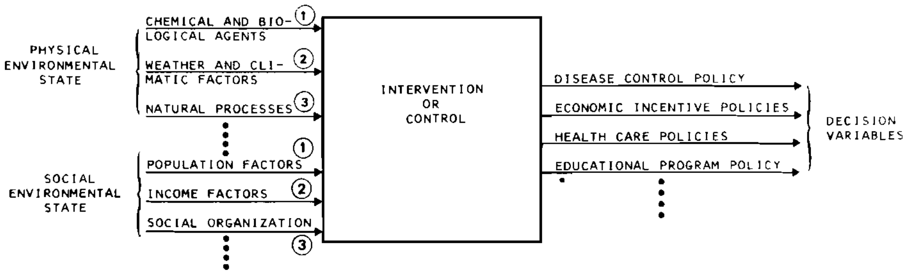

Figure 6. Input-output states of the intervention or control subsystem.

environmental states as inputs which may be manipulated in order to produce direct actions or policies as outputs to be applied to the health system. Input variables can be grouped into the following categories of control in the sense of intervention.

1. Control in the Physical Environment.

1A. Control of chemical biological agents, teratogenic and and mutatogenic factors, and physical hazards at their sources:

1A1. Control of natural processes and conditions;

1A2. Regulation of production, consumption and transportation;

1A3. Control of animal populations in contact with man;

1A4. Control of human sources of infection, genetic defects and physical hazards by isolating persons who pose a threat to others and rendering disease carriers innocuous.

1B. Maintenance of environmental media (air, water and land), in a health promotive state.

1C. Control of hazards through living land and water organisms to a greater extent than merely preventing or limiting contamination at the source.

1D. Control of diseases transmitted by insect vectors.

1E. Control of weather and climatic factors.

1F. Control of agent infection, infestation and food poisoning.

2. Control in the Social Environment.

2A. Control of general social factors:

2A1. Control of size, composition and distribution of population;

2A2. Control of income sources;

2A3. Control of education and information factors;

2A4. Modification of customs and behavior;

2A5. Modification of social organization.

2B. Control of derived social factors:

2B1. Regulation of occupations in the interest of health;

2B2. Regulation of the availability, accessibility and quality of health care;

2B3. Control of the nutritional state of the population;

2B4. Control of housing, goods and other amenities to promote and maintain health;

2B5. Control of mobility and migration of people;

2B6. Control of leisure and recreation facilities.

2C. Control of social adaptation processes.

3. <u>Control and Evaluation of Ecological, Economic and Aesthetic Effects of Proposed Policies</u>.

4. <u>Control in the Environmental Human System</u>.

4A. Control of exposure.

4B. Control of host factors.

4C. Modification of the individual capacity to react to existing and anticipated exposures.

4D. Control of tolerance or biological adaptation.

4E. Control, whenever possible, of failures of environmental control appearing as mental, physical and genetic diseases and disabilities.

The result of such control will provide the necessary feedback information and indicate the actions to be implemented, in the light of the changes in the community system needed in order to promote health. In Figure 6 this is represented as the output of the intervention and control subsystem in the form of actions to be taken. Some of these actions are as follows:

- Policies concerning natural processes and conditions;
- Policies concerning production, consumption and transportation to reduce pollution;
- Policies concerning disease transmission and infection;
- Policies concerning health education;
- Policies to counteract weather and climatic factors;

- Policies to modify customs and behavior;
- Policies to influence individual host factors;
- Policies to modify income factors;
- Policies to control mobility and migration;
- Policies to modify individual reactions to existing and anticipated exposure;
- Policies to modify the nutritional status of the population.

DYNAMIC AND MULTILEVEL CONSIDERATIONS

In dealing with the generalized health system relationships previously discussed, monitoring actions and intervention programs should take into consideration the dynamics of the different factors involved. In fact, the whole structure is a distributive parameter system in which different issues of concern are functions of time as well as space. Some health factors arise at a certain time and place and extend outward to other times and places. Some extend over great geographical distances and affect more communities than others. This will result in a multilevel control health system in which there is a need for control and coordination at different levels. The levels may be local, national, or international. The success of any preventive action will depend on the accuracy of information available, the organization or structure of the model proposed, the technological solution and the amount of resources in conjunction with the existing constraints. Figure 7 shows a multilevel model for the health system, in which the individual's health subsystem is clearly emphasized relative to other social and economic goals and factors. On the first level, cause and effect relationships should be clear for the individual's health as well as for other influencing subsystems. The coordinator or the administrator at the second level should be supplied with health objectives or goals in order to optimize the health promotion aspects of the system through the proper manipulation of feedback information from the different sectors involved.

SOME THRESHOLD MODELS FOR DISEASE CONTROL--THE HUMAN SUBSYSTEM [2]

As a first application of the previous concepts, we may consider Figure 7, in which the issue of concern is to describe and to control the spread of an infection within a population. For example, one thinks of a small group of individuals who have a communicable disease being inserted into a large population of individuals capable of "catching" the disease. Then, in an attempt to formulate the nature of the spread of the infection within the larger population group (in the context of

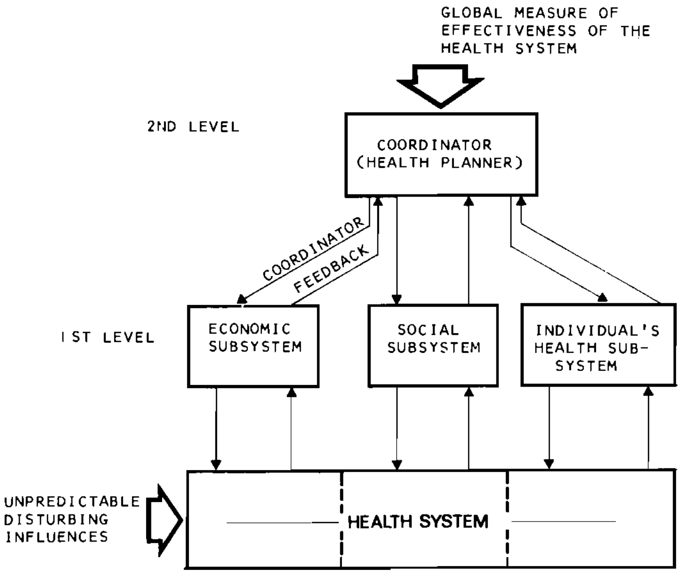

Figure 7. A multilevel approach for the health system.

Figure 7), the individual human subsystem is isolated as shown in Figure 8. In this figure, a state-space model description is utilized in which three state spaces, namely, the health state $\vec{h}$, the socioeconomic parameter space $\vec{P}$ and the control space $\vec{u}$ are considered. The health state $\vec{h}$ represents the discrete classes of individuals affected by the specific infection under consideration. In its simplest form, this is taken to be a three-dimensional space in which the components of $\vec{h}$ are:

- S: The susceptible class--i.e., those individuals who are not infective but who are capable of contracting the disease and becoming infective.
- I: The infective class--i.e., those individuals who are capable of transmitting the disease to others.
- R: The removed class--i.e., (1) those individuals who contracted the disease and died, (2) those individuals who contracted the disease, recovered and gained immunity, and (3) those individuals who are currently in isolation and acquire immunity.

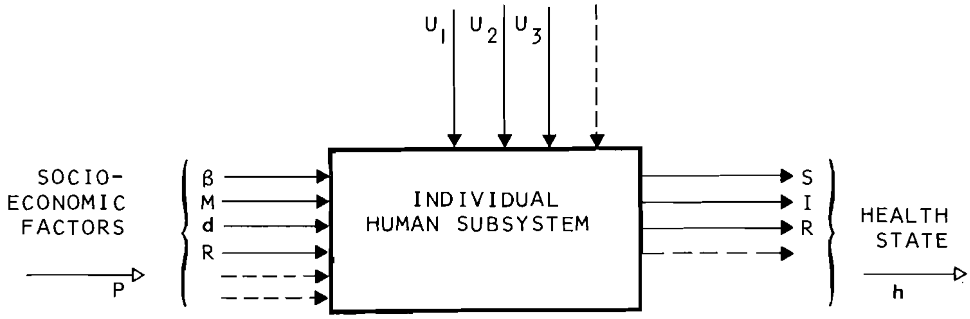

Figure 8. The human subsystem with the effect of other socio-economic subsystems as exogenous parameters.

The spread of infection is presumed to be influenced by the socioeconomic parameter space $\vec{P}$ which reflects the effect of the health system exogenous to the human subsystem. The dimensions of this space depend on the relevant socioeconomic parameters which the planner has to investigate. Some of these parameters are:

- β: birth rate;
- m: immigration rate;
- d: death rate;
- f: host factor;
- r: degree of exposure;

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In order to control the spread of infection, i.e., to shape the trajectory of the health state in the state space, the control vector $\vec{u}$ is introduced and is considered exogenous to the system. This represents possible courses of action to be implemented by the planner on the basis of optimal control techniques. The different courses of action are represented by the components of $\vec{u}$, namely:

- u_1: immunization of chemoprophylaxis;
- u_2: isolation;

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The technical description of the human health system depends on the type of infection considered, which gives rise to different mathematical relations in different cases. In general terms, we will be faced with a vector differential equation such as

$$d\vec{h}/dt = \vec{f}(\vec{h},\vec{P},\vec{u}) \quad , \tag{1}$$

in which $\vec{P}$ and $\vec{h}(o)$ are given and $\vec{u}$ remains to be selected. The components of the equation are a set of first-order differential equations depending on the components of $\vec{h}$, namely,

$$dS/dt = f_1(S,I,R,\ldots,m,\beta,d,f,\ldots,u_1,u_2,\ldots) \quad ; \tag{2}$$

$$dI/dt = f_2(S,I,R,\ldots,m,\beta,d,f,\ldots,u_1,u_2,\ldots) \quad ; \tag{3}$$

$$dR/dt = f_3(S,I,R,\ldots,m,\beta,d,f,\ldots,u_1,u_2,\ldots) \quad ; \tag{4}$$

$$\vdots$$

where $f_1,f_2,f_3,\ldots,$ are the technical functions or descriptions defined by the characteristics of the specified disease in question. The transition of individuals from one class of the population to another class depends on the current state of the art. This is shown diagramatically in the horizontal breakdown of the human subsystem in Figure 9. The effort expended in controlling an infection is represented by the program $\vec{u}$. For example, achieving a higher vaccination rate means that more equipment, personnel, supplies, etc., are needed.

Let such expenditures be described by a (nonlinear) cost function $C(\vec{u})$. Usually the program $\vec{u}(t)$ will be restricted to a discrete function. For example, $\vec{u}(t)$ can be thought of as being constant for one unit of time (a day or a work shift). If the infection causes serious harm to the individual, it is desirable to reduce the total number infected to an "acceptable" figure. On the other hand, it may be desirable to limit the number of individuals infected simultaneously in a given period of time (O,T). In more concrete terms this means that, given the dynamic equation representing the spread of infection within a population, one has to choose the program $\vec{u}$ to minimize the cost $C(\vec{u})$ while keeping the spread of infection within acceptable limits. This is an optimal control problem, and the sophisticated tools of the control theory would allow both general and specific problems to be treated.

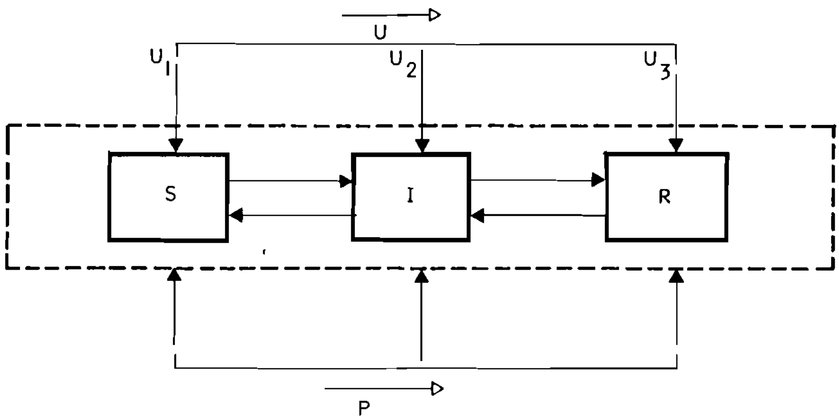

Figure 9. Horizontal breakdown of the human subsystem.

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Review of the Papers Presented on the Dynamic Modeling of Health Care Systems

A.G. McDonald

At the present stage in the development of national health care systems an intensification of management and planning methodology is required in order to: improve treatment and diagnostic technologies; increase scientific investigation of medical, biological and social problems; extend the medical establishment's health care networks; and achieve specialization of medical services.

A major contribution to promoting the required advances could be made by appropriate health service modeling, with the objective of improving health service management and planning on the basis of an optimal distribution of material, technical and manpower resources. Eventually, this could lead to an advancement in health service quality.

There was a very large measure of agreement about the need for dynamic macro-models for the efficient planning of Health Care Systems. There were differences of approach and emphasis between delegates, but four main groups could be identified.

One set of papers described mathematically compatible models which dealt with the balance of resources and how to plan them. Some models took account of many exogenous factors. Another model dealt with the planning and delivery system at several levels. Also described was a hierarchical control system at several levels linked to planning targets where the control system had functional subsystems going right down to small population groups. Yet another model reported was more data-based. Some other models presented were closer to the traditional economic models. These hold promise of contributing to the solution of some health care problems.

A second set of papers described the health care system pertaining to different countries or regions. These gave insight to the variety of problems which have to be faced.

A third set of papers was concerned with questioning the basic concepts of health care. Examples in this area suggested a basic shift in the spectrum of care. Another contribution examined the concept of basic health. Both called for greater attention to the conditions which were most conducive to mental and physical well-being. A further contribution gave a detailed description of the analysis of a particular disease.

The fourth set of papers was concerned with the problem of how and where health care models should fit into larger social systems, and some warnings were given about the adequacy or otherwise of present methodology. Disease or health indices were mentioned explicitly and implicitly, and there seems to be room here for international agreement and international effort.

The first group described models at present used in the system and based on current methodology. The second and third groups were working towards a more advanced set of criteria to be used at some future point. The fourth set was on yet a longer time scale. But, above all, it was apparent that the approaches described, taken as a whole, constituted the most promising and perhaps the only way to tackle a very complicated social system, and one which had good development potential.

It may be concluded that it is essential that three things should happen at the international level:

- Reported models that can and are being used at present in different countries should be coordinated. Each has its own capability. But the potential of a compatible combination of these formulations would increase the power of each to an immeasurable degree. In many cases these models take account of some of the exogenous variables (e.g. demographic and economic factors). It is now feasible to see the possibility of a decentralized joint approach by a small group of modelers actively involved with decision makers in national settings under the auspices of both IIASA and WHO.

- There is a need for further research at the international level to establish the most useful and valid indices of health and disease. This work, already involving WHO, involves a longer time horizon.

- In order to link the health care system to the social system as a whole a greater degree of understanding of their interrelationship is required. This also requires a longer time horizon.

A more extensive exchange between leading specialists in many countries is also of great importance here and should include IIASA, WHO and appropriate national groups.

Finally, we must not behave like that Duke of Brunswick who was described as a learned, highly cultivated pedant, cautious, painstaking and apt to examine every problem in such minute detail that the problem itself vanished from sight.

ON ORGANIZATION OF A PROGRAM FOR INTERNATIONAL COOPERATION IN CANCER RESEARCH

Action by the International Community On the Development of a Long-Term Program Of International Cooperation in the Field of Cancer Research

A.A. Klimenkov

Of recent years, the problem of malignant tumors has been the focus of attention of scientists, physicians, health authorities and governments in many countries of the world.

National programs of tumor studies have been significantly extended and intensified and a new impetus given to international cooperation in the field of cancer research.

This cooperation at present either takes the form of bilateral intergovernmental agreements (the USSR-France agreement, the USSR-USA agreement and so on) or is conducted on the basis of direct contacts between ministries of health, academies of sciences and large cancer research centers.

Examples of multilateral cooperation among some European countries to study oncological problems are the Scandinavian Cancer Union and the cooperation of the CMEA member countries in this area since December 1973.

At the same time, the scope and urgency of the problem demands further extension of complex scientific studies on a worldwide basis under the auspices of the World Health Organization (WHO), International Agency for Research on Cancer (IARC) and International Union Against Cancer, through the establishment and implementation of the long-term program of international cooperation in the field of cancer research--a program with a short but significant history.

As far back as 1959, the General Assembly of the United Nations adopted resolution 1398 (XIV) encouraging international support of cancer research; subsequently, WHO, IARC, International Union Against Cancer and other international and national organizations through the work of experts from many countries have made significant contributions to determining the most promising lines of cancer research, to establishing a more precise histological classification and tumor nomenclature and to developing a network of international and regional reference laboratories and information centers.

These activities enabled the WHO Executive Board, at its fifty-first session in January, 1973, to put on the agenda of the forthcoming Twenty-sixth World Health Assembly an item on a long-term program of cancer research with a request to the WHO Director General to submit a report on WHO activities in cancer research together with proposals for future development of international cooperation in this field. In the course of the Assembly's discussion on this report, the delegations of 10 countries--Bulgaria, Czechoslovakia, France, Hungary, German Democratic Republic, Poland, Rumania, the UK, the USA and the USSR--proposed a draft resolution on the elaboration of a long-term program of international cooperation in the field of cancer research, which was supported by delegates from many countries and accepted by the World Health Assembly.

At the same time, the sponsors of the resolution, realizing all the difficulties of working out a basically new coordinated methodology of cancer research, called for coordinated efforts in the field of cancer research by national institutions of member states; a comprehensive program should be set up to the extent feasible. The Assembly made WHO, IARC and the International Union Against Cancer responsible for the elaboration of such an international program; it also proposed the compulsory inclusion of questions such as methodology, standardization of terminology, epidemiological research, early diagnosis methods, treatment and prevention of cancer, drawing up of a list of the most promising lines of cancer research, lists of centers and cooperating institutions, and, finally, provision of a computer-based cancer research information service.

At its twenty-seventh session, the World Health Assembly considered the report submitted by the Director-General on long-term planning of international cooperation in the field of oncology. At the same session, a memorandum by the USSR delegation, based on a letter from the USSR Minister of Health, Academician B.V. Petrovsky, to Dr. Mahler, the WHO Director-General, was officially circulated. The Memorandum reviewed possible ways of implementing the World Health Assembly's resolution on the elaboration of the long-term oncology program and suggested an organizational and methodological plan for this purpose.

In the opinion of the Soviet specialists, the first and most important condition for the successful implementation of the international oncological program was to establish correctly its objectives and scope with attention concentrated on the scientific research aspects of the cancer problem. The program should be directed primarily towards acquiring new knowledge and discovering the mechanisms and causes of the incidence and spread of malignant tumors, with due regard to the fact that the implementation of practical measures of cancer control in terms of treatment and prevention should, as hitherto, be among the priorities of the national health care bodies in every country.

They thought it advisable to break down the program itself into the following four organizational and methodological stages.

The first stage should be to compile a list of the most promising research lines and specific research problems, as laid down in operative paragraph 3.1 of WHA resolution 26.61.

The second stage of development should concentrate on expert evaluation of each of the research lines on the international list, due regard being paid to the proposed methods of the approximate time required and the number of countries and scientific institutions which might participate.

The next stage might consist in working out a logical schedule of priorities in the implementation of the program, based on the expert evaluation mentioned above, which would combine individual cancer programs in the light of their duration and importance. This schedule should be worked out by the specialists in forward planning and programming working in WHO or other international and national organizations, including IIASA.

With regard to the period allocated for the implementation of this schedule, 10 years would seem to be the best, since 5 to 10 years would be too short in view of the program's scope, while 15 to 25 years would be too long and the program might no longer have relevance.

The fourth and final stage of working out the international program might include the organization of an international information center based on the WHO computer, as laid down in subsections 2 and 3 of operative paragraph 3 of WHA resolution 26.61. To this end, the USSR experts recommended making a start on elaborating the machine language, standardized coding of programs, research centers, methods, etc., to enable all national centers to use these international programs on a large scale. With this aim in view, it would be necessary to enlist the support of specialists working in WHO, IIASA, IARC, and national organizations of the leading states. The USSR experts expressed their willingness to take an active part in building the software for the international program.

They stressed the necessity of an informational basis as a condition for the success of the international program.

It is well known that detailed discussions at the twenty-seventh and the twenty-eighth sessions of the World Health Assembly resulted in the adoption of WHA resolutions 27.63 and 28.85 which confirmed the usefulness of the comprehensive international program of cancer research and emphasized the importance of elaborating an effective methodological basis for the success of the program.

The WHO Director-General has been requested to continue the efforts he initiated in pursuance of the program of international cooperation and to consider the question of the information system for the comprehensive cancer research program.

It is hoped that the work currently being carried out in the USSR in connection with the development of approaches to the international program and to its informational basis will be of general interest.

Towards the Development of a Coordinated International Research Program Based on Systems Analysis Of Subject Interrelationships

W.K. Olshansky

The progress of science mainly depends on the correct use of information, the organization of various types of information services and the accumulation of large quantities of information. But before new information can be processed and interpreted it first requires to be subjected to structural analysis based on expert evaluation and the use of computers. It is possible to apply structural analysis by analyzing the interactions between different fields of investigation. This is also related to the coordination of efforts in different scientific programs and in planning large-scale programs. This approach enables the organizer to combine different information paths and creates a favorable climate for constructive scientific competition; it would also help to overcome the language barrier between the scientists of the Western world and those in the USSR. At the present moment, only about ten percent of the results published in Russian are incorporated in the information systems of the West, the rest being lost to scientists there.

Implementing this approach to scientific planning and long-term programs will first of all require the definition of basic fields of research. It is then necessary to compile a list of subjects of scientific investigations. This information must be processed on a computer in order to select groups of subjects which show strong information linkage. New data must be distributed according to the interrelationships between these groups.

All sources of information on the subjects currently appearing on the list will be accessible to all participants.

The combined Working Group of the Institute of Control Sciences and the Oncology Research Center worked out such groups of subjects,* using the list of 13 areas and 121 subjects on the comprehensive problem of malignant tumors compiled by the Scientific Council for Cancer Research of the Praesidium of the USSR Academy of Medical Sciences.

Initially, each subject is entered in only one group, but after optimization, it may be included in any number. The view is that a subject appearing in a large number of groups is fundamental to the program.

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*For full details of their work, see the papers by L.I. Borodkin, I.B. Muchnik and A.S. Raben and by L.I. Borodkin et al., in this volume.

Organizers of a long-term program must pay special attention to research along fundamental lines, since the results so obtained affect a large number of subjects in the list.

In accordance with the basic approach to solving multidimensional problems, a complicated problem must be solved through the solution of a large number of simpler ones.

We suggest that instead of determining the resource requirements in time, money, manpower, etc., for the program as a whole, resources should be allocated separately for optimal groups of subjects. These groups have fairly simple relationships among themselves.

Expert estimates of the resources required within each group can be checked against those for fundamental subjects appearing in several groups.

If the estimates for fundamental subjects vary group to group, this naturally casts doubt on their reliability and they should be reconsidered. Modification of the estimates for fundamental subjects will result in a modification of those for other subjects in the groups concerned.

Such reconsideration of estimates and cross checking of data can be repeated until all the discrepancies are eliminated.

The next step, after the quantitive estimates for individual subjects is arrived at, is the compilation of a logical network diagram showing the sequence of program implementation. The diagram would show the progress of the fight against cancer in terms of decreasing morbidity and mortality rates caused by cancer.

Moreover, it may prove possible to evaluate the capacity of individual organizations participating in the program to solve the problems under study and to determine objectively the relative importance of contributions made by different organizations.

A diagram showing the implementation of the proposed program would consist of three sections: the middle section representing the actions required to implement the program, the left hand section giving the results of the actions carried out and the right hand section showing the final planning arrangements, namely the organization of the system for the selective distribution of information and construction of the logical network diagram of program implementation.

In the same way as all information eventually becomes outdated, so will the system for the selective distribution of information and the logical network diagram of program implementation. New information links will be required while those already in the model will be partially disrupted. The list of subjects in the program also may change: some subjects will lose their importance while new ones are introduced. Breakthroughs will be achieved in some directions while in other directions progress may be temporarily halted.

This will entail modifying the initial data in order to update future operational plans. Such modifications must be worked out by a Consultative Council of the International Oncological Program organized under the auspices of WHO and composed of oncologists and mathematicians representing WHO member countries and certain international organizations. This Council must function on the basis of the information center organized by WHO and structured in accordance with the principles described above. Among its functions must be the preparation of regular progress reports on the program, proposals for program development and preparation of forecasts on the program as a whole and on its individual sections.

A considerable part of the proposed international program will be developed by means of modern computer systems, and all the recommendations of computers will be analyzed by experts, namely specialists in oncology and systems analysis, to ensure the successful implementation of the program.

Based as it is on systems analysis, the proposed method of implementing the program will undoubtedly be conducive to the successful achievement of its objectives.

Development of a Long-Term Program for International Cooperation in Cancer Research

D.D. Venedictov, et al.

INTRODUCTION

In recent years many people in many countries have devoted much attention to the problem of cancer. National programs studying malignant disease have been greatly expanded and deepened, as has international cooperation in this field. At present, this is by bilateral intergovernmental agreements and by direct contacts between the health ministries, academies of science and big cancer research centers of various countries. Examples of multilateral cooperation are the union of scientists of some countries of Europe in the European Organization on the Study of Cancer Treatment, the Scandinavian Cancer Union, and the Cooperation of Scientists from countries of the Council of Mutual Economic Assistance.

Attack on the problem of malignant tumors needs to be intensified by a comprehensive scientific approach on a world scale under the aegis of the World Health Organization (WHO), the International Agency for Research on Cancer (IARC), and the International Union Against Cancer (UICC).

HISTORICAL BACKGROUND

In 1959 the United Nations General Assembly adopted resolution No. 1398 (XIV) on international support for cancer research [1] and in subsequent years WHO, IARC, UICC and other international and national organizations did much work finding out trends in cancer research, clarifying the histological classification and nomenclature of tumors, and creating a network of international and regional reference laboratories and centers on oncology, etc.

This led to the WHO Executive Board in January 1973 including in the agenda of the 26th session of WHA the special question of a Long-Term Cancer Research Program and entrusting the Director General of WHO to report on WHO activities on cancer problems and to propose further international cooperation in this field. Bulgaria, Hungary, Britain, GDR, Poland, Rumania, USSR, USA, Czechoslovakia and France drafted a resolution on a Long-Term Program of International Cooperation in Cancer Research which received wide international support and was adopted by the WHA.

This resolution [2], WHA 26.61 of May 23, 1973 notes "the extreme difficulty of the cancer problem and the very small probability that it may be resolved by a single country or by the uncoordinated efforts of many countries...concorded actions on an international scale can become an important factor, bringing closer the final solution of the cancer problem".

The initiators of the resolution obviously saw the difficulty of elaborating a new methodology for coordinating cancer research and said that--"the main efforts in the field of oncological investigations must be undertaken by national establishments of member states, but on condition that their activity is coordinated...within the framework of a single comprehensive program which they can join to the degree that they wish". The Assembly entrusted the elaboration of such an international program to WHO, IARC, and UICC. The program should have provision for unification of methodology and terminology, epidemiological investigations, methods of early case finding, treatment and prevention of cancer, and for determining the best directions for oncological studies. It should list reference centers and cooperating establishments and set up a computerized information service for cancer research.

Such an international unification of effort has become not only possible, but realistic and necessary due to wide support from the public and governments. It should be free of attempts of any sort of scientific pressure or dictate: each Program participant should clearly see the advantages of participating in it, and should choose for himself the subjects of interest and the direction of investigation. Advantages could be the undelayed recording in a computer memory of the results of research investigations, guaranteeing their certification of priority, and the right to extensive access to the results of research work of all the Program participants. Such a program can only be based on a systems approach.

MEMORANDUM TO THE 27TH WORLD HEALTH ASSEMBLY

At the 27th session of the WHA a memorandum [3] of the Soviet delegation was officially disseminated based on a letter of the Soviet Minister of Health, Academician B.V. Petrovsky, to the Director General of WHO, H. Mahler. The memorandum noted that the USSR Ministry of Health and the USSR Academy of Medical Sciences in conjunction with the Scientific Council on the complex problem "malignant neoplasms" under the Praesidium of the USSR Academy of Medical Sciences studied, in 1973-1974, proposals of experts and specialists of the Soviet Union and other countries on possible directions for an international program of cancer research and methods for effectively coordinating the efforts of different countries.

The Soviet Union studied the report of the Director General of WHO (document A27/63 of April 4, 1974) and noted with satisfaction its profound and constructive nature and the large number of favorable responses from member countries.

A program can be successful only if its methodological basis is correct so that scattered elements of scientific, medical, and oncological research can be united into a single purposeful International Program. So, an analysis had to be made for the reasons of failure of previous such attempts. The most important condition for success is the correct determination of goals, sufficiency of scale and concentration on the important research aspects of the cancer problem, namely the mechansim of the spread of cancer, and the evaluation of the different systems and methods of work of oncological services. Control measures (both therapeutic and preventive) must, as before, remain primarily the task of the national health services of each country, although generalization from international experience will obviously be very useful for all national health administrations. Such a limit to the aims of the Program is desirable and does not run counter to the interests of WHO or its member states.

The Program was divided into four stages. The first stage was compiling a list of the best directions and specific problems for research work. This list should not be regarded as fixed, but should be systematically reexamined since medical oncology may change rapidly.

The second stage consists of expert assessment of each research direction, including the International List of research elements, with due account being taken of the proposed methods of study of one or other research elements, the approximate time necessary for such research, and the number of countries or scientific establishments which could participate in the research. It was considered that this work could only be conducted at WHO, with participation by appropriate experts and specialists, as well as by national research establishments of member countries of WHO.

The third stage is the compilation of a logical time sequence for combining the separate oncological programs, due account being taken of their duration and importance. Specialists in long-term planning and programming from all national and international organizations should be involved in compiling such a network diagram, which should look forward ideally about ten years, since a shorter period would be difficult because of the complexity of a cancer program, and a longer period (15-20 years) would deprive it of its direct usefulness and importance for member countries.

The fourth stage is the creation of an International Information Center with the use of computers available at WHO. For this, work should be started immediately on elaboration of a machine language, standard programming code, research centers, methods, etc., to ensure wide application to these international programs by all national centers. Because machine languages and type of programs now used by various member countries are different in essence, it is necessary for specialists from WHO, IIASA, IARC, etc., to work out a truly international thesaurus and machine language for multilevel supervision and control of the International Cancer Program.

The most important condition for the success of the International Cancer Program was that it be actively jointed by the majority of member countries of WHO and by the many research establishments and laboratories situated in various countries of the world. Each country should carry out cancer research at its own expense and within its capabilities, but the methodology of such investigations must be coordinated according to the International Program. Such an approach would remove possible suspicion of scientific domination of certain countries or establishments, or of attempts to cause a brain drain, which in the past has had a bad effect on the development of medical science and health care in developing countries.

WHO (being intergovernmental) and IARC, and UICC are to play the leading role in implementing the International Cancer Program, while other international organizations would be guided as to what components of the research work their own funds could be directed.

FURTHER ACTIVITIES

In their statements at WHO, IARC, UICC and other international organizations Soviet representatives stressed that the Soviet Union would take an active role in working out and implementing the Program of International Cancer Research Coordination and that it is ready to extend all possible assistance and support to the Program in the future. At present, the Soviet Union has many bilateral and multilateral cooperative agreements and their results would be put at the disposal of WHO.

At the 27th and 28th Sessions of the WHA resolutions were adopted (WHA 27.63 [4] and WHA 28.65 [5]) reiterating "confidence in the usefulness of setting up a comprehensive international program for cancer research..." and underscoring the importance of working out an effective methodological basis. It was proposed that the Director General of WHO continue his work on the Program on the International Cancer Research Cooperation including "the setting up of an information system to support the comprehensive program of research in the field of oncology...". Of interest in this field is the set of approach elements being compiled at present in the USSR.

Extensive investigations in oncology are being carried out, especially with regard to detecting the mechanisms of carcinogenesis, at molecular and submolecular levels (biochemical, immunological, cytogenetic and virological). Questions that need resolution in the next 10-15 years are the mechanism of action of carcinogenic substances (viruses, endogenous and exogenous chemical substances, physical factors), their metabolism in normal and tumor cells, the detection and suppression of sources of contamination of the environment by carcinogenic substances, and cancer prevention steps.

PROSPECT FOR CANCER RESEARCH

In 1985-1990 the mechanisms of action of various blastomogens and viral agents may be discovered which will entail the working out of new methods of treatment and prevention of malignant neoplasms, and will create more up-to-date methods for the early diagnosis of cancer and the changes preceding it.

Research in the next ten years in oncology will deal with:

- The identification, characterization and mechanism of action of new viral agents of tumors and leucoses in man and animals;
- Immunological aspects of viral carcinogenesis and human tumors with the aim of immunotherapy of malignant neoplasms;
- Genetic aspects of malignancy: whether the malignant regeneration is a mutation of the somatic cell (genotypic transformation), or the result of deviations in the functioning of the normal genome (epigenomic change);
- Structure, metabolism and function of the cell membrane, and the mechanism of synthesis of nucleic acids and proteins in normal and tumor cells;
- Tumor-organism interrelationships, an understanding of which makes it possible to use selective methods of attacking the tumor (X-rays, chemical agents, specific enzyme therapy, etc.);
- The mechanism of action, circulation, metabolism and the fate of exogenous and endogenous carcinogenic substances at the cellular and subcellular levels; and a study of occupational factors and environmental contamination by carcinogens.

In clinical oncology scientific research will be directed to:

- Working out methods of early diagnosis of malignant neoplasms and pretumor states, by various methods, and with a wider use of computers, so that more patients can be treated radically;
- The synthesis of new antitumor drugs: in the next 10-15 years 20-30 new selectively active antitumor compounds

will be synthesized, thereby increasing the efficacy of tumor treatment, and new improved combinations of drugs and of drugs with radiation or surgery will be found;

- The possibility of using new types of irradiation (protons, pi-mesons, neutrons, laser rays) for the treatment of malignant tumors and new methods of irradiation therapy (mobile, general, interstitial, internal contact, extracorporeal, regional infusion and perfusion, and combined);

- The possibility of producing and using radioactive agents of humorotropic and organotropic substances as carriers for therapeutical purposes;

- The elaboration of infrared and other irradiation methods to discover the precise localization and extent of neoplasms to enable exact centering of irradiation treatment;

- Differential ray effects on the normal and tumor tissues with the aid of physical and chemical agents;

- Hormonal influences on the growth of tumors and, in particular, hormon-dependent cancers;

- Improvement of surgical methods of treatment--conservative, rehabilitative and replacement;

- Working out complex methods for treating malignant tumors by raising the defense level of the organism which obstructs the metastatic spread of the tumors.

In epidemiology, scientific research will be directed to:

- A study of the spread of malignant tumors of certain localizations and preventive measures with special attention to occupational factors, industrialization, and urbanization;

- Improving cancer statistics with standardized computer-readable forms; analysis and storage of statistical data;

- A study of the experience of oncological establishments in selected regions of a country and problems of specialized oncological assistance to the population.

CONCLUSIONS

The number of subscribing organizations, investigators and investigations are high and growing.

One of the important tasks that must be solved is the organization of exchange of information. At present, information exchange is mainly through publications and by personal contact at congresses, leading to significant delays in obtaining information. The growing volume of publications makes it difficult to find necessary information and there is the danger of unnecessary paralleling of work; work in similar directions which is carried out in different countries is hard to compare, since there is no standardization of methods. As a result considerable difficulties arise when attempts are made to coordinate and forecast results of investigations. However it is in principle possible for long-term international cooperation since much of the structure of the national programs is similar.

The global goal of the Long-Term International Cooperation Program in oncology is the maximum reduction of delay in obtaining results. The final goal is to reduce cancer morbidity and mortality.

Figure 1 shows the proposed structure of the Program [6]. The first stage of the Program is working out an information exchange system and assessing the scientific potentials of the participants. The network diagram should be based on the information system. A qualitative evaluation of resources (time, personnel, funds, equipment, etc.) is required for the solution of given tasks and the Program as a whole, while a quantitative assessment of resources is the first step for compiling a logical network diagram for the Program.

MAIN TECHNICAL FEATURES OF THE PROGRAM

Information exchange is crucial to the progress of modern scientific projects. Existing methods are slow and unmanageable but the system proposed here will make it possible to increase the specialization of information and to reduce the delay in its reaching researchers.

Information services in medicine already store a large amount of information but there is a need for a systems structural analysis of information (see Bailey and Pavlov in this volume) based on expert estimates and computer techniques rather than the simple but often insufficient analyses of today. Thus the main areas of world scientific activity together with the most important interactions between such areas and the display of a simplified dynamic structure of any scientific project is needed. This will assist in filling the gaps in scientific progress and planning.

The Information Service

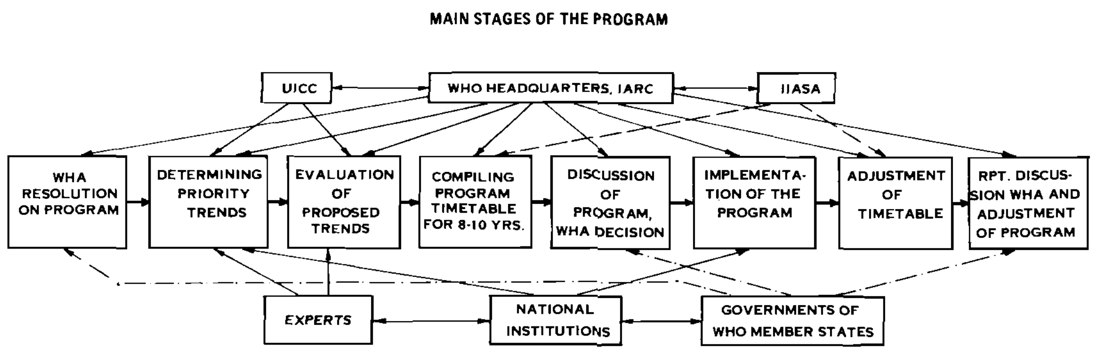
Each participant routinely sends results of his investigations to the International Information Center and has access to

FACTORS DETERMINING THE POSSIBILITY OF IMPLEMENTING THE PROGRAM:

1. Relatively limited program.
2. Increasing probability of fundamental discoveries in oncology.
3. Experience accumulated in cooperation in oncology.
4. Large-scale national programs for studying and controlling cancer.
5. Bilateral and multilateral agreements in cancer research.
6. Widespread response and support of the public and governments.

PROPOSED FUNDAMENTALS FOR DEVELOPING THE PROGRAM:

1. UN resolution 1398 (XIV) of 20.XI.1959 on international support of cancer research.
2. WHA resolution 26.61 (1973).
3. WHA resolution 27.63 (1974).
4. WHA resolution 28.85 (1975).
5. *Joint efforts of WHO (including* IARC), UICC, IIASA and national institutes.



NECESSARY CONDITIONS:

1. Voluntary participation of all countries and national establishments. No scientific dictate.
2. Advantages of participating in the program for national establishments (operative recording of results and priorities, results accessible to all participants).
3. *Systems approach to information service* (use of computers and operative use of results on basis of a unified registration of topics and research plans, their methodology and results).

FACTORS FACILITATING TIMETALBLE PLANNING AND IMPLEMENTATION OF THE PROGRAM:

1. Timetable combiled for 8-10 years, not for directive planning of program components.
2. Timetable does not predict future results, but operatively reflects state of research in respect to long-range goals.
3. Timetable is informational, not the grounds for financing, personnel and operative decisions. (This is the prerogative of national establishments.)

Figure 1. Long-term international program for cooperation in the field of cancer research.

the results of all other Program participants. The data will be registered in the name of the scientist or the group of scientists that sends them to prevent possible misunderstandings as to priority.

There will also be a system of selective dissemination of information, SDI, in which specialized information is available to participants.

To be more specific, our approach to the Cancer Program development is as follows:

First, the list of the priority research areas should be compiled. This can be a list of the problems and research elements presented by the Soviet Union to WHO (see later), or the list of approach elements of the National Cancer Program Plan of the United States [7], or some other research area list compiled through the efforts of experts representing WHO member countries.

Second, the informational links between these research areas should be identified. For this purpose, we have used both the criteria of expert assessment and scientific publication citations.

Third, the complex system of interconnections between the research areas is to be processed by computer to expose the groups of related elements (the approaches).

Selective dissemination of information (SDI) within these approaches will be made as soon as new research data are obtained and any Program participant will have access. By special request nonrelated approaches would also be given.

An essential feature of this SDI is that "invisible colleges" of researchers in similar fields are revealed, and the competing participants are provided with all relevant information.

Data in the SDI system (Figure 2) will regularly comprise research reports, and summaries and abstracts of these reports. For easier compilation, the form of reports and their processing must be standardized. For entry into the system, the report must be submitted by the Program participant to his National Information Preparing Center where report editing and recording of the results into the System Data Base will be performed. The International Information Center can then be smaller and its work reduced.

SDI Bulletins containing titles and abstracts of relevant reports, will be sent regularly to participants. On request a full text of the report of interest will be sent. Also Summary Bulletins of new incoming material containing titles and possibly summaries of all the prepared reports, will be published regularly. The bulletins will be divided into some fifteen subjects.

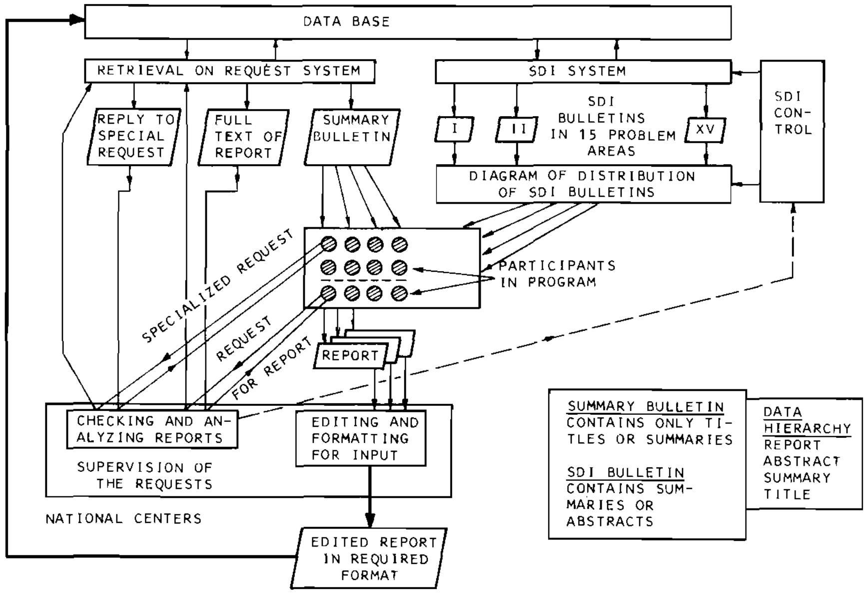


Figure 2.

In order to simplify the system, each participant, after computer analysis of his interest pattern, will be sent only the relevant bulletins.

Experts who find the connections between the listed research elements adopted for the Cancer Program have much responsibility here, as a mistake may mean that information required by a participant is not sent thereby causing delay.

Requests to the International Center must be supervised by the National Information Preparation Center (Figure 2). Unlike the existing bibliographic systems, the data base of the SDI system will contain factographic material, research reports of investigators and clinical reports so that a participant can receive not only bibliographic descriptions of the documents but also the documents themselves. In the future there may be transition to a logical factographic information system that can generalize document contents.

Account must be taken of available achievements in medical information retrieval systems, one of the most developed being MEDLARS [8,9]. Based soley on journal publications, it provides only bibliographic descriptions of documents, not the documents themselves. However, taking into account MEDLARS large data bank and its sophisticated software, it is expedient to use this system as much as possible.

The CANCERLINE information service [10] developed in recent years in the United States is also based on the MEDLARS system [11]. Moreover, the U.S. National Cancer Institute proposes to develop the cancer program of ICRDB by using the MEDLARS system and supplying it with an analysis of ongoing research [12,13,14]. We propose to go even further: to store on tape current research reports and to provide copies of these documents upon request so that Program participants can use results of research work before their formal publication.

INFORMATION LINKS PROCESSING

A significant character of the proposed system is that each element may be incorporated into a number of different approaches, thus distinguishing elements which are of interest to many approaches, the so-called key, or pivotal elements. These are research problems that transfer information from one approach into another so that they become the main research problems. Secondly, through the pivotal elements, we may evaluate the resources needed for fulfilling the whole Program.

The working group of the Institute for Control Sciences for the Cancer Program development in cooperation with the Soviet Cancer Research Center (CRC), (formerly the Institute of Experimental and Clinical Oncology), used the Approach Element List which included 121 elements of the initial 13 approaches. This List was discussed and approved by the conference of directors of oncological institutes of the socialist countries in September, 1973 and by the conference of WHO experts in December, 1973.

The Graph of Links

The experts of the CRC worked out a number of graphs of element links. These graphs had 121 nodes and approximately 2500 arcs. One of these graphs is presented in Figure 3, and shows only immediate information links. Approach elements are coded in the following manner: element 3.6 is the sixth element of the third problem of the List. The arrows show that results obtained, say in approach element 3.6, have an effect on investigations in approach elements 1.1, 2.7, 9.3, 9.5, etc.

The Approach Element List includes 121 elements--the vertices of the graph. Approximately 20 arcs of indirect links stem from each graph vertex. Evidently, it is impossible to analyze such an intricate structure without powerful computers.

The Element List has been divided into 13 approaches: (1) Biology and biochemistry of the tumor cells; (2) Viral carcinogenesis; (3) Chemical carcinogenesis; (4) Radiation carcinogenesis; (5) Immunology of tumors; (6) Tumor-host interaction; (7) Tumor morphology; (8) Malignant tumor diagnostics; (9) Experimental and clincal chemotherapy; (10) Surgical treatment;

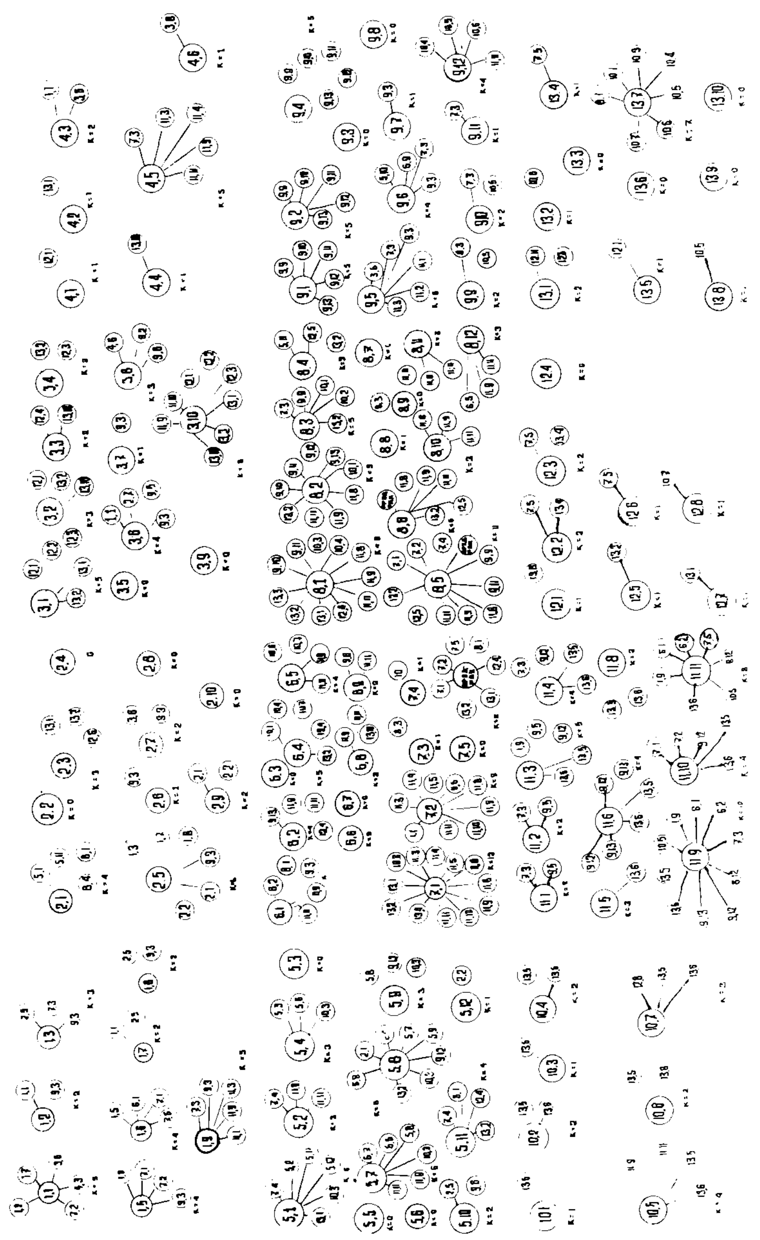


Figure 3. Large graph of element links with 121 nodes and about 2500 arcs.

(11) Radiobiology and radiological treatment; (12) Epidemiology and malignant tumor statistics; (13) Cancer prophylaxis and control.

Because of the complexity of information links within the Element List, it is useful to employ a smaller graph of the links between approaches as shown in Figure 4. This is still too complex, and to simplify it, a computer program was written to determine the simplest small graph of structure for the large graph of element links.

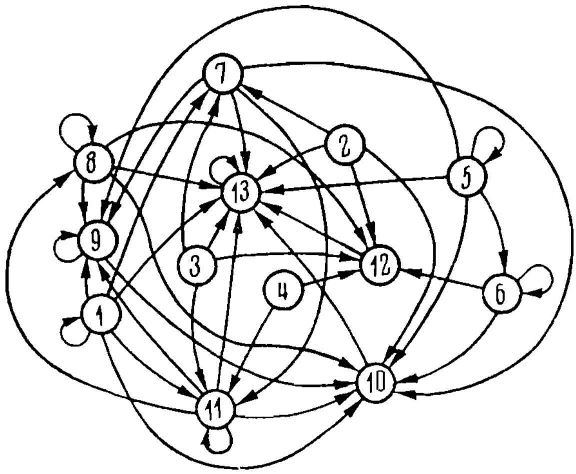


Figure 4.

The Compilation of Approaches

The main idea of forming new approaches is that the grouping of elements into the traditional 13 approaches is not necessarily the best: optimal approaches must be formed with consideration of information links that exist in reality. The elements of an approach are either strongly tied together with weak relations to elements of other approaches (see Figure 5a), or they are weakly tied together, but are uniformly strongly related with elements of some other approach (see Figure 5b). The numbers in parentheses in Figure 5 denote the numbers of elements in the approaches.

The computer program which compiles new approaches from the accepted Element List, minimizes a certain formal criteron [15] that expresses the amount of discrepancy between the graph of structure and the information links between the approach elements.

The structure graphs in Figures 5a and 5b correspond to different (but approximately equal) local minima reached from different initial links of the approaches and under different policies of minimum searching.

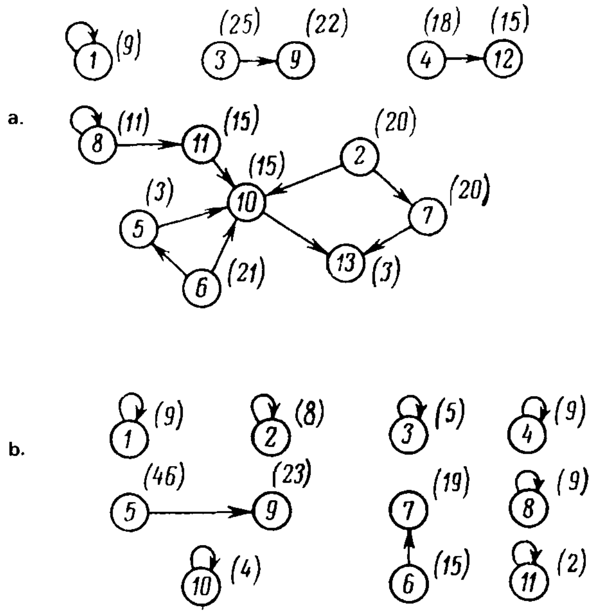


Figure 5.

A FORTRAN IV program for Element List structure optimization requires about 150K of the ICL System 4-70 core memory and approximately 40 minutes of processor time. The graph and approach lists resulting determine the structure of the system for SDI.

The research report abstracts of the members of any approach element should be sent to the Information Center, while the reports themselves should be stored in National Data Banks on tape, or otherwise, to provide for the production of copies on request. This document storage would be very useful in information logic systems of the future.

The Center disseminates abstracts to all the members of a particular and related approach. This makes circulation on non-relevant information sufficiently small. If some approach elements have not been included in any new approach, then participants are not included in the SDI system but get information from the Center by special requests.

In the initial Element List an element contained in a single approach, may be included in any number of optimal approaches after processing. Elements simultaneously contained in a large number of approaches, usually greater than three, are the main research tasks of the Program and should attract special attention by the Program managers. Results attained in these pivotal problems influence a large number of approach elements.

The optimal approach structure and the approaches themselves are strongly affected by the large graph of element links (Figure 3) worked out by medical information experts, and sequential verifications of this and of the optimal approaches are therefore necessary. To carry out these verifications in the Soviet CRC, an expert commission formed from leading professionals in traditional cancer-related research was organized.

Thus the work being carried out in the USSR in organizing the Long-Term Program for Cancer Research may become a basis for setting up an international thesaurus and language for SDI within the International Cancer Program. The need to carry out such work on the fourth stage of the International Program was noted in resolution WHA 27.63.

RESOURCES ASSESSMENT

Instead of determining resource requirements (time intervals, finance, manpower, workshops, etc.) of the Program as a whole, we determine the resources separately within the optimal approaches. Figure 6 shows the rather simple inner structure of these; double circles are the pivotal elements.

Expert estimates of resources necessary for separate approaches may be balanced by comparing expert estimates for the pivotal approach elements in several approaches. If pivotal elements get different estimates in different approaches, this naturally causes one to doubt the reliability of these estimates. The correction of the pivotal element estimates will cause changes in other element estimates within corresponding approaches, etc. This adjustment of expert estimates and balancing data may be done successively until all contradictions are eliminated.

The composition of a logic network diagram for the Program comes after working out a resources estimation and this would display the advance of scientific attacks on cancer while reaching for the final goal--the reduction of the incidence, morbidity and mortality of cancer.

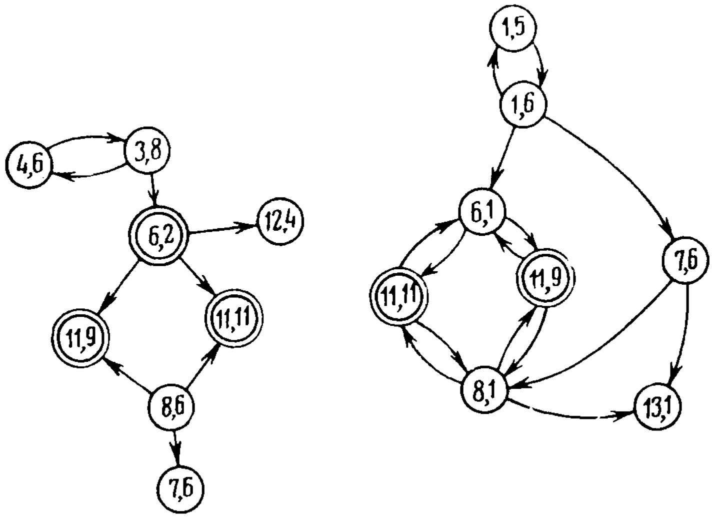


Figure 6.

HOW THE PROGRAM WOULD BE RUN

The Program implementation stages are presented in Figure 7. The middle part shows actions to fulfill the Program, the left part the results of the actions, and the right part final results of planning--organization of SDI service and compositon of the logic network diagram. The procedures of expert assessments are circles.

As any information has a tendency to become obsolete, the proposed SDI system and the logic network diagram may well become obsolete too. The need for new information links will arise, and some old links will partially break off. The Element List may be changed--some research problems will lose their significance while new problems will be included. Successive breakthroughs will occur in some directions of the Program while in other directions there may be temporary stagnation. All this will force us to adjust planning in the future. The adjustment should be made by the Advisory Council for the International Cancer Program created under the auspices of WHO and incorporating the scientists--oncologists and mathematicians--who would represent WHO member countries, international organizations (UICC, IARC, IIASA) etc. and experts in cancer research. The Council's duties should be regular reports on the fulfillment of the Program, working out forecasts on the program as a whole and the particular approaches. These may be taken into account for adjustment of the logic network diagram.

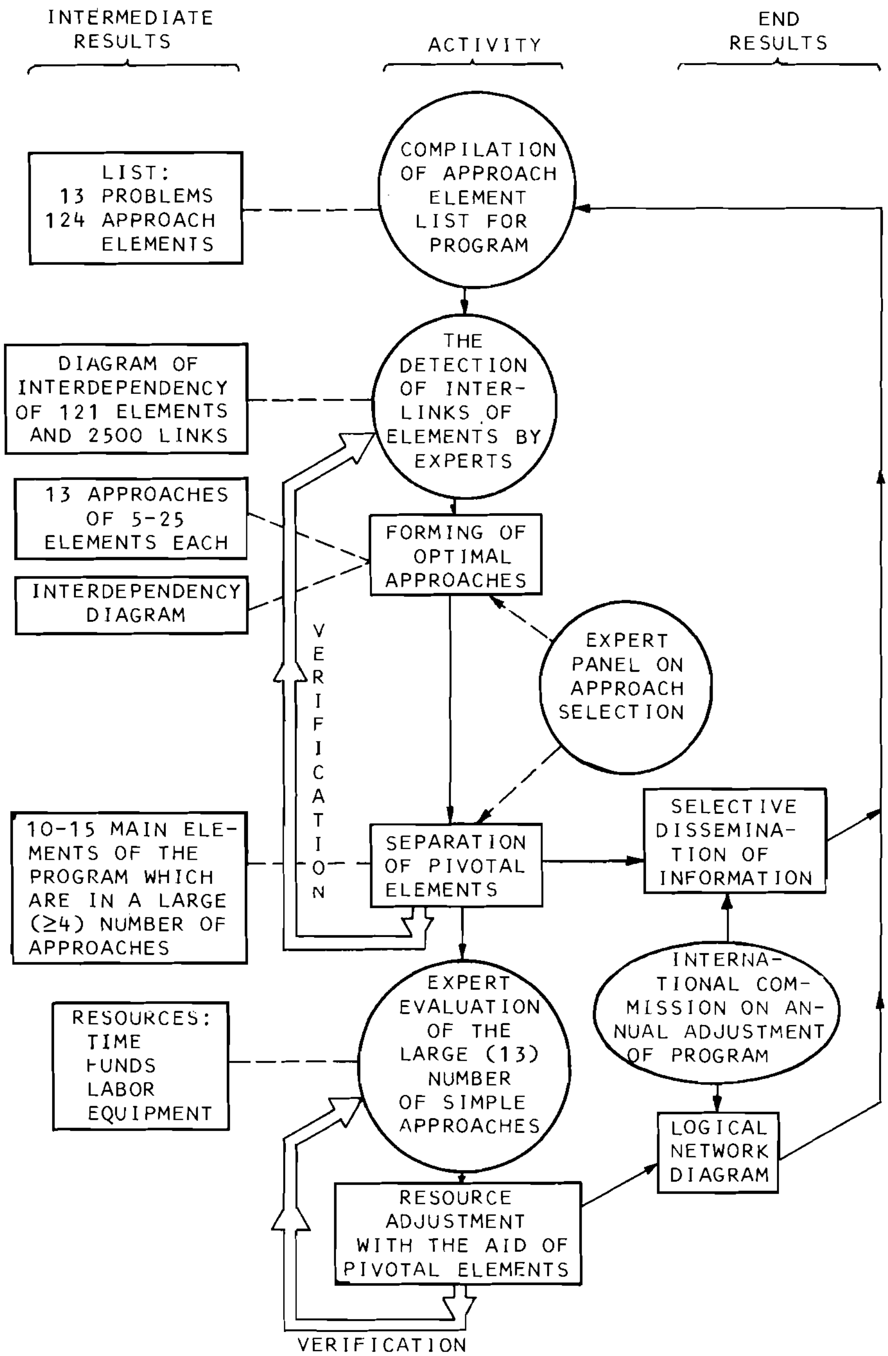

INTERMEDIATE RESULTS
ACTIVITY
END RESULTS
LIST: 13 PROBLEMS 124 APPROACH ELEMENTS
COMPILATION OF APPROACH ELEMENT LIST FOR PROGRAM
DIAGRAM OF INTERDEPENDENCY OF 121 ELEMENTS AND 2500 LINKS
THE DETECTION OF INTER-LINKS OF ELEMENTS BY EXPERTS
13 APPROACHES OF 5-25 ELEMENTS EACH
INTERDEPENDENCY DIAGRAM
FORMING OF OPTIMAL APPROACHES
EXPERT PANEL ON APPROACH SELECTION
VERIFICATION
10-15 MAIN ELE-MENTS OF THE PROGRAM WHICH ARE IN A LARGE (≥4) NUMBER OF APPROACHES
SEPARATION OF PIVOTAL ELEMENTS
SELECTIVE DISSEMINA-TION OF INFORMATION
INTERNA-TIONAL COM-MISSION ON AN-NUAL ADJUSTMENT OF PROGRAM
RESOURCES: TIME FUNDS LABOR EQUIPMENT
EXPERT EVALUATION OF THE LARGE (13) NUMBER OF SIMPLE APPROACHES
LOGICAL NETWORK DIAGRAM
RESOURCE ADJUSTMENT WITH THE AID OF PIVOTAL ELEMENTS
VERIFICATION

Figure 7.

With some slight changes the man-machine procedures for analyzing the information structure of cancer research that were worked out in the USSR in the CRC and the Institute for Control Sciences can be adopted. It is clear that the greater part of working out the International Long-Term Cancer Program is played by a modern computer technique but this should not disconcert participants of the Program because as may be seen in Figure 7, virtually any computer recommendation is controlled by experts in medicine or in systems analysis. Close man-machine interaction realized in the Program organization creates prerequisites for mutual error corrections and guarantees successful Program completion.

The method we propose for implementing the Cancer Program [16] is based on a systems approach, and we hope that this will ensure its success.

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The Potentialities of a Systems Approach to The World Health Organization's Role in Coordinating International Cancer Activities

A.S. Pavlov and N.T.J. Bailey

INTRODUCTION

There appears to be general agreement that:

- The group of diseases generically labelled 'cancer' is a top priority concern in the world today, certainly for developed countries and increasingly for developing countries;

- Enormous resources have been, and are being, expended in the fight against cancer, without final control having been achieved; and

- New efforts are accordingly required in the overall coordination and management of cancer activities on an international level.

Moreover, the Twenty-Seventh World Health Assembly, in its resolution on the long-term planning of international cooperation in cancer research, WHA 27.63 (*Off. Rec.*, No. 217, p. 32), specifically

> ...requests the Director General to continue the work that has been started on a comprehensive program for international cooperation in cancer research and research methodology, including suggestions on an effective system of its implementation, taking into account all resources at his disposal, calling on the services of any experts needed, representative of Member States and representatives of the international organizations concerned....

In a subsequent WHO Executive Board document (EB55/7, 9 December 1974) the Director-General presented a report on the further actions and developments that had taken place.

Consequently, WHO is committed to the task of coordinating international cancer activities through the development of an appropriate comprehensive program. The extent to which, in practice, such activities should involve general problems of applying present knowledge and managing existing resources, as well as the development of research, is a matter to be decided. On the whole, it seems preferable to define research in such a way as to include new methods of application and implementation, in addition to the traditional connotation of fundamental research.

OVERALL OBJECTIVES

The ultimate objectives of the WHO program are to prevent the occurrence of cancer so far as possible and to improve the diagnosis, treatment, cure and alleviation of cancer when it occurs.

This is an heroic undertaking. Its vast dimensions require that more limited, subsidiary objectives also be identified to enable effective work to be done in the right direction. There is a big gap between WHO's planning activities and the practical applications to those individuals whose health must be promoted. WHO has direct contacts, primarily of an administrative nature, with other national and international organizations. This means that limited objectives are required in terms of specific programs designed to further overall objectives.

TYPES OF PROBLEMS

Important problems in the cancer field occur on many different levels, and in many different areas of study. For example:

- The pursuit of epidemiological research, including geographical pathology;
- The prevention of carcinogenic hazards due to environmental, behavioral and occupational factors;
- The screening of populations to detect cases at early stages or precancerous stages;
- The biological understanding of tumor growth and host response;
- Improvement in techniques of early diagnosis;
- The development of chemotherapy, radiotherapy and surgical techniques;
- The application of better combinations of the foregoing methods of treatment and prevention;
- The search for more cost-effective methods and the use of cost-benefit analysis;
- The provision of better cancer health services;
- The establishment of better overall planning, coordination and management for cancer control;

to mention only some of the major aspects.

A serious difficulty in pursuing a well-balanced development lies, however, in the following conflict. It is easy to concentrate attention on specific, concrete activities like dealing with an individual patient, investigating the properties of a whole series of possible anticancer drugs, developing a new surgical technique, or even studying practical mathematical models of alternative screening programs. However, it is difficult to deal with the broad aspects of planning and policy analysis without incurring the appearance of merely playing with abstractions.

THE SPECIAL ROLE OF WHO

Most of the problems mentioned above are primarily the concern of individual institutions around the world at the country level, e.g. universities, hospitals, medical research centers, etc. But considerable assistance is already given by WHO in various forms.

Thus the WHO Cancer Unit, headed by Dr. A.M. Garin, provides technical guidance on the development of cancer control programs; helps define criteria for the identification of high risk groups; promotes and assists education in cancer control; encourages research into new methods of diagnosis and treatment; helps in the development of various types of cancer registries; and has developed international standards for histological classification.

Work has also been carried out in other HQ units dealing with the international classification of disease as applied to cancer; the study of the immunological response to tumors; the investigation of carcinogenic hazards in food and environment; and the development of new techniques of diagnosis and treatment using nuclear medicine and radiation therapy.

To assist in the development and systematization of a broad approach to the problems of cancer control, a small working group has been formed within WHO headquarters, which is currently attempting to explore the potentialities of systems analysis methods; the present paper is an outcome of the discussions that have taken place.

Another component of WHO is the International Agency for Research on Cancer (IARC) situated in Lyon, France. This Agency is predominantly concerned with research on carcinogenic factors in the human environment. Its program is therefore mainly directed to epidemiological research on cancer in man and related studies in environmental carcinogenesis.

In addition, the majority of the Regional Offices of WHO have already developed instruments for the establishment of regional programs for cancer prevention and control.

There is, finally, an Interdisciplinary Team on the WHO Cancer Program, under the Chairmanship of Dr. A.S. Pavlov, Assistant Director-General, which has been set up to further the integration of all activities. The Team exercises a broad control over the development of the whole cancer program and thus has an opportunity to strike a balance between the multifarious activities in progress. It is in fact the specific and unique role of WHO to improve coordination and organization at the global level.

NEED FOR A BROAD SITUATIONAL REVIEW

Naturally, the Interdisciplinary Team in WHO is already acquainted with the general world situation. But it is suggested that there has been, as yet, no sufficiently explicit and systematic analysis to serve as a basis for developing firm recommendations on the planning/policy level that will be generally convincing and acceptable.

There is an enormous amount of oncological knowledge and data at the level of countries and individual institutes, hospitals, registries, etc., covering all aspects, including histology, immunology, clinical medicine, epidemiology, public health, etc. A vast amount of time, money, personnel and effort is expended in many countries in trying to achieve the overall objectives already outlined, but the results are not yet satisfactory to mankind.

What is required, from the point of view of improving overall performance, is not, of course, a comprehensive systemization of all known data about cancer--this would be almost impossible to compile, and too complex to interpret even if it existed--but a judicious sketching out of the main areas of world activity, together with the more important interactions between such areas. Even to do this would be a herculean task if one were starting from scratch, but many areas have already been critically surveyed and evaluated by those most competent to do so.

This means that we should first embark, not on any new major projects of research or vast surveys for data collection, but that we simply review the total world picture in its broad outlines as it is, with all the inefficiencies, duplication of efforts, lack of vital data, counter-productive efforts, etc.

A major task in this context is to develop some schematic representation, or conceptual framework, for activities and their interactions over the whole field. Such a conceptual framework, or model, would help to:

- Clarify thought and discussion about the whole subject;
- Identify gaps in knowledge and inadequate coverage of specific topics;

- Point to inefficient services;
- Develop cost/benefit analyses;
- Form a basis for appropriate information systems;
- Improve decision making in overall planning and management.

A special feature of this analysis is that it would somehow have to relate WHO's main contacts with other agencies on a rather abstract policy level to the more technical activities that involve the carrying out of clinical research and the treatment of patients.

In addition, it will almost certainly be necessary to consider a multisectoral system, in which the health sector component deals primarily with the ramifications of cancer, while other sectors cover such aspects as economics, social structure, education, industry, urbanization, energy options, pollution, etc. This is because what can be done within the cancer field is highly dependent on constraints imposed by interactions with other fields. Ultimately, planning may be assisted by the use of dynamic, multisectoral models that permit one to predict, to some extent, the consequences of choosing particular decision strategies.

This of course is rather looking ahead to subsequent stages of a comprehensive, systematic approach. But the success of future developments will be partly dependent on the way in which the initial situational analysis is carried out, and on the structure adopted for the conceptual framework.

OUTLINES OF A CONCEPTUAL FRAMEWORK

It may be useful to distinguish between:

- The technical subject matter itself, i.e. the biological, medical and health care aspects of cancer; and
- The broad administrative and organizational superstructure, especially WHO's role, required for general planning and management.

Technical Subject Matter

Recognizing that there are more than 100 clinically distinct types of cancer, each having a unique set of symptoms and requiring an individual course of therapy, we are more or less forced to start with a fundamental classification by site. For each site or group of sites, subclassification is required. From the multitude of specialized aspects, it is difficult to see what basis can be used for aggregating the subgroups formed by taking each aspect separately. One way, that relates to the fundamental distinction between theory and practice, would be to distinguish between knowledge and action. Thus "knowledge" includes all the specialized biological, clinical, epidemiological, statistical, etc., understanding that exists; while "action" is concerned with diagnosis, screening, treatment, cure, rehabilitation, etc., involving specific medical or health care interventions.

The success or failure of the latter must be judged by an appropriate monitoring or evaluation activity, which could be subsumed under "knowledge", or specified as a separate self-critical, quality control on the part of action.

To summarize, this suggests the broad classes:

(i) Site (appropriately grouped);

(ii) Knowledge (biology, clinical medicine, epidemiology, statistics, etc.);

(iii) Action (diagnosis, screening, treatment, cure, rehabilitation, prevention, etc.);

(iv) Evaluation of activities in (iii).

Such a classification can in principle be made on a static basis, relating to a fixed period of time, e.g. one year. But a more useful dynamic picture will emerge if we consider a time flow as indicated in Figure 1.

But of course this is only a beginning. Some way must be found of relating the monitoring of mortality and morbidity for given sites to interventions that might be made, or have been made. In short, we need quantitative assessments of (a) the actions that have already been taken to test their effectiveness, and (b) new actions that could be put into effect in the future. And, as already mentioned, proper account must be taken of the constraints within which one must inevitably work, as well as of the cost-effectiveness aspects of the situation.

In addition, comparisons between the sites will draw attention to deficiencies in both knowledge and action, and suggest where more effort is required or where the existing concentration of effort is perhaps excessive, having regard to the needs of another area.

To begin with, any serious attempt to construct a wide-ranging conceptual framework is bound to be tentative and experimental, but improvements would come with actual use and critical testing.

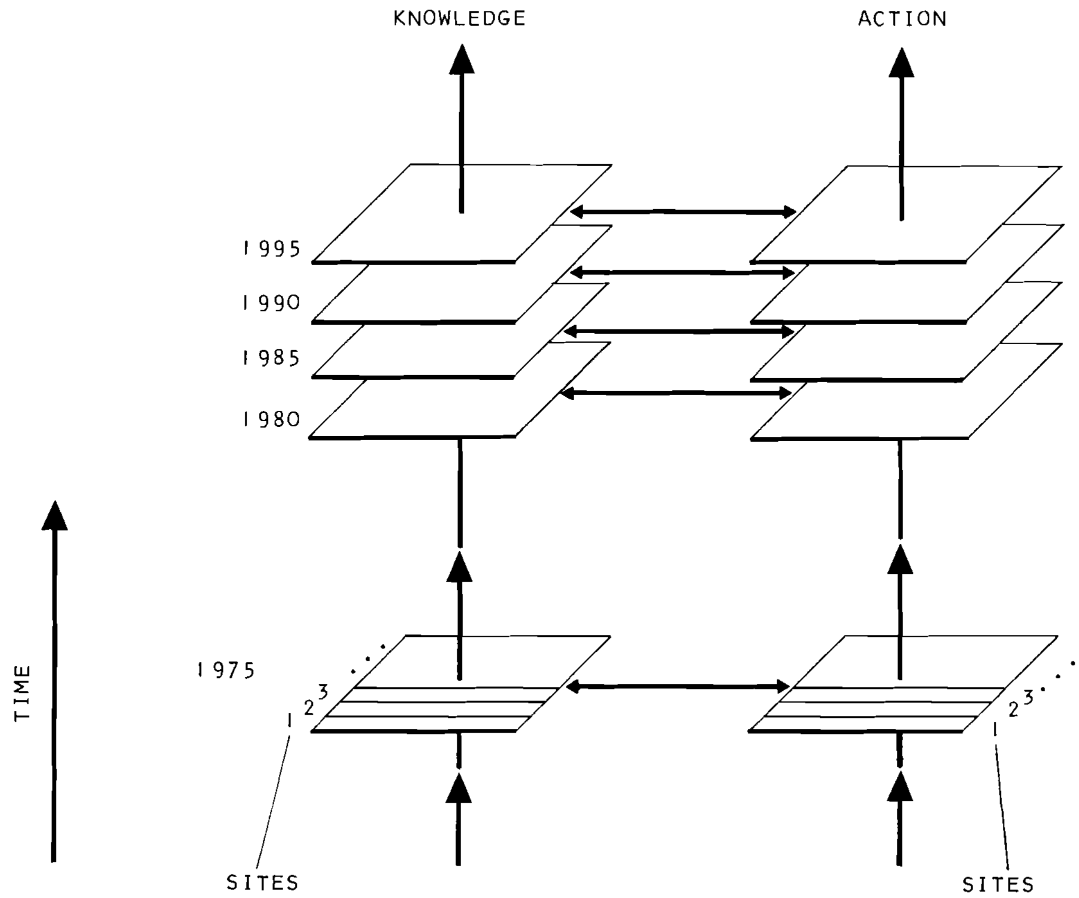


Figure 1. Diagram showing parallel but interacting flows of knowledge and action, classified by sites of cancer

To begin with, any serious attempt to construct a wide-ranging conceptual framework is bound to be tentative and experimental, but improvements would come with actual use and critical testing.

Organizational Superstructure

As well as a conceptual frame of reference for the more concrete, technical activities in the cancer field, we also need a picture of the existing administrative and organizational structure. Unless there is a well-ordered description of the main features of the mechanisms through which decisions are made and implemented, there will be managerial chaos with a low efficiency in the use of knowledge and resources.

In addition to the various activities of WHO as a whole, there are other international organizations, such as the Union Internationale contre le Cancer (UICC), and the European Organization for Research on Treatment of Cancer. Cancer is also of concern to institutions like the International Atomic Energy Agency (IAEA); and we must not forget the current potentialities of developments by IIASA itself in the application of systems analysis and policy analysis to the whole cancer field. In addition, there exist a large number of cancer institutions at country level.

Although there is much fragmented and anecdotal knowledge about the activities of all these agencies and institutions, a systematic and comprehensive information system is urgently required if WHO is to be able to exert the administrative and political leverage essential to major effective action.

DYNAMIC MODELING

While we are discussing the potentialities of a systems approach to the whole cancer field, it is perhaps worth giving consideration to the possibilities of some form of dynamic modeling. A systematic analysis of the whole field will certainly clarify thinking, but if a serious attempt is to be made to define alternative strategies for future action, we need in addition a method of forecasting in broad terms the likely consequences of any particular choice. It may be rather too early to concentrate much attention on this aspect, but the existence of an appropriate subobjective would tend to focus thinking in a useful direction.

It goes without saying that more mathematical work at the physiological and cellular levels could be highly beneficial, but our purpose here is with the broader picture of population phenomena and health care. A good deal is already known about mortality and morbidity rates for given sites in different age and sex groups, depending on occupational activities, geographical location, known risks form radiation pollution, etc. Thus, given the existing demographic processes and present trends in industrialization, urbanization, alternative development of various energy options, etc., there is at least a quantitative basis for making projections of expected variations in the incidence of various types of cancer. We could begin to assess an order of magnitude in evaluating the desirability of some particularly expensive program that has been proposed.

The cautious development, with careful testing, of possible models to represent population phenomena could be a useful adjunct to a more qualitative type of policy analysis. Thus a careful investigation of screening processes--for example, the current collaborative work on cervical screening between the Cancer Unit, WHO, and the Biomedical Project, IIASA--could by generalization provide valuable information as to the desirability of such approaches over a wide section of the cancer field.

Proper interfacing between systems investigations at the technical level and more qualitative studies at a policy level is almost certainly essential to the success of both enterprises. Otherwise, there is danger of a serious conflict between abstract, high-echelon maneuvers and down-to-earth concrete activities dealing with the specific diseases of real patients.

In the same way, an adequate interface is needed between population models and models of tumor growth in individuals. This is to ensure that decisions on diagnosis and treatment made for a large series of individuals correspond accurately to the underlying physiological facts.

ACTION REQUIRED

It would be premature to try to foresee in any detail what would follow from the first step involving a systematic situational analysis. Obvious shortcomings in the world control of cancer would clearly be subjects for further substantive investigation. But an appropriate program would first have to be hammered out at the policy level, using the material provided by the situational analysis in the light of generally agreed priorities and objectives. In other words, a well-organized process of planning, coordination and management would have to be instituted.

This requires a certain minimum participation of appropriately qualified staff. The small working group, set up as a short-term effort by the Interdisciplinary Team of WHO, has already been mentioned. It has four members in all--a cancer specialist, a statistician and two experts in systems analysis and information systems. There is a balance between medical officers and nonmedical scientists (two of each), and both technical and policy levels of the Organization are represented.

As soon as an agreed basis for further work is reached in this Headquarters group, it is hoped to extend its representation to include members of IIASA. Such a group would be broadly based and would have access to a wide range of expertise such as cancer epidemiology and health care, statistics, systems analysis, information systems, computing, etc.

The real problem in developing the approach is that all the people involved, or proposed, are likely to have several existing major commitments. While it may be undesirable for members of the group to have no other involvements, a priority commitment to the group on the part of several appropriately qualified people is absolutely essential if any substantial progress is to be made.

We would welcome discussion and criticism of these proposals, especially in regard to the composition of an effective working team which would have not only the responsibility of undertaking the tasks indicated, but also sufficient time and resources to do the job properly.

The Volume and Value of Information on Cancer

A.M. Garin

It is a well-known fact that vast quantities of money and manpower are being swallowed up by work on the cancer problem in many countries. Research is being vigorously pursued on all continents and the scale of completed studies and investigations is indicated by the number of articles and abstracts published yearly. The bibliographical bulletin issued annually by the Institut Gustave Roussy lists 20,000 articles published in 1000 scientific journals. Excerpta Medica Cancer deals with 12,000 articles, Carcinogenesis Abstracts with 7200 papers and Cancer Chemotherapy Abstracts with 10,000, etc.

How can this flood of information be digested, and how is it possible to assess or compare the results of research carried out on different models, by different methods, with different approaches to the selection of patients or the evaluation of results and with different interpretations of histological or cytological preparations, etc.? How can the research worker compare the results of his own experiments on selecting an anticancer substance by means of a given model with the results of other research testing the same or other chemicals on another model?

The World Health Organization is devoting a great deal of attention to the standardization of methods, standards, classifications and ways of evaluating immediate and long-term results of treatment.

The WHO program for standardization of histological classification is an all-embracing one. Histological classifications and cytological descriptions have been, or are being, developed, on a collective basis, for every form of human tumor. It is, of course, of the utmost importance to ensure the wide application of these classifications in all countries and regions throughout the world.

Multiplicity of clinical classifications makes it difficult to compare the results of diagnosis, the effectiveness of methods of treatment, etc.

Each country carrying out research on tumor chemotherapy has its own methods for the primary screening of active preparations; quite often different methods are used in different institutes in the same country.

A meeting of experts convened by WHO considered that it would not be advisable to standardize the entire screening process, since that might lead to a narrowing of the field of search for anticancer preparations. However, the meeting took two important decisions which will make it possible to compare data and easier to assess the reliability of screening systems. It was decided not to change the models currently used for screening chemicals in each institute or country, but to stipulate that an additional investigation should be carried out on one common model, namely L1210 mouse leukemia. Another very important decision, making it possible to test the screening system used in any given country, was to publish a report on the efficacy of 20 anticancer preparations already in clinical use when tested on the models employed in different countries.

Hospital registries form the basis for scientific analysis in clinical oncology. They provide the only means of assessing such points as the effectiveness of various methods of treatment, long-term results, bed occupancy, complications, and differences in the results of treatment of the same condition over a period of time. But the hundreds of hospital cancer registries in the USA, for example, have different capacities, attach different degrees of importance to recording many important aspects of the natural course of the disease and have different systems for monitoring treatment. WHO has analyzed the registers kept at 26 leading institutes in various countries and has found that they all differ in their use of pathological nomenclature in cancer, have different methods of staging different tumors and have different ways of assessing long-term and immediate effects. Only seven of the 26 registries took account of the patient's occupation, three recorded the duration of hospitalization, and eight noted the cause of death. A standardized hospital register has been developed by WHO. Its chief merit is that it is applicable to all countries, whether developed or developing. The register helps to break down language barriers and offers an international basis for comparison of many problems in clinical oncology. Such standardized registers also give the heads of national health care services valuable information, which helps them in planning expenditure, resources and manpower. There is, as I said earlier, a vast amount of information available on cancer; yet, at the same time, it is pitifully meager.

No situational analysis has yet been carried out on the range of cancer research or on the operation or equipment of cancer control services in all countries. This is a task WHO intends to accomplish in the near future. The directory of oncological establishments prepared by the International Union against Cancer is short and inaccurate and does not make it possible to assess the research potential of various countries.

With regard to data on cancer, the WHO Statistics Unit has mortality figures available only from territories representing 27 percent of the total world population. Mortality indices for cancer in Africa and Southern Asia can be supplied only from territories representing no more than seven to ten percent of the total population for the zone. WHO has no cancer mortality data from 132 countries. Documentation on cancer morbidity in various geographical regions is often inaccurate. The gaps in our knowledge about the frequency of any given form of cancer in various countries are responsible for such mistaken assertions as that cancer is not a problem of current concern in developing countries. The main point that I wish to make is that it is not enough to gather information. The crux of the matter is to make sure that scientific and statistical data comply with international standards. This may be achieved by collective agreement on the procedures, methods and techniques for gathering such data. Standardization in oncology will consolidate existing achievements, raise the level of individual national efforts, create a quantitative and qualitative basis for the development of new general theories and hypotheses and accelerate progress in oncology.

The SABIR-C Cancer Literature Information System

G. Wagner

As in many fields of science (particularly the natural sciences), publications in the field of oncology have been steadily increasing in scope and number. Whereas in 1880 the total number of medical treatises published all over the world was about 20,000, today almost as many papers are published annually on the subject of cancer alone. An oncologist with an average reading speed of 15 minutes per article, who devoted three hours a day to reading, could keep up with little more than 20 percent of cancer literature as it is first published--quite apart from all the difficulties of procurement, language, costs, etc.

So far, there is nothing to indicate that this trend of steadily increasing scientific output will cease; this, however, means that it will become increasingly more difficult, if not impossible, for the individual scientist to keep up to date with regard to the progress made and the latest results of research in his particular specialty. The only possibility offered today of coping economically with the "flood of literature" is by electronic "information retrieval"--storing pertinent literature in the computer and making it accessible again. For years, scientists in various fields have been engaged full-time in making accessible (indexing or abstracting) and disseminating scientific information, be it by editing survey articles or lists of titles of new papers (Current Awareness Services), by providing Dissemination of Information selected according to the scientific interest profile of the "customer" or by supplying Special Demand Bibliographies.

The first major project of an electronic information system in the field of medicine--*MEDLARS* of the National Library of Medicine in Washington--has since 1964 covered more than 200,000 publications each year from all fields of medicine; in the comprehensive project of Excerpta Medica Foundation in Amsterdam roughly 300,000 titles and short reviews are stored annually. In addition to such big systems which cover the entire range of medical literature, it is reasonable to have information systems which, while covering only the literature of a certain sector, do so in a more detailed manner than the comprehensive systems mentioned above. Such a system is the SABIR-C cancer literature system developed by the French Cancer Research Center in Villejuif in cooperation with the German Cancer Research Center in Heidelberg.

SABIR-C is an acronym derived from "Système Automatique de Bibliographie, d'Information et de Recherche en Carcinologie". Its aims are:

- To cover the relevant literature of clinical and experimental cancer research;

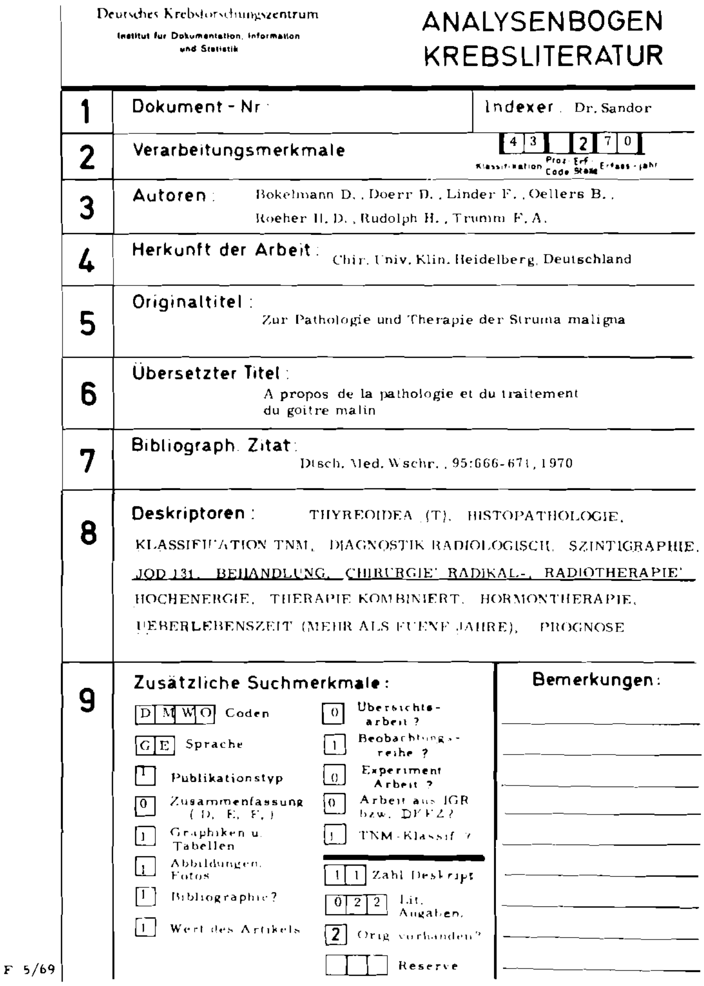
- To analyze this literature with a high degree of specificity;

- To disseminate information slectively and to process special requests for the literature available.

At present, a total of about 1000 journals are being screened for papers on the topic "cancer", which are processed, recording the most important bibliographical details (such as name of the author or authors, place of origin, original title, translated title, journal) and additional search features for which the computer may be asked. Figure 1 shows the analysis sheet used in Heidelberg over many years. The original paper together with the analysis sheet is sent to one of the indexers who, if at all possible, should be an expert in the field treated in the paper. For instance, a virological paper will always be entrusted to a virologist, an article on the surgical treatment of cancer of the intestinal tract to a surgeon. The indexer will read the paper and characterize its contents by an appropriate number of key-words, called descriptors. The terms which he may use to characterize are contained in the catalogue of descriptors. The indexer may use any synonym listed for a certain concept; however, the computer will later on print out only the corresponding "preferred term".

Having indexed the paper, the indexer returns the analysis sheet to the literature documentation group where formerly the data used to be transferred to paper tape. However, for about a year now, we have been using an analysis sheet form which is typed in machine readable OCR-B-type. These forms are processed in an optical reader, the contents being automatically transferred to magnetic tape. A free text copy is then printed out for optical error checking by a human reader. At the same time, there is a second automated check for formal errors in the computer. If errors are detected, they can be corrected at once by means of a video terminal. Only after this double checking and, if necessary, correction, is the new material finally accepted into the data base (Figure 2).

The master file is stored index-sequentially and has as a key a six-digit document number. Storage takes place in variable record length with a maximum of 1500 digits. On data input, the document numbers of new citations are integrated into the inverted file at the same time (Figure 3). The inverted file consists of seven-digit key-word numbers with the corresponding six-digit document numbers. The records in the inverted file consist of a nine-digit code and five bytes per record



Deutsches Krebsforschungszentrum
Institut für Dokumentation, Information und Statistik

ANALYSENBOGEN KREBSLITERATUR

1	Dokument - Nr :	Indexer : Dr. Sandor
2	Verarbeitungsmerkmale	4 3 Klassifikation · Proz. Code · 2 Erf. Stand · 7 0 Erfass.-jahr
3	Autoren : Bokelmann D., Doerr D., Linder F., Oellers B., Roeher H. D., Rudolph H., Trumm F. A.	
4	Herkunft der Arbeit : Chir. Univ. Klin. Heidelberg, Deutschland	
5	Originaltitel : Zur Pathologie und Therapie der Struma maligna	
6	Übersetzter Titel : A propos de la pathologie et du traitement du goitre malin	
7	Bibliograph. Zitat : Dtsch. Med. Wschr., 95:666-671, 1970	
8	Deskriptoren : THYREOIDEA (T), HISTOPATHOLOGIE, KLASSIFICATION TNM, DIAGNOSTIK RADIOLOGISCH, SZINTIGRAPHIE, JOD 131, BEHANDLUNG, CHIRURGIE' RADIKAL-, RADIOTHERAPIE' HOCHENERGIE, THERAPIE KOMBINIERT, HORMONTHERAPIE, UEBERLEBENSZEIT (MEHR ALS FUENF JAHRE), PROGNOSE	
9	Zusätzliche Suchmerkmale:	Bemerkungen:

D M W O Coden	0 Übersichtsarbeit ?
G E Sprache	1 Beobachtungsreihe ?
1 Publikationstyp	0 Experiment Arbeit ?
0 Zusammenfassung (D, E, F,)	0 Arbeit aus IGR bzw. DKFZ ?
1 Graphiken u. Tabellen	1 TNM-Klassif. ?
1 Abbildungen, Fotos	1 1 Zahl Deskript.
1 Bibliographie ?	0 2 2 Lit. Angaben.
1 Wert des Artikels	2 Orig. vorhanden ?
	Reserve

F 5/69

Figure 1. Sample of analysis sheet used in the SABIR-C system.

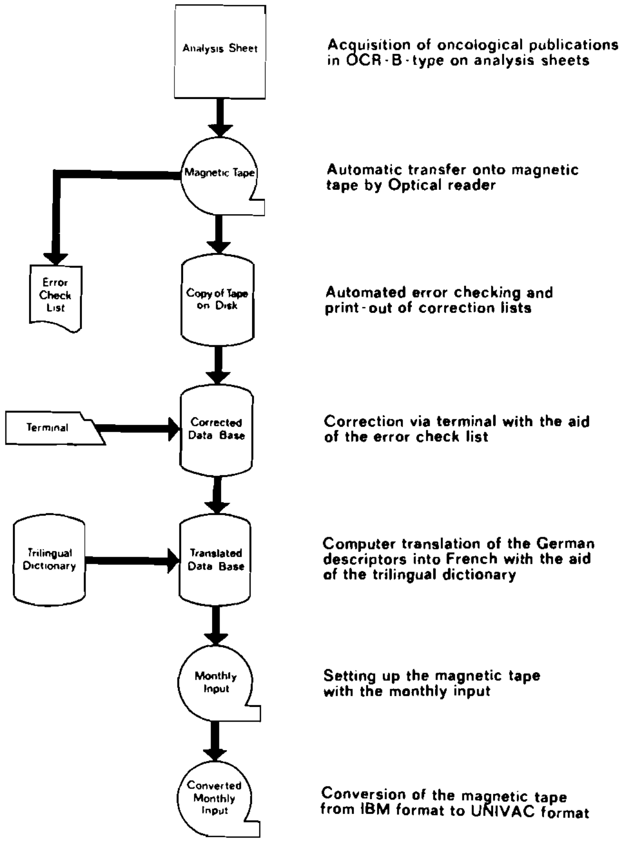


Figure 2. Processing of SABIR-C input.

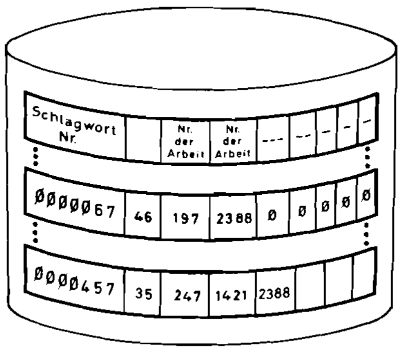


Figure 3. Inverted file of document numbers according to key-word.

for a frequency counter which increases by one at each search for the respective key-word. In this simple manner, key-word statistics may be set up.

Tapes are exchanged between Heidelberg and Paris at about monthly intervals. Since the computers available in Paris and Heidelberg are not compatible, the material to be exchanged has to undergo several recoding procedures. The seven-channel-code used in Paris has to be converted in the nine-channel-code of the Heidelberg installation or vice-versa; then the signal coding and the record format are changed and the key-words translated into French or German as the case may be.

The data base is stored on disks. In order to retrieve certain information, the search request has to be phrased in a form which is intelligible to the machine. For this purpose, we use the formalism of logic algebra developed in the middle of the last century by George Boole. The most important logical operations are the "and" and the "or" relations. If we connect several key-words as search terms with the "and" relation, this implies that a paper will be considered relevant only if it is indexed under all of the given key-words. In the example shown in Figure 3, a search request "67 OR 457" would yield all six papers noted, i.e. Nos. 35, 46, 197, 247, 1421, and 2388, as being relevant; a search request "67 AND 457", however, would yield only paper No. 2388.

The search for descriptors or combinations of descriptors is by far the most frequent type of search. It is carried out in the inverted file already mentioned. The document numbers found are those of the relevant titles which are subsequently printed from the master file in the form of lists or as index cards.

The search process and the output of citations found to be relevant can be achieved on-line via terminal or via typewriter terminal or off-line via fast printer. It takes a few second to answer a search request when about 65,000 papers are stored.

The SABIR system is trilingual, i.e. the key-words characterizing the contents of a paper may be printed in English, French or German. The central management and the coordination of the system are located in Paris where--thanks to the large staff of scientists built up systematically since 1955--the main portion of the work is done. The concept of the SABIR system provides for the axis Paris-Heidelberg be gradually extended to form an international information network in which all countries interested could integrate their national cancer literature and, in turn, be supplied with the entire material. We feel that this concept is designed to satisfy as economically as possible the ever increasing need for information on the part of scientists concerned with the cancer problem in theory and practice. As the first of additional partners, Italy, Poland and Yugoslavia have joined the system.

The SABIR system has grown considerably during its first four years. At the end of 1975 nearly 70,000 citations were stored in the master file.

Detailed key-word statistics are indispensable for the optimal operation and development of a literature information system. Table 1 compiled in October 1975, for example, shows that a total of 530,900 descriptors were used to cover the first 67,772 papers in the SABIR memory. The number of key-words assigned per paper fluctuated between 1 and 26. The table further demonstrates that about half the papers covered were characterized by five to eight key-words and that the curve of the key-word frequency distribution shows a strongly positive skewness.

Table 1. Frequency distribution of key-words (descriptors) assigned per paper.

Number of Key-Words (Descriptors) x	Frequency h(x)	Relative Frequency h(x)/n
1	32	0,001
2	406	0,006
3	1855	0,027
4	4587	0,068
5	6948	0,103
6	8069	0,119
7	8475	0,124
8	8155	0,120
9	7347	0,108
10	6071	0,090
11	4741	0,070
12	3809	0,056
13	2675	0,039
14	1723	0,025
15	1197	0,018
16	711	0,010
17	401	0,006
18	240	0,004
19	155	0,003
20	93	0,001
21	44	0,001
22	22	
23	9	
24	5	0,001
25	1	
26	1	
	n = 67772	1,000

Further details of SABIR-C statistics are shown in Table 2, which summarizes the frequency of occurrence of 3844 descriptors, classified into 14 categories, with intervals corresponding to the successive powers of two. From this table, it can be observed that of 3844 descriptors, 150 (3.9 percent) had never been used in the material processed. It goes without saying that these terms should be rechecked within a reasonable time in order to decide whether they should remain in the thesaurus. Class 4 with 593 descriptors (15.5 percent) is the class with the highest relative frequency, i.e. the descriptors were used 7 to 14 times; however, each of the 86 descriptors in classes 11 to 14 occurs more than 1022 times.

Table 2. Frequency of occurrence of key-words (descriptors) according to length of interval.

Class	Length of interval	Class interval	Absolute frequency h(x)	Relative frequency h(x)/n
1	0	0–0	150	0,0390
2	2	1–2	316	0,0823
3	4	3–6	435	0,1132
4	8	7–14	593	0,1543
5	16	15–30	586	0,1525
6	32	31–62	560	0,1457
7	64	63–126	453	0,1179
8	128	127–254	342	0,0890
9	256	255–510	158	0,0411
10	512	511–1022	165	0,0429
11	1024	1023–2046	53	0,0137
12	2048	2047–4094	24	0,0062
13	4096	4095–8190	8	0,0020
14	8192	8191–16392	1	0,0002
		0–16392	n = 3844	1,000

The results of key-word statistics also have an important bearing on phrasing the search requests. The searcher phrasing the user's search request in the form of a Boolean expression may, if he knows the relative frequencies of the key-words to be processed at least forecast how many "hits" the retrieval will yield. Searches yielding several thousand publications are, in practice, just as unsatisfactory as those which turn up no (or perhaps one or two) relevant papers. In the first case, it is advisable to restrict the retrieval profile (i.e. to specify more narrowly the key-words); in the latter case, the search request should be extended or generalized. In narrowing the search profile containing key-words of frequent occurrence, in order to avoid undesirable "ballast", care should be taken not to lose essential information. The optimal phrasing of a search request requires an excellent knowledge of the literature and of the structure of the system.

Key-word statistics also yield material for interesting structural analyses, e.g., for the investigation of trends, focuses of research, etc.

Figure 4 shows the frequency of publications on various organ cancers. Numerically most frequent in the world literature of today are the papers on cancer of the breast and the lungs, followed by publications on tumors of the skin, the cervix and the stomach. By comparison, there is relatively little about cancers of the penis and urethra.

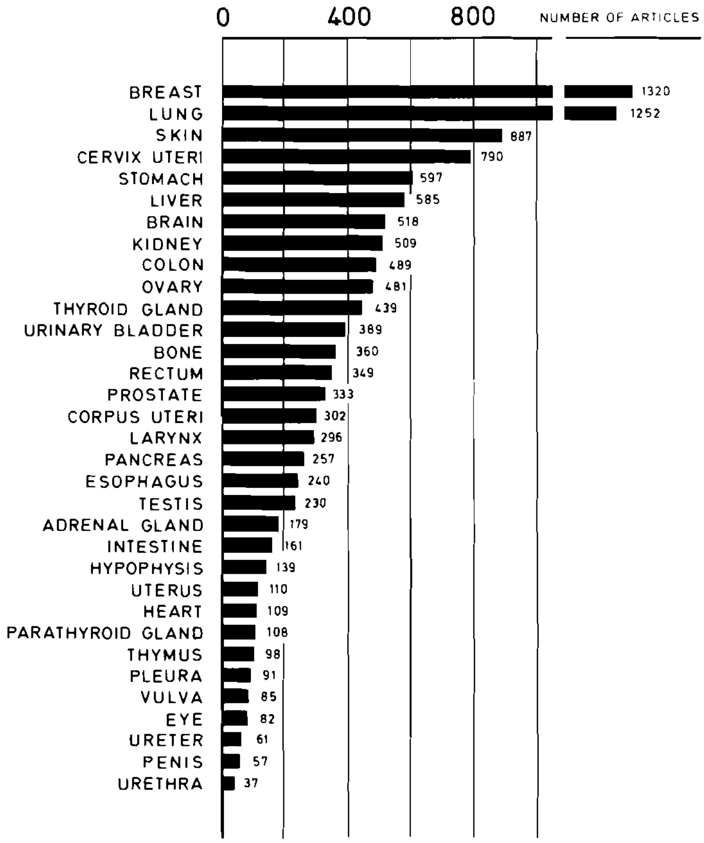


Figure 4. Frequency of articles according to site of tumor.

Immunology and biochemistry are specially topical fields of experimental cancer research, while in clinical oncology the main interest in recent years has been centered on hemoblastoses.

It is surprising to find that lymphadenectomy is by far the most frequently used key-word in surgery.

The total number of papers assigned to the different radioactive isotopes can be subdivided according to their use in nuclear medical diagnostics and in therapy. It then becomes evident that, in nuclear medical diagnostics, the isotopes technetium-99 and iodine-131 occur most often and in therapy, iodine-131 occurs most often, followed by caesium-137 and iridium-192.

Cobalt-60 and radium-226 have not been taken into account, since it turned out that these descriptors are sometimes included under the terms "high voltage radiotherapy" or "endocavitary radiotherapy" and are not listed separately.

Figure 5 shows that among oncogenic DNA-viruses, the SV40 virus and among RNA-viruses, the Rous sarcoma virus attract the greatest interest from scientists.

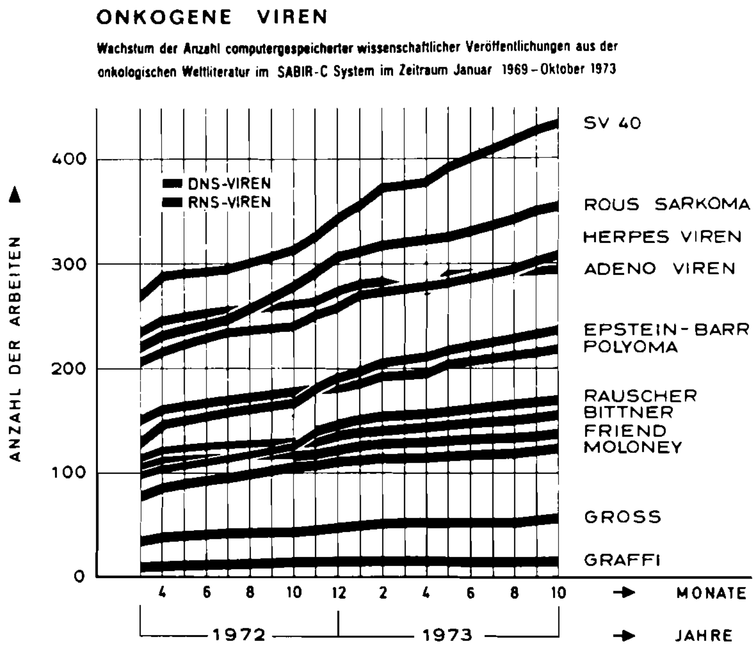


Figure 5. Frequency of articles according to type of oncogenic virus.

Statistics on cancer literature stored in the SABIR-C system also make it possible to convey an idea about the journals that are most important for cancer research and about the contribution of the different countries to the present cancer literature.

The 50 most important journals according to the number of papers covered originate for ten countries and 12 biomedical disciplines (Table 3). As in Garfield's analysis of the leading oncological journals in the *Science Citation Index*, the journals *Cancer*, *Cancer Research* and the *Journal of the National Cancer Institute* take the first three places in the SABIR-C system for the number of publications. The *Voprosy Onkologii* is in fifth place.

Table 3. Ranking of journals in SABIR-C system, according to the number of oncological publications covered, January 1969 to September 1974.

	Journal	Category	Number of papers	Language	Country of origin
1.	Cancer	Oncol	2193	EN	USA
2.	Cancer Res.	Oncol	1955	EN	USA
3.	J.nat.Cancer Inst.	Oncol	1578	EN	USA
4.	Proc.Amer.Ass.Cancer Res.	Oncol	944	EN	USA
5.	Vop.Onkol.	Oncol	891	ML	USSR
6.	Radiology	Radiol	870	EN	USA
7.	Strahlentherapie	Radiol	848	ML[1]	Germany West
8.	Nature	Sci mult[2]	725	EN	Great Britain
9.	J.Urol.	Urol	654	EN	USA
10.	Int.J.Cancer	Oncol	650	ML	Switzerland
11.	Proc.nat.Acad.Sci.USA	Sci mult	610	EN	USA
12.	Amer.J.Roentgenol.	Radiol	589	EN	USA
13.	Exp.Cell Res.	Cytol	553	EN	USA
14.	Radiat.Res.	Radiol	532	EN	USA
15.	Proc.Soc.exp.Biol.Med.	Sci mult	514	EN	USA
16.	Biochim.Biophys.Acta	Biochem	510	ML	Netherlands
17.	Europ.J.Cancer	Oncol	471	EN	Great Britain
18.	Brit.J.Cancer	Oncol	470	EN	Great Britain
19.	Brit.med.J.	Gener med	467	EN	Great Britain
20.	Virology	Virol	456	EN	USA
21.	Neoplasma	Oncol	421	EN	USA
22.	J.Virol.	Virol	414	EN	USA
23.	J.Radiol.Electrol.	Radiol	405	FR	France
24.	Fortschr.Roentgenstr.	Radiol	404	ML	Germany West
25.	J.Amer.med.Ass.	Gener med	399	EN	USA
26.	Lancet	Gener med	398	EN	Great Britain
27.	Sem.Hop.Paris	Gener med	396	FR	France
28.	Amer.J.Obstet.Gynec.	Gynecol	388	EN	USA
29.	Z.Krebsforsch.	Oncol	370	ML	Germany West
30.	Comptes rendus Acad.Sci.(D)	Sci mult	367	FR	France
31.	J.Immunol.	Immunol	362	EN	USA
32.	Amer.J.Surg.	Surgery	361	EN	USA
33.	Gann	Oncol	361	EN	USA
34.	Int.J.Radiat.Biol.	Radiol	357	EN	Great Britain
35.	Science	Sci mult	356	EN	USA
36.	Brit.J.Radiol.	Radiol	355	EN	Great Britain
37.	J.Cell Biol.	Cytol	331	EN	USA
38.	Arch.Geschwulstforsch.	Oncol	319	ML	Germany East
39.	Proc.roy.Soc.Med.	Gener med	312	EN	Great Britain
40.	Dtsch.med.Wschr.	Gener med	302	GE	Germany West
41.	Arch.Otolaryng.	Orl	292	EN	USA
42.	J.Urol.Nephrol.	Urol	292	FR	France
43.	Obstet.Gynec.	Gynecol	287	EN	USA
44.	Surg.Gynec.Obstet.	Surgery	286	EN	USA
45.	Experientia	Sci mult	281	ML	Switzerland
46.	Biochem.biophys.Res.Commun.	Biochem	278	EN	USA
47	Arch.Surg.	Surgery	275	EN	USA
48.	Nature new Biol.	Sci mult	275	EN	Great Britain
49.	New Engl.J.Med.	Gener med	268	EN	USA
50.	J.molec.Biol.	Biochem	266	EN	Great Britain

1) ML = Multilingual
2) Sci mult = Science multidisciplinary. Journals publishing papers in various branches of science

The list of all journals and papers according to country of origin (Table 4) shows the leading position of USA. Roughly 45 percent of the entire SABIR material is of American origin. Nearly 14 percent of the papers originate from French publications. British and West German periodicals follow with about ten percent each.

Table 4. Distribution of journals screened and oncological papers covered, according to country of origin, January 1969 to September 1974.

	Country	Number of journals	Number of papers	Percentage of papers
1.	USA	282	24650	45,23
2.	France	166	7472	13,71
3.	Great Britain	90	5844	10,72
4.	Germany West	128	5569	10,22
5.	Switzerland	64	2285	4,19
6.	Soviet Union	22	1229	2,26
7.	Germany East	18	911	1,67
8.	Japan	33	764	1,40
9.	Netherlands	18	694	1,27
10.	Sweden	14	662	1,22
11.	Czechoslovakia	9	553	1,02
12.	Poland	9	522	0,96
13.	Canada	15	484	0,89
14.	Italy	41	446	0,82
15.	Denmark	13	370	0,68
16.	Austria	8	324	0,59
17.	Romania	7	279	0,51
18.	Australia	10	262	0,48
19.	Spain	12	160	0,29
20.	Brazil	8	149	0,27
other 24		66	867	1,60
		1038	54496	100,00

Summary of International Cancer Research Data Bank (ICRDB) Program

C.A. Linsell

OBJECTIVE

The objective of the ICRDB Program is to "actively promote and facilitate, on a worldwide basis, the exchange of information between cancer scientists and the dissemination of information (through cancer centers and other appropriate organizations) to all physicians for the public good".

BACKGROUND

The ICRDB Program has been developed in response to a congressional directive in the National Cancer Act of 1971, Section 407(b)(4), which states that the Director of the National Cancer Institute (NCI) will:

> ...collect, analyze, and disseminate all data useful in the prevention, diagnosis, and treatment of cancer, including the establishment of an international cancer research data bank to collect, catalog, store, and disseminate insofar as feasible the results of cancer research undertaken in any country for the use of any person involved in cancer research in any country.

Under Section 410(8), the Director is authorized:

> ...to take necessary action to ensure that all channels for the dissemination and exchange of scientific knowledge and information are maintained between the National Cancer Institute and the other scientific, medical, and biomedical disciplines and organizations nationally and internationally.

After a preliminary planning phase, the ICRDB Program moved into an initial operational phase with the implementation of an on-line system called CANCERLINE (CANCER on-LINE) during the summer of 1974. Since that time, many other facets of the Program have begun operation.

CANCERLINE

CANCERLINE is a computer-based system for on-line retrieval of abstracts derived from published results of cancer research and descriptions of ongoing cancer research projects. The system is composed of several separate data bases, CANCERLIT (Cancer Literature) and CANCERPROJ (Cancer Projects) being the two most important. Through an interagency agreement, CANCERLINE is accessed by computer terminals connected to the central computer facility located at the National Library of Medicine (NLM) in Bethesda, Maryland. These terminals are located at more than 430 locations throughout the United States and in nine foreign countries. Searches can be requested at any location and mailed within days.

CANCERLIT contains approximately 60,000 abstracts of published articles appearing in biomedical and scientific journals from 1963 to date. Beginning in January 1976, books, monographs, symposia, reports, etc. are also being screened for cancer-related articles to abstract for CANCERLIT. One ICRDB contractor (M.D. Anderson Hospital and Tumor Institute) screens these sources to identify documents related to cancer and another ICRDB contractor (the Franklin Institute) prepares abstracts from these documents. The CANCERLIT data base is updated monthly and is expected to grow at a rate of 20,000 abstracts per year.

The CANCERPROJ data base is comprised of summaries of ongoing cancer research projects submitted by scientists in many countries. This data base contains approximately 10,000 summaries with a projected increase to approximately 15,000. CANCERPROJ covers the most recent two or three years of federally and privately supported grants and contracts and is updated every three months. The project descriptions are collected and processed by the Current Cancer Research Projects Analysis Center (CCRESPAC) which is operated by the Smithsonian Science Information Exchange (SSIE) in Washington, D.C.

Cancer Information Dissemination and Analysis Center (CIDACS)

The ICRDB Program is implementing Cancer Information Dissemination and Analysis Centers in three broad areas of cancer research. These are staffed by scientists who have a thorough and detailed understanding of the subject areas covered by the particular CIDAC. The areas of cancer research covered by the three CIDACS are:

- Cancer detection, diagnosis, therapy, rehabilitation, and other clinical aspects;

- Chemical, environmental, and physical carcinogeneis (plus epidemiology);

- Cancer virology, immunology, and cancer biology.

The CIDACs will serve to stress the active dissemination of cancer research information to scientists and will act as reference and referral centers for investigators. As a result of CIDAC efforts, a steady stream of abstracts of recently published research literature (as contained in a new publication called *Cancergram*) in specific subject areas will automatically be sent to scientists working in those areas as part of a program for the Selective Dissemination of Information (SDI). Another publication (*Technical Bulletins*) containing an intensive compilation of the most significant abstracts on a specific topic will also be issued. Information for these bulletins will be obtained by computer searches of the data base by CIDAC subject specialists. CIDAC staff will not only provide quality control and determine the scope of information entered into CANCERLINE but also conduct on-line computer searches in response to requests for information. Additionally, each Center will develop methods for indexing, retrieving, and summarizing scientific information and findings. On a continuing basis, CIDACs will identify and implement new projects to promote exchange of technical information between cancer researchers on a worldwide basis.

Computer Support

A range of computer-related services is being provided to the ICRDB Program by the IIT Research Institute (IITRI), Chicago, Illinois. Reformating of machine-readable input from various sources for inclusion in CANCERLINE has been undertaken. IITRI also assists the CIDACs in providing current awareness services (*Cancergrams*), *Technical Bulletins*, specific retrospective searches, and other special products and services as needed for selected user groups.

Current Cancer Research Project Analysis Center (CCRESPAC)

An interagency agreement with the Smithsonian Science Information Exchange (SSIE) established this Center. CCRESPAC has collected and processed over 10,000 descriptions of ongoing cancer research projects. This information is available for online searching through the CANCERPROJ data base, as discussed above. Descriptions of 6600 research projects have been compiled into a six volume publication released in 1975. Compilations of abstracts of ongoing projects in a specific area of cancer research are being produced as *Special Listings*. During 1976, approximately 35-40 of the *Special Listings* were issued. The *Listings* are being distributed to contributing scientists currently working on each specific topic so they can easily identify and establish direct communications with other scientists working in the same area.

CCRESPAC also serves as a reference and referral center for researchers and provides quality control for entries in the CANCERPROJ data base.

Clearinghouse for Ongoing Work in Cancer Epidemiology

This is a cooperative project supported jointly by the ICRDB Program, the International Agency for Research on Cancer (IARC) in Lyon, France, and the German Cancer Research Center in Heidelberg, Germany. The Clearinghouse deals with detailed data on research related to cancer epidemiology and studies in human cancer causation in countries around the world. The Clearinghouse will provide lists of epidemiology researches and resources. The Clearinghouse also responds to technical questions and produces a series of publications and services. One such publication is an annual directory of ongoing cancer epidemiology research projects.

An International Registry of Tumor Immunotherapy

This project, supported by the ICRDB Program, has collected, analyzed, and disseminated listings containing more than 220 clinical tumor immunotherapy protocols. This registry is updated approximately three times per year and the information is distributed to investigators who have submitted descriptions of their clinical trials. Additionally, a fact sheet which provides a listing of protocols by title is periodically distributed to a larger audience of researchers working in the field of cancer. One of the primary purposes of the Tumor Immunotherapy Registry is to facilitate communication between clinicians and investigators conducting clinical trials.

Clinical Cancer Data Methods

Initial steps toward improving methods of handling clincal cancer data have been taken by the ICRDB Program. This includes organizing meetins between cancer centers in the USA to plan and implement a uniform system of collecting and reporting clincal information on cancer patients. A procurement has been initiated to establish a Statistical Analysis and Quality Control Center (SAQC). Comprehensive Cancer Centers in the United States will submit data to SAQC for inclusion in the Centralized Cancer Patient Data System (CCPDS).

An Improved Classification for Coding Histopathologic Cancer Data

In cooperation with the World Health Organization (WHO), the ICRDB Program is supporting the development of a revised coded nomenclature for neoplasms called the International Classification of Diseases for Oncology (ICD-O). This coding scheme is currently undergoing field trials in Europe, the Middle East, North America, South America and the USSR. The completed classification will be published by WHO in English, French, Russian and Spanish. The English language version was scheduled for issuance in late 1976. In the USA, the ICD-O will be utilized by the Comprehensive Cancer Centers in the Centralized Cancer Patient Data System (CCPDS).

SPECIAL INTERNATIONAL PROGRAMS

A Project to Promote International Collaboration Between Cancer Research Organizations

In cooperation with the International Union Against Cancer (UICC) in Geneva, support is provided for a Special Committee for International Collaborative Activities (CICA) within the framework of the UICC. The Executive Secretary and members of CICA are providing advisory, consultative, and liaison services to support the international activities of the United States National Cancer Program in general, and the ICRDB Program in particular. CICA aids in the collection of data about ongoing cancer research projects (including clinical protocols) from countries around the world. CICA personnel also identify and promote collaborative projects among cancer centers and cancer scientists in different countries. An International Directory of Specialized Cancer Research and Treatment Establishments was prepared for distribution in 1975.

International Scientist-to-Scientist Communication

The ICRDB Program, through the International Union Against Cancer (UICC) in Geneva, Switzerland, encourages international scientist-to-scientist communication. The two-part project is composed of the International Cancer Research Technology Transfer Program (ICRETT) and the International Cancer Research Workshop Program (ICREW).

Individual grants for short-term visits are awarded by ICRETT. These visits may be for the purpose of conducting brief research projects, collaborating with a fellow investigator, or traveling to present lectures and/or demonstrations on cancer research technology.

ICREW provides basic support for workshops in cancer research where scientists meet on an international basis. The aim is to increase the frequency, speed and efficiency of direct information exchange among small groups of cancer investigators. These researchers, although working in different countries, are all active in the same field of basic, clinical or behavioral research related to cancer.

ICRDB Publications and Services to Cancer Researchers in Developing Countries

The World Health Organization (WHO) Library in Geneva, Switzerland, will cooperate with the ICRDB in providing on-line searching of CANCERLINE, referral services, and ICRDB publications to cancer researchers in developing countries. WHO will assist in collecting cancer-related information from researchers in these countries for input to the ICRDB data bases.

A Center for Collection and Analysis of ICRDB-Related Data in Latin America

Coordinators from various Latin American countries met in Sao Paulo, Brazil in November, 1975 to establish a center for rapid screening of Latin American biomedical literature. The Pan American Health Organization (PAHO) is utilizing the services of its Regional Library of Medicine (BIREME) in Sao Paulo for this purpose. The participation of the Regional Library of Medicine will make it possible to secure and expedite the inclusion of Latin American literature in the CANCERLINE system.

PAHO is collecting data about ongoing cancer-related research projects in Latin America. To date, about 100 abstracts from seven countries have been completed.

PAHO is also editing the Spanish and Portuguese versions of the International Classification of Diseases for Oncology (ICD-O) and is conducting ICD-O field trials in Latin America.

Additionally, PAHO is acting as the focal point for updating the Latin American entries for the UICC directory of cancer centers and mechanisms are being established to disseminate ICRDB publications and information services to cancer researchers in Latin America.

An ICRDB-Sponsored Information Center in Japan

The development of an ICRDB-sponsored center in Japan has been initiated. This Center will coordinate the screening and collection of cancer-related information from Japan and neighboring countries for entry in the data bank. It will also include mechanisms for providing ICRDB publications and other information services to scientists working in the Far East.

Interrelationships Among Scientific Research Areas--A Step in Developing International Collaborative Programs

L.I. Borodkin, et al.

In dealing with various aspects of an international scientific collaborative program (program development, research preparation, organization of symposia, creation of information exchange systems, etc.), the first step is to determine the structure of the problem. By the word "structure" we mean identification of key areas of scientific research ("approaches" to a major research goal) and description of the interrelationships (interlinkage) among them. This structure should be detailed and at the same time comprehensive, for upon this basis a collaborative program is to be planned, its main services implemented and the operating principles of these services established.

The method of determining the primary element of a structure, by listing key approaches, is well known. It is based on accumulated scientific know-how in compiling classifiers and on a diverse repertory of already-existing classifiers [1,2].

At the same time, however, a standardized description of interrelationships among identified approaches has not yet been generally agreed upon and the descriptions traditionally presented are a state-of-the-art review. In this form, completeness and consistency are often wanting since authors' preferences can unconsciously distort the real situation.

The aim of this paper is to outline an objective method of describing interrelationships among scientific research areas--a method which would include only strict procedures for collecting and analyzing the necessary data and present the requisite description in a standardized form. It must present the description concisely in order to facilitate firsthand analysis.

As a standardized language for this proposed method, we shall use the language of graph theory. The universal nature of this language makes it possible not only to determine an existing system of interrelationships among scientific research areas but also to forecast the system's future development. From this point of view the proposed method may be compared to the systems analysis approach to science generally [3,4].

This paper consists of three sections. The first and second describe the method used and the last section an experiment showing the central position tumor immunology research holds among the main cancer research areas.

PROCEDURE FOR FORMING THE INITIAL GRAPH OF INFORMATION LINKS

This work was based on the list of main cancer research areas and subjects compiled by the Scientific Council for Cancer Research of the Presidium of the USSR Academy of Medical Sciences. This includes 13 areas (listed in the Appendix), each consisting of approximately 10 subareas (which we shall call subjects)--121 subjects in all.

We proposed to carry out the identification of interconnections among elements of the above list through structural analysis of a graph of citations in cancer literature. At this stage, cancer research specialists selected publications to serve as initial information for subsequent analysis--references in these publications to other publications yielded objective data regarding the structure under study [5].

The following method was used to form the graph of citations. At the Moscow Cancer Research Center, a panel of experts was organized consisting of one to three professionals for each of the 13 areas listed. Each of the 13 groups of experts was asked to select from the available cancer literature 10 of the most important, authoritative works from 1972-1974 dealing with each of its subjects and two or three such works from 1960-1971. Each group was asked to represent in their selection Soviet, American and other countries' authors in approximately equal proportions. The bibliography compiled in this way contained 1620 publications (including more than 120 monographs) representing the work of 4000 scientists from various countries.

Each of the selected publications was characterized by the following set of data:

- The "serial" number of the publication (from 1 to 1620);
- A number identifying the research area and subject to which the publication related;
- The author(s), title and source of the publication;
- A list of the serial numbers of those of the 1620 selected publications cited by the publication.

These data define the graph of citations G^o, the set of whose vertices corresponds to the set of 1620 selected publications; an arc on this graph directed from the ith to the jth vertex corresponds to a citing of the ith work by the jth work. (In this way, the direction of an arc corresponds to the information flow.) For our purposes, it is necessary to construct weighted graphs G' and G" assigning the flow rates for citations among publications on any pair of research subjects or research areas (see Figure 1). The elements of the adjacency matrix g^o_{ij} $(i,j = \overline{1,1000})$ are 1s if "i" cites "j", and zeros otherwise.

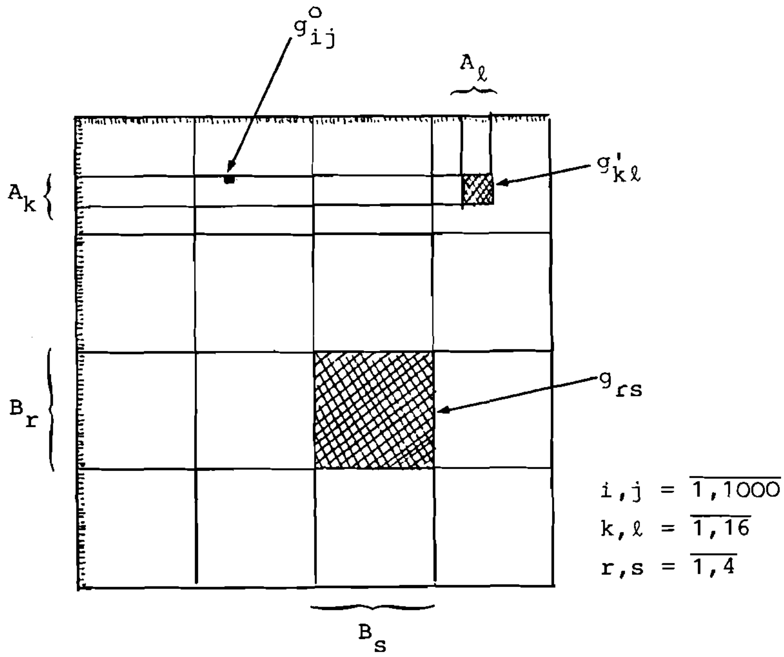


Figure 1. An example of a citation graph G^O, of, say, 1000 publications.

All the publications relate to 16 research areas, each subdivided into four research subjects. The graph G' with its matrix $\|g'_{k\ell}\|^{16}$ is such that weights $g'_{k\ell}$ are equal to the sum of 1s in the cell $A_k \times A_\ell$. The graph G" with its matrix $\|g''_{rs}\|^4$ is such that weights g''_{rs} are equal to the sum of 1s in the block $B_r \times B_s$.

Graphs G' and G" were constructed by computer. In this operation, each of the 1620 selected publications was represented in the array of initial data by its serial number, research area-subject index and the list of publications it cites.

The arc weight $g'_{k\ell}$ for the graph G' is defined as the total number of citations by publications on the kth subject from publications on the ℓth subject:

$$g'_{k\ell} = \sum_{\substack{i \in A_k \\ j \in A_\ell}} g^o_{ij} \quad , \qquad (k,\ell = \overline{1,21}) \quad ,$$

where g^{o}_{ij} determines the arcs of the graph G^{o}; $\{A_k\}$ is the set of serial numbers of publications related to the kth research subject and $k,\ell = \overline{1,121}$.

The weight of the arc g''_{rs} of graph G" is defined as the total number of citations by publications on the rth area from publications related to the sth area:

$$g''_{rs} = \sum_{\substack{k\in B_r\\ \ell\in B_s}} g'_{k\ell} = \sum_{\substack{k\in B_r\\ \ell\in B_s}} \sum_{\substack{i\in A_k\\ j\in A_\ell}} g^{o}_{ij} \quad , \qquad (r,s = \overline{1,13}) \quad ,$$

where $\{B_r\}$ is the set of research subject numbers that belong to the rth area and $r,s = \overline{1,13}$.

To study specifically the external links among the 13 cancer research areas listed, the diagonal elements g''_{ii} $(i = \overline{1,13})$ were disregarded. In order to establish "equality" among research areas, the matrix of arc weights of graph G" was standardized in one of two ways:

$$\hat{g}''_{ij} = \frac{g''_{ij}}{\sum_{\ell=1}^{n} g''_{i\ell}} \cdot 100 \quad . \qquad (1)$$

or

$$\hat{g}''_{ij} = \frac{g''_{ij}}{\sum_{\substack{\ell=1\\ \ell\neq i}}^{n} g''_{i\ell}} \cdot 100 \quad . \qquad (2)$$

After standardization, the element $\hat{g}''_{ij}$ becomes equal to the percentage obtained by comparing the number of citations by publications on the ith area from publications related to the jth area with the total number of all citations by publications on the ith area.

It should be noted that in standardization, Equation (2) disregards citations by publications on the ith area from publications related to the ith area.

PROCEDURE FOR AGGREGATING THE GRAPH OF INFORMATION LINKS

A suitable technique for solving the stated problem is the graph approximation method [6]. The aim of this method is to create a concise, aggregated description of the main interlinkage flow pattern among elements of the given system in the form of a small number, k_o, of blocks, i.e., lists which consist of these elements. The interlinkage structure among these lists is given by a "small" graph Γ with k_o vertices. Here the elements contained in the blocks are generally not just a regrouping of the initial set of system elements.

Let $||g_{ij}||^n$ be a matrix of links (i.e. interrelationships) among n research areas with numbers from the set $I = \{1,...,n\}$. (As such a matrix we may use, for example, the citation flow rate matrix G".) Let $R = \{R_1,...,R_{k_o}\}$ be the set of lists. To the set R corresponds the distribution of elements $i \in I$ for k_o lists $R_p (p = \overline{1,k_o})$. This distribution may also be set using a $(n \times k)$ binary matrix $\Phi = ||\phi_{ip}||$ such that

$$\phi_{ip} = \begin{cases} 1 , & i \in R_p , \\ 0 , & i \overline{\in} R_p , \end{cases}$$

where

$$i = \overline{1,n} \qquad \text{and} \qquad p = \overline{1,k_o} .$$

If the set of lists R and the graph Γ, which determines the structure of links among the lists, are given (graph Γ being represented by its adjacency matrix $||\gamma_{pq}||^{k_o}$), we can construct the approximating matrix (graph) $\tilde{G}$, using the aggregation technique described in [6]. For $i,j = \overline{1,n}$:

$$\tilde{g}_{ij} = \begin{cases} \dfrac{\sum\limits_{p,q=1}^{k_o} \phi_{ip}\phi_{jq}c_{pq}\gamma_{pq}}{\sum\limits_{p,q=1}^{k_o} \phi_{ip}\phi_{iq}\gamma_{pq}} , & \sum\limits_{p,q=1}^{k_o} \phi_{ip}\phi_{jq}\gamma_{pq} \neq 0 \\ 0 , & \sum\limits_{p,q=1}^{k_o} \phi_{ip}\phi_{jq}\gamma_{pq} = 0 \end{cases} \tag{3}$$

where C_{pq} is the average "linkage" magnitude of elements of list R_p to elements of list R_q, i.e.

$$C_{pq} = \frac{\sum_{i,j=1}^{n} g_{ij}\phi_{ip}\phi_{jq}}{\sum_{i=1}^{n} \phi_{ip} \sum_{j=1}^{n} \phi_{jq}} , \qquad p,q = \overline{1,k_o} . \tag{4}$$

The quality of approximation is evaluated here by the criterion:

$$\underline{I} = \sum_{i,j=1}^{n} (g_{ij} - \tilde{g}_{ij})^2 .$$

Algorithms for local optimization of this criterion are given in [7]. There it is also shown that the distribution of elements in the lists--a distribution corresponding to an extreme value of criterion $\underline{I}$--is such that linkages among the elements of any pair of lists joined by an arc of graph Γ, have a "uniform" magnitude which is close to the magnitude of the average linkage among elements form this pair of lists.

EXPERIMENTAL TRIAL OF THE PROPOSED METHOD

The method described above of revealing the main links among research areas was verified by analyzing the structure of information links among the main areas in cancer research. As initial data, the (13 × 13) matrix $\|g_{ij}\|^{13}$ of the graph G", i.e. arc weights of the citation graph G" (Figure 2) was used. How the graph G" was formed has been already described.

The fact that 55 percent of all links belonged to the diagonal elements may be seen as an indication of the "representative" nature of the initial data. This fact is in accord with the view that the research problems themselves are subsystems of closely interrelated subjects in a general system of information links.

At the same time (as may be seen from Figure 2), a substantial percentage of the total number of citations--about 45 percent--involves publications related to "external" areas. Thus by revealing basic flow patterns for citations among areas we can determine information links that play an essential role in the general system of cancer-related research.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	58	6	4	0	14	0	0	1	6	1	2	1	1
2	17	5	0	2	22	2	0	1	2	0	0	2	0
3	8	1	53	0	5	2	4	0	3	0	1	6	0
4	2	0	1	8	1	1	0	0	0	0	1	1	0
5	0	10	0	1	76	1	0	1	6	0	1	1	1
6	2	3	1	0	10	8	1	2	7	1	1	0	0
7	12	3	9	3	8	2	8	1	1	0	3	1	0
8	1	0	1	0	2	0	3	22	1	0	1	1	0
9	0	1	2	0	6	5	0	0	51	1	2	1	2
10	0	0	0	0	4	0	0	0	0	7	0	1	0
11	1	0	0	0	0	1	0	0	3	0	40	0	2
12	0	0	3	0	2	0	0	0	0	1	1	46	7
13	2	0	1	0	1	0	1	2	0	0	0	3	4

Figure 2. Arc weights of citation graph G".

The structure of matrix $\|g_{pq}\|^{13}$ was analyzed by means of the aggregation method already described. In this operation, the structure of graph Γ was not set a priori; instead, the complete graph was used:

$$\gamma_{pq} \equiv 1 \quad , \qquad p,q = \overline{1,k_o} \quad .$$

The initial matrix was standardized according to Equation (2). The number of blocks (lists), k_o, was set as equal to 3, i.e. $k_o = 3$. The results of the experiment are shown in Figure 3. The name of a block corresponds to the "idea" common to the areas incorporated within it. So the block "clinics and experiment" includes the areas: X-surgical treatment; IX-experimental and clinical chemotherapy; XI-radiobiology and radiation therapy; XIII-scientific principles in the organization of the fight against cancer; VIII-malignant tumor diagnostics; IV-radiation carcinogenesis; III-chemical carcinogenesis. The block "theoretical research" includes: I-biology and biochemistry of the cancer cell; II-viral carcinogenesis; III-chemical carcinogenesis; VI-mutual interrelationship of tumor and organism; XII-epidemiology and cancer statistics.

Figure 3 shows only those inter-block links the magnitude of which exceeds the threshold $C^0 = 10$. The numbers near the arrows represent the average "magnitude of linkage" of the areas of one block to the areas of another block. Thus, the number 18 above the arrow pointing from block B to block C means that on the average, 18 percent of all "external" citations in publications related to the areas included in the block "theoretical research" referred to publications on area V-tumor immunology; almost the same percentage referred to publications on area II-viral carcinogenesis. As is apparent from Figure 3, the macrostructure of the system of interrelationships (the "linkage system") of the research areas listed is described basically by three flow patterns for citations: citation of publications related to the block "theoretical research" by publications on the block "clinics and experiment", and citation by publications related to both these blocks from publications on areas V and II respectively.

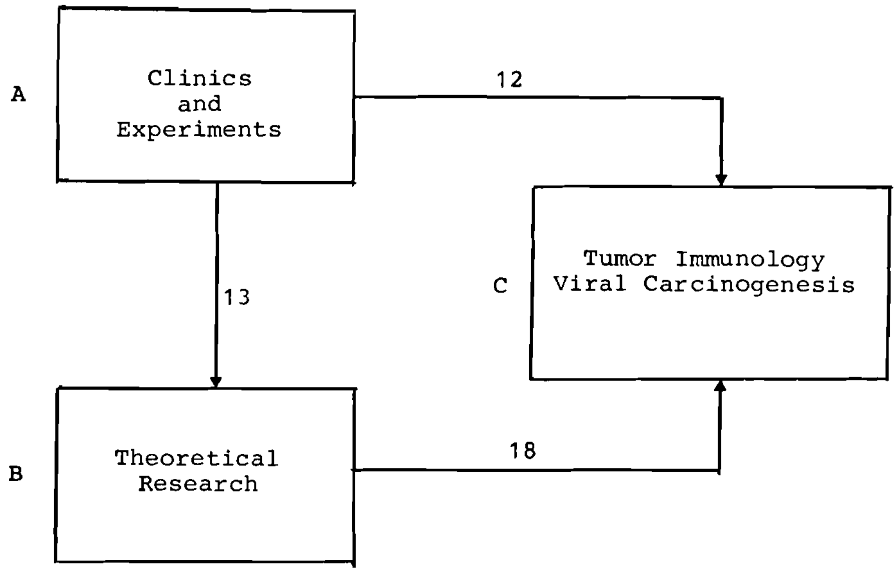


Figure 3. Macrostructure of a linkage system.

The validity of this conclusion may be checked by conducting an analogous analysis of the graphs of information interlinkage using other initial data, for example those compiled by direct expert assessment. Nevertheless, taking into account the present state-of-the-art in cancer research, the result obtained may be recognized as a basis for describing the structure of information links among the main research areas in this field of medical science.

In conclusion, we should note that the results of this experiment agree well with the classification scheme of the International Cancer Research Data Bank Program of the U.S. National Cancer Institute [8,9], which divides the areas of cancer research into three categories in somewhat the same manner.

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Appendix

List of the most important oncological research areas, compiled by the Scientific Council for Cancer Research of the Presidium of the USSR Academy of Medical Sciences:

I - Biology and biochemistry of the cancer cell;

II - Viral carcinogenesis;

III - Chemical carcinogenesis;

IV - Radiation carcinogenesis;

V - Tumor immunology;

VI - Mutual interrelationship of tumor and organism;

VII - Morphology of tumors;

VIII - Malignant tumor diagnostics;

IX - Experimental and clinical chemotherapy;

X - Surgical treatment;

XI - Radiobiology and radiation treatment;

XII - Epidemiology and cancer statistics;

XIII - Scientific principles in the organization of the fight against cancer.

Analysis of a Graph of Citations In Cancer Research Literature

L.I. Borodkin, I.B. Muchnik, and A.S. Raben

Publications [1,2] deal with the feasibility of developing an international long-term cancer research program.* The first stage in such a program should be the implementation of a cancer information service. In this service, an essential role is played by a system for the selective dissemination of information (S-SDI), the main function of which is purposive information exchange among program participants who work on closely related research problems. The data base of an S-SDI should regularly receive participants' research reports as well as abstracts and summaries of these reports. The system then regularly sends out bulletins appropriate to participants' area of research, containing the titles and abstracts of research reports that have been received. (On request, a participant may be sent the complete text of a report.) There are about 15 such bulletins, each assembling information from one of the basic research areas of the program and their contents may partly overlap.

To introduce this system for cancer research, it is proposed to use the list of the main cancer research areas compiled by the Scientific Council for Cancer Research of the Presidium of the USSR Academy of Medical Sciences. This list contains 13 research areas** each of which consists of about 10 subareas called "subjects"--121 research subjects in all.

An important stage in developing a S-SDI is the analysis of interrelationships and interconnections among elements of this list. The purpose of this analysis is to determine the degree of autonomy of research subjects within each of the 13 research areas. If research subjects within individual areas are strongly related to one another, while subjects from different areas are weakly interrelated, then a S-SDI can be based directly on the list. Otherwise, the problem arises of building up new blocks (lists) of research areas within each of which the data relevant to a particular informational profile must be circulated.

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*See also D.D. Venedictov, et al., *Development of a Long-Term Program for International Cooperation in Cancer Research*, in this volume.

**See L.I. Borodkin, et al., Appendix 1, in this volume.

One of the best indicators of the degree to which the elements of a list are interrelated is the frequency with which publications on particular subjects (or areas) are cited by publications on other subjects (or areas) [3]. If the main flow of citations from publications on a given research area is directed toward other publications in the same area, this affirms the "autonomy" of the area concerned and permits its use as one of the blocks in a S-SDI.

This paper presents a method for testing whether or not the above assumptions regarding the autonomy of scientific research areas are true. As initial data characterizing the extent to which research subjects (areas) are interrelated, it is proposed to use a graph of citations G^o. This graph indicates, for a set of 1620 publications selected by experts as representative of the given list of 13 research areas and 121 subjects, whether or not any of these publications have been cited by other publications of the same set. The method for forming this graph is described elsewhere in this volume,* along with a technique for compiling graph G' showing the flow rate for citations among research subjects (this graph, naturally, has 121 vertices) and graph G" showing the flow rate for citations among the 13 research areas. Borodkin, et al.* (Figure 2) show the (13 × 13) matrix $\| g''_{pq} \|^{13}$ of the arc weights of graph G".

Analysis of the degree of autonomy of respective research areas is done by compiling (on the basis of the graph of citations G^o) 13 new "independent" areas and comparing these with the given ones. Some preliminary conclusions regarding the degree of autonomy enjoyed by different areas may be drawn by analyzing the flow rates for citations among the areas as indicated by graph G". Even manual analysis of this matrix structure shows than in 10 of the 13 rows the maximal elements are the diagonal ones. Moreover, in nine, the diagonal elements are more than the sum of all the remaining elements of the corresponding row. Fifty-five percent of all the citations are connected with the 13 diagonal elements. This allows us to conclude that the main citation flows are among publications on the same areas and that the original list of 13 areas, in fact, identifies groups of research problems whose subjects are most interrelated with one another (in terms of citation rates).

Some of the areas of the original list, however (II-viral carcinogenesis, VI-mutual interrelationship of tumor and organism, VII-morphology of tumors), are distinctive in that their publications cite chiefly publications of the two areas, V-tumor immunology and I-biology and biochemistry of the cancer cell.

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*L.I. Borodkin, et al., in this volume.

The area citation graph G" is useful in analyzing the degree of autonomy of an area as a whole. However, subjects belonging to one and the same research area may substantially differ from one another in terms of their contribution to that area's autonomy, i.e. certain subjects represented by a comparatively large number of citations may in fact be characterized by their high degree of inter-linkage with other subjects of the same area, whereas other subjects in the same area represented by a small number of citations may have ties with subjects in some other area. This is why an area which is quite heterogeneous may at the same time be characterized as autonomous on the basis of graph G".

To deal with this peculiarity, we should analyze the subject citation shown in graph G'. Here an adequate technique for solving this problem is the graph approximation method [4]. However, taking into account the large dimensions--121 × 121--of graph G', it is necessary to employ a method for aggregating large linkage matrices [5], to reduce the number of computations. This method uses description of a graph approximation criterion [4] in the special case when a criterion optimization problem is solved by regrouping an initial set of elements.

In [5], it is proposed to use this representation of an approximation criterion also in the general case when an aggregation problem is solved by an arbitrary set of element blocks (or new areas) that does not, in general, appear to be a regrouping of the initial element set. Elements that have not been included by the optimization algorithm in any block (or new area) are included in a special block whose links with other blocks are "penalized". (In this "penalty" block should be incorporated "isolated" elements that are very weakly linked with all other elements.)

Thus the problem of linkage graph aggregation reduces to the problem of minimizing the criterion

$$J = \sum_{(p,q)\in\Gamma} C_{pq}^2 N_p N_q - \sum_{p=0}^{k_o} \alpha C_{op}^2 N_o N_p - \sum_{p=1}^{k_o} \alpha C_{po}^2 N_o N_p$$

where

k_o = number of blocks;

$\Gamma = \| \gamma_{pq} \|^{k_o}$ is the graph that assigns the aggregated link structure among k_o blocks;

N_p = number of elements in the pth block, $\overline{0,k_o}$;

C_{pq} = magnitude of average linkage from the elements of the pth block to the elements of the qth block;

α = penalty value;

the index "0" denotes variables which relate to the supplementary "penalty" block.

In the given case, the problem of aggregating the graph G' is tantamount to compiling 13 autonomous lists (blocks) of research subjects, i.e. the criterion being maximized is

$$J = \sum_{p=1}^{13} C_{pp}^2 N_p^2 - \alpha\sum_{p=0}^{13} C_{po} N_o N_p - \alpha\sum_{p=1}^{13} C_{op}^2 N_o N_p \quad .$$

Table 1 shows a distribution of subjects across 13 lists that corresponds to a local maximum of criterion J. The last row of the table contains those subjects that were not included in any of the 13 lists.

Table 2 contains data on which subjects from each of the original 13 areas are placed in each of the new 13 lists (new areas) compiled by the algorithm.*

As one can see in Table 2, for each area of the original list except XIII (scientific principles in the organization of the fight against cancer) the following holds true: never fewer than half the subjects in any area are included in any one of the 13 lists. This shows that the subjects are not scattered throughout the new lists, but are concentrated in such a way that the "kernel" of any one original area appears in one of the newly compiled 13 lists.

For instance, in list I (biology and biochemistry of the cancer cell) the "kernel" of the new list includes seven to the eight original subjects. In list V (tumor immunology) the "kernel" includes 9 of the 12 original subjects. List XII (epidemiology and cancer statistics) includes seven of the original eight, and so on. This fact is reflected by the way in which the "diagonal" stands out in Table 2.

In the majority of the new lists, the "kernels" are complemented by subjects intrinsically linked with them. For instance, in list V are included, in addition to the nine "kernel" subjects of the original area V (tumor immunology) three more elements from the original area II (viral carcinogenesis).

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*Research subjects in Tables 1 and 2 each have two indices--the serial number of the area (from the original list of 13) to which it belongs and its own subject number. For example, indices V.3 denote the third subject of the fifth area.

Table 1. Distribution of research subjects according to local maximum of criterion J.

Serial number of new autonomous groups (blocks).	List of subjects from original list enumerated here to indicate new autonomous groupings.	Total number of subjects in each autonomous group.
I	I.1; I.2; I.3; I.4; I.6; I.7; I.8; V.11.	8
II	II.2; II.4; II.6; II.7; II.10; IV.1; IV.5; VI.3; VI.7; VI.8; VII.5; VIII.7; VIII.12; IX.19; X.1; X.5; X.7; XI.9; XI.10; XIII.3; XIII.4; XIII.9.	22
III	III.2; III.3; III.4; III.6; III.7; III.8; III.9; III.10.	8
IV	IV.1; IV.3; IV.6; V.10.	4
V	V.1; V.2; V.3; V.4; V.5; V.7; V.8; V.9; V.11; II.5; II.8; II.9.	12
VI	VI.1; VI.4; VI.5; VI.6; III.5; IX.2; IX.5; IX.6; IX.8; XI.7.	10
VII	VII.1; VII.2; VII.4; VII.6; II.3; III.1; III.5; XI.1.	8
VIII	VIII.1; VIII.3; VIII.5; VIII.6; VIII.8; VIII.9.	6
IX	IX.1; IX.3; IX.4; IX.7; IX.9; IX.10; IX.11; IX.12; IX.13; VI.2.	10
X	X.2; X.3; X.4; X.5; XI.7; XI.9.	6
XI	XI.2; XI.3; XI.4; XI.6; XI.8; III.9.	6
XII	XII.1; XII.2; XII.3; XII.4; XII.5; XII.6; XII.7.	7
XIII	XIII.1; XIII.5; XIII.10; I.5; VIII.2; IX.2; IX.9; XI.9.	8
	II.1; IV.4; V.12; VII.3; VIII.4; VIII.9; VIII.10; X.6; XII.8; XIII.2; XIII.6; XIII.7; XIII.8.	13

Table 2. Distribution of subjects from original list among newly compiled autonomous groups.

Area serial number from original list / Serial numbers of newly compiled autonomous groups (blocks).	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	
I	7												1	
II		5			3		1							1
III			8			1	2				1			
IV		2		3										1
V	1			1	9									1
VI		3				4			1					
VII		1					4							1
VIII		2						6					1	3
IX		1				4			9				2	
X		3								4				1
XI		2				1	1			2	5			
XII												7		1
XIII		3											3	4

These elements are II.5 (the mechanisms of tumofacient viruses and cells on the molecular level), II.8 (viral defectiveness and carcinogenesis), and II.9 (the induction mechanism of carcinogenic viruses in the cell).

In list IX is included, in addition to nine "kernel" subjects from the original area IX (experimental and clinical chemotherapy), subject VI.2 (hormones and tumor growth).

In list I, in addition to the seven "kernel" elements from the original area I (biology and biochemistry of the cancer cell), subject V.11 (improving methods of tumor immunodiagnostics) is included.

In list IV, in addition to the "kernel" elements from the original area IV (radiation carcinogenesis), subject V.10 (interferon, interferonogenesis and carcinogenesis) also appears and so forth.

On the other hand, as can be seen from Table 1, nine of the 13 newly compiled lists draw more than one half of their subjects are from the corresponding original areas. For example, the newly compiled lists III, VIII and XIII consist of subjects related solely to corresponding original areas: III (chemical carcinogenesis), VIII (malignant tumor diagnostics), XII (epidemiology and cancer statistics). Furthermore, in list I, seven of its eight elements are from the original area I. In list IV also only one element does not come from the original area IV. In list V, nine of the 12 subjects relate to the original area V and so forth.

Note that of the four lists (II,VI,VII,XIII) where this does not obtain three contain a "kernel" of subjects from one of the original areas. These are the blocks II, VI and VII. List II includes half of subjects from the original area II, list VI--half of those from the original area VI, and list VIII--four of the six subjects from the original area VIII. It is significant that these same research areas--II, VI, VII--were singled out during an analysis of a matrix of arc weights of graph G". In this matrix, the diagonal elements of rows corresponding to II, VI, and VII were not maximal, in contrast to the diagonal elements of the matrix's other rows.

As one can see in Table 1, eight of the 121 research subjects are included in more than one list (block). According to [1,2]* these elements may be interpreted as "pivotal" research

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*See also D.D. Venedictov, et al., *Development of a Long-Term Program for International Cooperation in Cancer Research*, in this volume.

tasks that provide for the transfer of information from one block of subjects to another. These are:

- III.5 Endogenic carcinogens;
- III.9 Transplacental blastomogenesis;
- V.11 Improving methods of tumor immunodiagnostics;
- IX.2 The synthesis of more effective analogues of known antitumor preparations;
- IX.9 Methodological aspects of clinical cancer chemotherapy;
- X.5 Surgical methods in the comprehensive treatment of cancer;
- XI.7 Pre-radiation preparation of oncological patients (topometry, syntopy, etc.);
- XI.9 The computer in radiation cancer therapy.

To sum up this short comparison of the newly compiled lists of autonomous blocks with the original 13 research areas, we note that nine of the 13 blocks have the following two properties:

- In each case, over half their respective subjects relate to the same original area;
- Each of these blocks may be identified with one of the original areas--one which has not less than half its subjects (the "kernel") in the corresponding block.

On the basis of these features, these nine original areas may be considered autonomous.

It is not so easy to interpret the content of the remaining areas: II (viral carcinogenesis), VI (mutual interrelationship of tumor and organism), VII (morphology of tumors), XIII (scientific principles in the organization of the fight agains cancer). Available data do not allow us to infer the autonomy of these four areas.

In conclusion, we may consider assumptions concerning the autonomy of research areas as having been confirmed. This is true for 9 out of 13 of the research areas on the basis of the citation flow pattern for the elements listed.

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The Work of the International Information Office on Controlled Therapeutic Trials in Cancer

R. Flamant, C. Fohanno, and H. Sancho

In 1967, at its first meeting, the Committee on Controlled Therapeutic Trials established by the International Union Against Cancer (UICC) headed by Professor Denoix, decided to create an international information office on controlled therapeutic trials in cancer.

In fact, because of the work, the time, and the cost involved in such trials and because of their important consequences, it seemed necessary to create a data bank where trials in progress, or terminated but still unpublished, would be registered.

The Information Office has steadily developed since 1968 when it actually became operative. It has recently been decided that it should now develop on an independent basis, while maintaining very close relations with the Committee on Controlled Therapeutic Trials.

A detailed description of the way the Information Office works can be found in the latest technical report prepared by the Committee on Controlled Therapeutic Trials [1].

Data on current, or terminated, but still unpublished, trials are collected by the Central Office which is located at Villejuif (France). The Central Office is supported in this task by a network of 35 corresponding members from all over the world. Every new trial brought to the notice of the Information Office is reviewed from a methodological point of view by a physician with a good knowledge of statistics. Following this, the trials are recorded and filed in a central card index.

Once a year the central office writes to those responsible for the registered trials concerning the status of their trials, i.e., in progress, abandoned, completed, terminated, published. Table 1 gives a summary of the work of the Information Office.

Several uses are made of the collected data:

- Any physician planning to start a controlled therapeutic trial in cancer may apply to the Information Office for information on trials on similar or related subjects. He may also refer to the lists of trials which are regularly published. In these lists the trials are classified according to sites, and within these headings,

Table 1. UICC Information Office: the collection, registration and utilization of information.

Collection	Registration	Utilization
1. Initial data	a. Review of the trial	1. Distribution
	b. Registration of the trial in the central card index	2. Cooperation
2. Follow-up of registered trials	a. Review of publications	3. Methodology
	b. Inclusion of a summary of publication in the file of the trial concerned	4. Strategy
		5. Impact

according to treatments to be compared. In addition, the names and addresses of those responsible for the trials listed are also published.

- Exchange of information may facilitate contacts between individuals working in the same field of cancer research.

- Physicians may apply to the Information Office with regard to special methodological problems.

The problems encountered in the registered trials constitute valuable material for the Committee on Controlled Therapeutic Trials, whose main task is to endeavor to improve trial methodology.

From 1967 to 1974, the Information Office registered 672 trials. The analysis of registered trials according to sites (Table 2) and to countries (Table 3) gives interesting information as to general policy on therapeutic research in cancer.

Table 2. Breakdown of 491 registered trials according to sites.

Status of the central card index of the
Information Office on
Controlled Therapeutic Trials in Cancer (UICC)

Site	Percentage
Head and neck	6
Lung	12
Digestive system	9
Gynecology	6
Urological sites	6
Breast	15
Skin	4
Leukemias & Haematosarcomas	33
Bones & soft tissues	2
Neurology	3
Miscellaneous	4

Table 3. Breakdown of 491 registered trials according to countries.

Staus of the central card index of the
Information Office on
Controlled Therapeutic Trials in Cancer (UICC)

Country	Percentage
Africa:	4
America:	
Canada	3
USA	44
Others (less than 10 trials/country)	1
Multinational	1
Asia:	
Japan	7
Europe:	
Czechoslovakia	2
France	6
Great Britain	9
Norway	2
Poland	2
Switzerland	2
USSR	3
Others (less than 10 trials/country)	7
Multinational (EORTC)	5
Oceania:	1
International (WHO)	1

The data made available to the Information Office is useful to the Committee on Controlled Therapeutic Trials in fulfilling its task of assessing the role played by controlled therapeutic trials in the progress of cancer therapy. Tables 4 and 5 show the way the information can be analyzed: it would seem to be particularly important, for example, to assess negative or uncertain results, mean number of patients included in trials, mean duration of trials, etc. All these data enable us to judge the impact of clinical trials in cancer therapy.

In the future, the Information Office proposes to improve the procedures used so far. In particular, it intends:

- To obtain wider collaboration in the collection of information;
- To computerize the procedure used hitherto for the classification, storage and review of information;
- To improve the distribution of the registered information.

From now on, and provided it is granted permission to do so by those responsible for the trials brought to its notice, the Information Office shall supply the International Cancer Research Data Bank Program at the National Cancer Institute of the USA with data on these trials. The data will be entered into an online data base system called CANCERLINE. On the other hand, the Information Office, besides the lists of trials it publishes regularly, plans to institute and operate a system of selective dissemination of information about trials relating to certain specific sites or types of treatments.

Table 4. Classification of the results of 47 trials registered at the Information Office which have been published.

I.	Method(s) on study at least partly better than control method(s)	11
II.	Method(s) on study inferior to control method(s)	4
III.	No differences between method(s) on study and control method(s)	21
IV.	Uncertain conclusions	11
		47

Table 5. Number of patients included and duration of trials: (analysis of 47 publications reviewed by December 1975).

	Mean duration of inclusion of patients (16 publications)	Mean number of patients included at time of analysis (45 publications)	Mean interval separating beginning of trial and analysis (11 publications)	Mean interval separating beginning of trial and publications (26 publications)
I. Method on study at least partly better than control method(s) (11 publications)	30 months	176	29 months	68 months
II. Method on study inferior to the control method(s) (4 publications)	34 months	199	16 months	61 months
III. No difference between methods (21 publications)	50 months	252	53 months	74.5 months
IV. Uncertain and complex conclusions (11 publications)	60 months	323	18 months	65 months
General mean	46 months	246	37 months	70 months

Created eight years ago and limited to a precise, scientific area, this Information Office appears to be a model achievement in the field of information and international cooperation relating to on-going research.

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Problems of Developing an International Automated Information System for Oncology

A.I. Kitov

The problem of cancer is one of the most acute in modern medicine and an efficient coordination of the efforts of scientists in different countries is required for its solution. A first step in this direction might be the development of an international automated information system for oncology that would make it possible to systematize, store and process experimental and clinical data relating to the diagnosis and treatment of malignant tumors and to bring such information rapidly to the attention of scientists and practitioners in different countries. Access to a very great deal of information of this kind would have the effect of a chain reaction, bringing about deep qualitative changes in the conception of cancer and in fundamental discoveries, which in any case never occur in an information vacuum.

THE MAIN PURPOSES OF DEVELOPING AN AUTOMATED INFORMATION SYSTEM FOR CANCER

An important aim is to provide all research workers and practitioners in the field with rapid and practical means of access to present and future scientific and chemical data on oncology. This will be achieved in the following ways:

1. The time lag between new data being received and becoming generally available will be considerably reduced. At present, data become available through the publication of articles and the shortest time lag is six months. As the Information-Retrieval System (IRS) develops, they will be available for practical use from the time they are received.

2. New data input and previously stored data will become equally accessible to all the scientific and medical institutions participating in the system, irrespective of the distance of these institutions from each other and from information centers.

3. In the course of input, data will be systematized and compared with previously stored information by automatic or semiautomatic means. It will be stored in the computer memory in a form suitable for subsequent generalized output and analysis. During this process, all relevant data, irrespective of the date or source of information, will be brought together and supplemented with critical or general comments and references to

information on related problems. Periodically, (once a year or as necessary) the accumulated data will be revised and replaced by generalized data, previously stored information being transferred into the file for long-term storage.

4. The language barrier to the exchange of scientific and clinical results between scientists and doctors in different countries will be eliminated. The data input and output would be in the form of standardized phrases with precisely established sense relationships and syntactic structures. Automatic indexing and classification of data are quite feasible. Relevent algorithms already exist. Multilingual terminological machine dictionaries (thesaurus) for oncology can be compiled in parallel with the introduction of documentation. Compilation of this type of dictionary will also promote uniform oncological terminology--an important achievement in itself.

A second aim is to record objectively and completely the contributions of every person or institution to the solution of scientific and practical problems in oncology. All new input data must be accompanied by information on the input date and the author (person or institution). Data will always be stored and provided on request together with this information. Generalized data, obtained by analyzing the initial input data, will be introduced into the system as new data, together with information about the person responsible for the generalization and critical comment. After the introduction of data into the system and at the author's request, the system can automatically print a "receipt" or copy of this input data showing the input date and a single system inventory number. If comments (appreciation, refutation and comparisons) are received relating to the data, the system will forward them to the author. In addition, the system will print periodically (e.g., once a year) summaries or bulletins of new data giving their authorship and an appraisal of their validity, novelty, etc.

Third, automatic analysis and generalization of accumulated data should be carried out. Since all the data will be stored in the computer memory in systematized and standardized form (by coded phrases, tables, diagrams and other means), it will be possible to analyze and generalize this data automatically using statistical, logical and pattern recognition methods, automatic classification and so on.

A fourth aim is to ensure the continuous development, renewal and specification of the oncological information system, i.e. that the system will remain active regardless of the changing generations of scientists, doctors and others who create and use its information.

The main prerequisite for automating the accumulation, analysis and generalization of factographic information on oncology (and on medicine in general) is to introduce it into the computer memory in a standardized form, i.e. in the form of phrases of fixed structure and lexicon. The process of recording scientific information in such a form will probably be carried out, as a rule, by specialists.

The program of the International Cancer Research Data Bank (ICRDB) for the organization of an international data bank for oncological research, that is being developed by the National Cancer Institute of the USA, is of great interest in the development of an international oncological information system. The ICRDB program involves recording short reports on the subjects, methods and results of work in the field of oncology with details of its date and location.

However, this system is being developed as an information-inquiry system; it does not involve the use of any standardized language to record factographic information and this would limit its use in the automatic systematization, analysis and generalization of data. But, in view of the scale on which work on cancer is being undertaken throughout the world and of the complex and lasting nature of the problem, it is worthwhile to start from the principle of standardizing factographical medical information as a basis on which to develop an international cancer information system in order to make automatic analysis and generalization possible.

In developing the system, it will be essential to make use of the considerable experience acquired by the Sabir-C specialized bibliographical cancer information system, developed under the direction of M. Wolff-Terroine (France) and G. Wagner (Federal Republic of Germany), which has for a number of years supplied scientists in western European countries with oncological information.* The results of analysis of the distribution of the literature over various topics, and data about frequency of use of descriptors, published by the authors of this system, are of great interest.

The experience of general purpose medical bibliographical information systems, such as MEDLARS, EXERPTA MEDICA and others, is also of interest.

However, bibliographical systems cannot provide an effective answer to the problems of accumulation and exchange of oncological information outlined above. For this purpose, it is necessary to have a new type of information system that combines the features of the bibliographical and factographical systems.

In medicine, a semantics for diagnoses, medical comments, prescriptions, and so on have been developed over the years and are still evolving. The most widely used systems are the international classification of diseases, traumas and causes of death

*For details see G. Wagner in this volume.

and the American Systematized Nomenclature of Pathology (SNOP), which is designed for the storage and retrieval of clinical information. The work on an automatic medical diagnosis indexing system carried out by A. Pratt in the American National Health Institue is worth attention.

The language used in the IRS at the Central Institute of Medical Information of the USSR Ministry of Health may serve as an example of a formal language which is designed to record search patterns for medical documents. This language includes the lexicon (terminology) for a particular branch of knowledge and a set of eight sense relations (definition, objective, negative, prescription or purpose, causal-temporal relationship, conjunction, disjunction, use of conditions or factors). All the words in this language are used in only three grammatical forms: the nominative case and genitive case singular, and an abbreviated adjective form. The language makes it possible to represent the search patterns of documents in phrases constructed with the use of the three types of word-forms and the eight sense relations. Experience of indexing documentation in medicine and biology with the help of this language has shown that it is efficient for bibliographical IRS. But the powers of expression of this and other known languages are not adequate for automatic factographical medical information systems (AFMIS).

AFMIS systems must make it possible to accumulate, systematize, generalize and retrieve the original data in different branches of medicine. Such systems are required to handle the tremendous amount of investigations, observations and publications in the field of oncology to meet the needs of the great number of bodies of specialists, individual scientists and practitioners who are interested in the efficient exchange of medical information.

In view of the international character of the new system it will be necessary to use a multilingual input and output of information with a common (intermediary) information language. Information in the computer memory must be stored, not in any specific natural language, (even if it is a formal language), but in a machine information language which includes codes of notions (descriptors) and codes of syntactical and semantic relations. IRS of the STAIRS type is not suitable for the new system because it represents data in a natural language (English). However, it is not only because they use a natural language that such IRSs are unsuitable, but primarily because they are not intended to record scientific, experimental and clinical data in a succinct, standardized and accurate form suitable for machine analysis and generalization.

To sum up, it is necessary to distinguish two types of language: standardized input-output languages based on several natural languages and a single machine (intermediary) information language. The system must include a bibliographical subsystem and a number of specialized factographical subsystems which conform to the main input information flows and information user classes. For example, one of the main input flows will be clinical data on the results of treatment classified according to site and method of treatment particularly, information on testing new preparations and methods of treatment. Another important flow of clinical data will be diagnostics and causation of malignant tumors. A separate flow will cover experimental data of investigations on cancer etiology, pathogenesis in animals, etc.

DEVELOPMENT OF STANDARDIZED LANGUAGE FOR MEDICAL INFORMATION

The main problem in the development of an international oncological information system is developing a uniform language of standardized medical descriptions which covers the systems of standardized input and output languages (Russian, English, German and others) and a single machine information language (MIL).

There are two objectives in developing such a language:

- Machine representation of medical information in a form suitable for automatic systematization, analysis, retrieval and generalization;

- Translation from each input language into each of the output languages. The general problem of the machine translation of texts written in natural languages has been under study for over 20 years and so far no satisfactory solution has been found. It is therefore inappropriate to raise the question of using the medical vocabulary of natural languages as input and output languages in the AFMIS.

It will be necessary to develop a system of standardized input and output languages which it would be possible, by means of modern machine linguistics, to translate accurately into one completely formal machine information language (MIL). These input-output languages must, as far as possible, be akin to the medical vocabularies of natural languages in order to facilitate their practical assimilation by broad circles of medical, scientific and practical workers.

Common principles in developing these languages must be: uniformity and more precise definition of terminology, uniformity of standard medical records, uniformity of sentence structure and prepositional usage, uniformity of units of measurement and criteria of evaluation of different situations, etc. Undoubtedly, the solution of these problems will take a long time. In developing factographical IRS designed for the retrieval of original reference data concerning the topics and results of scientific research work and their automatic analysis and generalization, methods of manual and automatic analysis must be harmonized with the indexation of input information (description of case reports, subjects of scientific research papers, medical publications).

Specialist indexers must write these descriptions in the standardized scientific vocabulary of natural languages to present accurately and completely the main concept of the documents (reports, subject cards, etc.). Automatic indexation must then ensure accurate translation of these descriptions into the single machine information language (MIL).

To make the system usable on a world scale, it is necessary to employ an agreed thesaurus to translate the terms of the input language or languages into an input language of the NORMIN type thus enabling automatic syntactical and semantic analysis of texts.

In addition to common generic-specific and context-free relationships in the thesaurus, each term must have the characteristics of two semantic categories: specific medical categories (diagnostics, treatment, prophylaxis, etiology, morphology, medicament, etc.) and common categories (substance, process, energy, information, measure, location, time). The thesaurus must be composed of four parts: a dictionary of word-stems, a dictionary of concepts (steady word combinations), a dictionary of general affixes and endings and a dictionary of specific medical affixes. The most important principle of a standardized language for medical documents is an accurate classification of propositions, cases and functional link-words according to meaning. Time will make it possible to use efficient algorithms for the semantic and syntactical analysis of standardized sentences.

Multifaceted Classification of Medical Scientific Research: Concept of Systems Approach

A.S. Kiselev, A.B. Petrovsky, and B.J. Pimenov

System analysis is now widely used in different branches of scientific and practical activities: it uses the achievements of a number of disciplines and is gradually becoming one of the main methodologies to solve problems or organizational control.

The most important problems are those of developing long-term scientific research programs in the important areas of modern medicine that constitute a promising form of international cooperation.

Problems arising at different stages in preliminary study and implementation include evaluation of the future prospects of a number of scientific trends and subjects, coordination of investigations in the light of their interrelationship and extent of their influence upon the attainment of the objective and a prompt application of important results by all the participants in the program. Such problems are so complex and multifaceted that they do not permit of a simple solution but call for ingenuity and resourcefulness on the part of the program designers and the possibility of a wide choice in methods of attack.

In this respect, an interesting approach to the development of a long-term international program in the field of oncology would be the system of selective dissemination of information by groups of "interconnected subjects".

In the opinion of its designers, such a system ensures a rapid exchange of information among all the participants of the program, a greater specialization of information and a rapid assessment of the results of experiments.

The successful functioning and development of any information system depends greatly on the appropriateness of its technological structure and underlying concept. The tool of such systems is data classification.

The present paper suggests one of the possible logic approaches to the construction of a medical research classification, based on systems analysis of medical science as a separate branch of new knowledge. Such an approach may be suitable for program development not only in oncology but also in other areas of medicine and public health.

The widely used classification systems of medical science are based on the traditional division of medicine according to the main disciplines. This approach has justified itself in the bibliographical systematization of publications and is used in the well-known MEDLAR System, but it is of little use in coordinating research activities linked by the general nature of the problems under study but differing in behavior "technology". Medical research classification must be primarily problem-oriented for the purpose of effectively coordinating the program. Formulation of a scientific problem must be expressed in terms of its purpose.

Furthermore, such a classification must be suitable for the quantitative and qualitative analysis of the processes of medical research development including an assessment of the nature and value of the contributions of program participants, their ability to develop their subjects effectively, an estimate of the funds necessary to fulfill the program and so on. The classification must therefore cover different aspects of research activities. At the same time, it must be sufficiently detailed to reflect as comprehensively as possible the contents of specific subjects.

At present, medicine covers such a wide range of activities that the objective can be attained only by means of a well-organized information system enabling program participants to make their contributions where they will be most effective and to avoid irrational waste of money and efforts. The development and effective functioning of an information exchange system is possible only on the basis of modern computer facilities. Therefore, medical research classifications must be usable in man-computer information systems, easy to·apply and offering their users considerable possibilities of retrieval of the many aspects which interest them.

These requirements are met by the systems approach which we suggest for the construction of a classifier for medical research based on the following principles:

- Multiaspect feature: the classification is based on a number of independent features inherent in medicine as a separate branch of science;

- Polystructural feature: different types of classification structures (additive, hierarchic, multiplex) are used as functional components of the classifier.

The first step is the selection of common classification categories which are defined by specificity in medical research and by the character of the problems under study.

The special characteristic of medical science and its social importance lies in its tendency to deal with problems connected with the preservation and improvement of the health of individuals and of society as a whole. Medical science comprehensively investigates the living activity of human beings in interaction with their environments in order to reveal the causes and mechanisms of diseases, to find the best methods of detection and treatment and to develop effective preventive and other measures. At the same time, like any other science, medicine has internal aims connected with its own development needs.

Scientific cognition of the evolution of the organic world and the development of various forms of life offers a wide range of objects of research in medicine, from molecular and subcellular structures, research on which will uncover the essence of living matter, to social-economic systems which influence the viability of a human being and of human populations.

The specific feature of medical science is its multiprofile and complex character. As one of the natural sciences, medicine uses widely both methods peculiar to itself and those applied in other fundamental sciences, primarily biology, physics and chemistry. Mathematical, cybernetic and economic methods are becoming increasingly important.

Simultaneously, for practical tasks relating to the coordination of medical scientific research we need information particularly about the nature of research being carried out, the participation of scientific research organizations in the development of certain scientific problems and the resources (manpower, material, technical and financial) available in relevant scientific fields. Thus the classification of research on the basis of management and resources is of obvious importance.

By presenting medical scientific research as a single complex system, it is possible to distinguish the following main classification concepts:

- General aim of research,
- Functional status of the object of research,
- Structural level of the object of research,
- Character of research,
- Methods and means of research, and
- Factographical information.

It would appear useful to divide each class of notions in the classifier into a small number of hierarchic levels. This ensures the "visibility" of the classifier and makes it comparatively easy and fairly rapid to screen research work and disseminate information.

At the present conference, there has been considerable discussion about the advantages and disadvantages of information systems with retrieval of documentary or factographical information. The strong and weak points of different systems are dictated by the purpose they were intended to serve. In our multiaspect classification we have attempted to combine the advantages of all the approaches discussed.

An Information System to Assist in the Selection Of Pharmacological Substances

L.M. Zakharova and A.M. Petrovsky

The amount of information used by a physician in treating an individual patient is rapidly increasing. This is typical, especially, of pharmacotherapy today. Modern complex pharmacotherapy of patients requires that account should be taken of a great number of indications, contraindications and drug compatibilities. The complexity of this process is even greater in geriatric practice, in cases of multiple pathology in the same patient, of individual intolerance to particular substances or of a history of using "habitual groups" of drugs (for instance, the continual use of antidiabetic drugs). In addition, the drugs available constantly increase in number as knowledge of pharmacotherapy grows. All this calls for the prompt application of complex pharmacological information in complicated clinical cases. To solve this problem an information system named "Consultant" has been worked out.*

The main outlines of the system are as follows: each drug in a well-defined list is assigned a list of conditions** for which it is indicated or contraindicated. The results are summarized in a drug-condition matrix (L - C), where the rows correspond to the list of drugs, while the columns correspond to the list of conditions. The intersection of a column and a row gives the evaluation of the effect of the drug on the condition concerned. An evaluation of +1 means that the drug is indicated; an evaluation of -1, that it is contraindicated; absence of effect or absence of data regarding the effect is marked 0. Figure 1 shows part of the L - C matrix.

In making up the list of conditions account was taken of their intensity (severe, medium or mild) and in some cases--of their duration (stable or transient). This was done because of differences in the preparation recommended for such variations. Ultimately a Classificator of conditions for pharmacotherapy was compiled which included 900 items. The greater part of the

*Dr. V.I. Shtabtsov from the Soviet Union took part in working out the system.

**The list includes nosological forms, syndromes and symptoms, i.e., the clinical classification elements, regarded as separate units in pharmacotherapy. In the context, the word "condition" implies all varieties of the clinical terms.

DRUG CONDITION	INSOMNIA	ASTHENIC CONDITION	VEGETATIVE DYSTONIA
MERAZIN	+1	0	+1
COFEIN	-1	0	0
PHENAMINE	-1	+1	0
EUPHILLINE	0	0	-1
GERONTABOL	+1	+1	0

Figure 1. Part of the drug-condition (L - C) matrix.

Classificator is devoted to clinical disciplines like neuropathology and psychiatry, cardiovascular, gastrointestinal, endocrinological, kidney and urinary tract diseases and infections and fungus diseases.

The difficulties experienced in compiling the Classificator resulted primarily from lack of a standardized classification of symptoms for pathological conditions and from insufficiently precise recommendations on drug usage in the reference literature.

In making up a list of preparation for the L - C matrix, the authors analyzed the available sources of information containing more than 3000 entries of drugs produced in the USSR and abroad. Priority was given to the most frequently used drugs. Identical drugs and those similar in composition and effect were defined under the same item. The list contains 850 entries.

The size of the L - C matrix was thus 850 × 900. The data were processed to provide a program that prints a list of drugs each of which produces an effect on at least one of the conditions manifested by a particular patient. The form of printout is determined by the user. It is convenient to have the list of drugs with an indication of the group to which each belongs and a de scription of the type of effect it will have on each of the patient's conditions. (A section of the matrix is printed as shown in Figure 1). Within each group, the drugs can be arranged according to the number of indications and contraindications; attention may be drawn to those drugs for which the number of contraindications exceeds the number of indications and it has been found useful to point out which drugs out of those indicated are incompatible.

Information on incompatible drugs should naturally be collected and fed into the computer memory in advance.

The Consultant system was tested in a number of clinical institutions in Moscow and was highly praised by the clinicians.

It appears that in complicated and urgent clinical situations where it is difficult to analyze every symptom with due regard for all indications and contraindications, the assistance rendered by the information system will be timely.

The Role of the IIASA Computer Network in Establishing an International Information System to Coordinate Cancer Research

A.V. Butrimenko and V.G. Dashko

In principle, the extensive and increasing use of computers by national health care organizations and medical research institutes makes it feasible to establish an international information system to coordinate cancer research under the auspices of the World Health Organization. International institutes, established by WHO, also have computer centers.

The modern use of computers shows that the maximum effect of computerization is achieved only if individual computer centers are combined into a network of computers which carry out an exchange of information between widely separated locations. This is achieved by establishing a computer system combining the specialized functions of large computers and the simpler configuration of individual computers. The organization of maintenance on a network basis makes it possible for an individual institution to eliminate the costs of maintaining its own computer, maintenance personnel and system programmers. When an organization includes its computer in a network, there is a redistribution of its load and more efficient utilization of available resources. This is the reason for the growing popularity of computer networks.

The communication network linking the computers is effected by specialized minicomputers or programming communication processors which have standard software and are simple to maintan and therefore inexpensive and reliable.

Computer networks enable us to establish centralized data banks and program libraries. This both eliminates the costs of duplicating program data and provides the prerequisites for establishing regional, national and global information systems.

The following services are already available in the existing computer networks:

- Solution of problems in multiprogramming and time-sharing modes;
- Access to information systems in the "request-reply" mode;
- Organization of conferences and communication exchanges with colleagues in other organizations;

- Accumulation and distribution of textual information between individual computer centers;
- Facsimile transmission of images and graphic information;
- Establishment of personal files and local data bases.

A IIASA project is directed toward the development of an international computer network for scientific research. It is assumed that each country (each national organization) would install a specialized minicomputer to operate as an international communication node in the IIASA computer network and to control access to the national computer network. Computers would be linked to the national computer network or directly to the international communication network by specialists in the country concerned.

Inter alia, the following functions are assigned to the international communication node:

- Transformation of the initial information to the form convenient for transmission in the international IIASA computer network; transmission and reception of information;
- Opening of files for transmitted and received information; assessment of use of computation resources of the network;
- Check on permission to transmit information in accordance with the regulations of each national computer network.

Data in the IIASA network will be transmitted both through leased and through normal lines of the international telephone communications network.

However, IIASA is conducting research into developing its own data bank.

An important feature of the IIASA computer network is the requirement that it must ensure the possibility of communications between computer centers in socialist and market economy countries.

In view of the universal character of cancer research, it is natural to assume that each country will want to have its own data bank on this problem and will centralize international cooperation by regulating scientific contacts and information exchange.

The experience of advanced laboratories that make active use of computers in research demonstrates that scientists and leaders of scientific teams need local information systems which include the preparation and editing of texts, compilation of work files and catalogs and the storage of their own data and programs. It is also necessary to be able to process graphic information and communicate with other specialists.

Communication between local information systems and the national data bank by means of a computer network will make it possible to retrieve and distribute information through a direct link with the users.

By using the services of the IIASA computer network, it will be possible to accelerate data exchanges between the international center (WHO) and any national organization and to organize operational interaction between the international data bank and the banks of individual countries.

Thus, the projected IIASA computer network can be used to develop the international information system for the coordination of cancer research (IISCCR). Moreover, the special requirements of IISCCR could be taken into account in developing the IIASA network. From the standpoint of collecting and distributing information, IISCCR will be a distributed multilevel information system. Work on establishing IISCCR could be started simultaneously by WHO and the national organizations concerned.

In the light of the foregoing arguments, it seems expedient that the IIASA project participate in developing IISCCR.

Simulation Methods in Cancer Research And the Organization of Health Care

I.N. Vorontsov, M.M. Greshilov, and A.M. Petrovsky

Fundamental research on the biochemical mechanism of a cell and physiological processes on the level of organism systems and on the interaction between an organism and its environment determines the development and use of methods of diagnostics, and treatment as well as research on epidemiology. These, in their turn, shape the whole complex of research connected with the organization of health care: dynamics of morbidity among different population groups, training of personnel, detection of sick individuals, medical and preventive measures.

The main indicator of a population's health is the dynamics of morbidity: these depend on the organization of health care, itself a complex of social and economic arrangements.

The interrelation of the main indicator of a population's health with fundamental research is determined both by a complicated set of biological phenomena and by organizational and technical measures.

IMPROVING THE RESULTS OF RESEARCH WORK AND THE ORGANIZATION OF HEALTH CARE

The following measures are required:

- Create highly efficient methods of synthesizing adequate descriptions for models of processes occurring in the organism (biochemical reactions, cell metabolism, interaction between cells and viruses, interaction between the tumor and the organism), of interaction between the organism and the environment, of epidemiological phenomena and of the organization of health care;

- Build the relevant sets of models; and

- Develop methods of control in conformity with the functional regularities of the different systems as reflected in their descriptions.

There are two types of systems concerned: systems that exist in nature (those of which we are to discover the phenomena), and synthesized systems developed by man. Both types of models have the following features in common:

- High heterogeneity of processes (it is necessary to use concepts and methods from various mathematical disciplines);

- Large dimensions of the descriptions.

It is difficult to give a description of natural phenomena; building models requires collaboration between many groups of research workers, information about the individual components of the mechanism under study being often scattered over a number of laboratories in different countries. It is common knowledge, for instance, that much effort is going into research on the properties of one fermentation. This information is essential to biochemists in all countries. But we propose to study and use descriptions of biochemical cycles information about tens of thousands of fermentations.

Increased efficiency in solving the above mentioned complex problems can be achieved by developing new research methods; and by developing new methods of coordinating them.

THE PRINCIPAL PHASES OF THE TRADITIONAL RESEARCH CYCLE

These phases are as follows:

- On the basis of studying many results of experimental work and generalizing publications, some hypotheses are formulated about the functional regularity and properties of the system to be investigated.

- Hypotheses are formulated about the interaction of this system with the environment.

- The experiment is planned and its execution organized.

- The experiment is carried out.

- The results of the experiment are processed and analyzed.

- Arrangements are made for publication.

Experience shows that, since the systems to be investigated are very complicated, we make many mistakes in composing descriptions of them and formulating hypotheses.

In order to discover any phenomenon, to obtain new results, to develop a new method of control or treatment, a new pattern of health protection care we must always go through a number of research cycles eliminating some errors and inconsistencies each time. In addition to the mistakes made by individual research workers, mistakes, inconsistencies may arise as a result of cooperation between many research workers.

The most labor-intensive, long and expensive stages are those of the physical experiment and processing of results; overlong delays occur during the transmission of information from one group of research workers to others by means of publication; it is difficult to organize cooperative activities; it is also hard to describe phenomena when formulating hypotheses. It is possible to spend many months or even years over one research cycle.

THE POSSIBILITY OF REDUCING RESEARCH CYCLES AND INCREASING THE NUMBER OF SUCCESSFUL EXPERIMENTS

Experience in using mathematical methods of simulation shows that it may be possible to do this.

The main purposes of applying formalization and simulation methods to increase efficiency are the following:

- All inconsistencies connected with the formulation of hypotheses can be detected and eliminated without conducting an expensive physical experiment by means of studying a mathematical model with the help of another physical analogue computer; this analogue being known and available, the experiment is much simpler.

- The procedures of data processing and analysis are simplified to a great extent.

- The system of publication is greatly changed: information is stored in one place in a machine model. Other research workers get the necessary information rapidly from the machine since all the data are readily available, without passing through printing, a library, etc.

It may seem at first sight that the procedure of formulating hypotheses, by synthesizing formal models, is a somewhat labor-intensive operation, since special arrangements are required to use computers.

However, experience proves that by shortening research cycles and reducing their number, i.e., the number of iterations in physical experiments, it is possible to increase tenfold efficiency in research and developing methods of control.

PROGRAMMING LANGUAGES

The development of special modes of synthesis and model research with the help of computers has been made possible by the creation of programming languages and methods of simulation.

Programming languages have special formal constructions to allow a simple interpretation of a concept; they are used for the description of complex physical phenomena. They are a powerful tool in formulating, and verifying the compatibility of, complicated hypotheses. They permit the organization of coordinated cooperative work on models by making it possible to analyze the demand for, and quality of, information about the individual elements of a model.

FUTURE DEVELOPMENTS

In order to take full advantage of the methods under discussion, simulation systems using highly efficient networks of computers must be developed.

It is both possible and highly desirable to develop an international information and simulation system working in parallel with national information and simulation systems. Such a system equipped with data banks in the form of complicated sets of machine models would be able to accumulate a vast volume of information in a systematized form and will make it possible to organize international research on the most important problems.

An urgent problem at the moment, for instance, is to build an efficient model of a living cell in order to discover the secret of cell differentiation and interaction between cells and viruses. This is the key problem of oncology, as well as of most biological subjects.

The creation of such a system would also facilitate generally the use of scientific knowledge in medical treatment and the organization of health care.

There are currently scientific methods and technical facilities to create both standardized national and international information and simulation systems.

Summary on Present and Future Possibilites for International, Intranational and Local Cooperation In Oncological Research and Practice

C.R. Gillis

The present wave of enthusiasm for cancer research, which has been gaining increasing momentum in many parts of the world, especially since the late 1960s, has generated so many plans, papers, research reports, conferences, etc. that a state of indigestion has now been reached. Those involved in cancer research and practice turn in hope to their scientific colleagues in systems analysis for a remedy. A major body assisting in the task of coordination is the World Health Organization (WHO). The proper coordination of all activities in cancer is essential as the variety of different diseases grouped under the heading cancer are of major concern to developed and developing countries. Considerable resources have been, and are being, spent, on the cancer problem. There appears to be no immediate prospect of the prevention of cancer: promising programs for cancer control are in their early stages and it will be some time before their effectiveness can be determined. New efforts are required and it is timely that this conference is taking place so that new inputs of effort into cancer research and treatment will be better coordinated and thus more fruitful than those in the past. There is still a large gap between the broad objectives of the WHO cancer program and current attempts to attain these objectives.

While limited objectives are needed to achieve at least some measure of success in the short term, more important is a broadly based long-term plan for cancer research. If this is not done, due account being taken of the successes and failures of the past, the specificity of limited objectives will be lessened and the possibility of a coherent program of international collaboration greatly reduced. Such a long-term plan must cover at least the following areas: epidemiology, environmental carcinogenesis, screening on a population basis, tumor biology, improved diagnosis, and further development of combined modality treatment with special emphasis on cost benefit. However, progress in any of the above fields cannot be fully achieved until national health care systems become more efficient.

While it is comparatively simple to concentrate on specific activities, it is considerably more difficult to study the balance of efforts now being made on a world scale in the above topics which appear in the WHO list and in the list of 13 topics and 121 subsections, suggested by many of the delegates, which forms part of the USSR program for cancer control.

There are many units within the WHO which assist in the coordination of oncological activities. There is special concentration on programs for cancer control with a general epidemiological approach to cancers. The work of Cancer Registries is evaluated and there is particular emphasis on classification. These activities are complemented by those of the WHO sponsored International Agency for Cancer Research (IACR), which concentrates on environmental carcinogenesis with emphasis on occupation. This is clearly of great importance since at least 80 percent of cancers are now considered to be environmental in origin. Finally, in WHO, there is an interdisciplinary team which is responsible for the integration of all of these activities on a continuing basis, thus helping to ensure balance between the work of the various units and the reduction of gaps. There must be some framework for activities relating to the whole field of endeavor in cancer and such activities should be seen to interact. This can be achieved only by further and more effective cooperation among all agencies concerned with the coordination of cancer activities regardless of the extent to which they are presently related to WHO.

If such cooperation is to be fruitful it must operate at two levels; first, in the various areas of cancer research and practice and, secondly, in planning and administration since the objectives of health care organizations must be taken into account if the results of cancer research and practice are to be usefully implemented. Thus cancer should be a concern of IIASA since the interacting areas of cancer research, practice and health care systems need to be viewed as a dynamic model.

One of the subjects discussed at this Conference has been the WHO program for the standardization of histological classification. It is relatively unimportant which classification is used so long as scientists throughout the world agree to use the same one, and the promotion of such agreement must be one of the tasks of the participants. Another candidate for standardization is the classification of anti-cancer drugs, and the elaboration of their side effects. The volume of literature on cancer is increasing more rapidly than ever before, but only 10 percent of Eastern European literature about cancer is available in the data files of the major cancer literature research systems. One question that must be asked about all these scientific publications and research reports is: at what stage do their contents become knowledge? There has to be some element of selection in the literature included in any international collection. Such literature must be freely available to all those who seek it. One international information system discussed was the SABIR-C system where the analysis of the input is carried out by experts who continually update the key words used. The system outputs free text and includes error checks. The output is provided in English, French and German. Although there are many journals in common with the well-known MEDLARS system, there are at least 1000 journals included in SABIR-C that are not scanned by the MEDLARS system.

With regard to duplication of effort the International Information Office on Controlled Therapeutic Trials in Cancer established by the International Union Against Cancer (UICC) now has information on a worldwide basis on nearly 700 clinical trials either in progress or terminated, whether published or unpublished. It is hoped that the negative and the positive information contained in these data will assist in the dissemination of information in the fields concerned and that the greater use of this information system will avoid unnecessary duplication of work, especially with regard to the negative effects demonstrated. Some indication of the present inadequacy of collaboration and cooperation among countries in cancer information exchange can be inferred by the fact that WHO possesses mortality data from only 27 percent of the total world population and has none from 132 countries.

A further step toward the achievement of international collaboration, at least at the epidemiological level, is the Clearing House for Ongoing Research in Epidemiology. This is a joint program of the IARC, WHO, and the Deutsches Krebsforschungszentrum, Heidelberg. The program is essential because of the considerable length of time needed for epidemiological studies. Although it is estimated that this system is currently receiving only 20 percent cooperation from investigators throughout the world, it is anticipated that this will improve in the near future; if it does not, there is likely to be considerable duplication in this field of research.

Another system dealing with the problems of duplication in research and incorporating a large data bank of published work and information on ongoing research is the International Cancer Research Data Bank of the Office of International Affairs at the National Cancer Institute, USA. This organization has as a fundamental objective the free exchange of scientific information at every level from the molecule to the community. It incorporates programs for the exchange of scientists, for improving classification and coding, and also acts as an international cancer epidemiology clearing house, in cooperation with the above mentioned project in France and Germany.

Reference has already been made to the need to study relationships between the various areas of cancer research; a step in this direction has been the cross referencing, by means of graphs, of the literature relating to the topics and subsections in the USSR research program.* The graphs of the citations from the literature were prepared from a selection of approximately 1600 publications, under headings similar to those chosen by WHO, in experiemntal and clinical cancer research for the period 1960-1965. The selection of publications was carried out by experts in the various fields and the structure of each graph

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*See papers by L.I. Borodkin, et al. and L.I. Borodkin, I.B. Muchnik, and A.S. Raben, in this volume.

is as follows. First, there is the serial, cardinal number of the publication; second, a double code representing the topic and subsection; third, bibliographical data, listed alphabetically under authors; and finally, the serial numbers of the other selected publications cited by the publication concerned. These graphs have been analyzed by a computer system and the major result is the identification of a macro-structure for this complex system, with a set of three or four groups of subjects with external links between them.

At the Conference discussions held in Moscow information was given about an Austrian method of collecting and using data from surveys dealing with other aspects to collect statistical information relevant to cancer. The example dealt with the use of a questionnaire sent to samples of the Austrian population to determine the effects of cigarette smoking; the validity of the method was shown by presenting standardized mortality ratios for lung cancer by sex which approximated to the expected values. This method will make it possible to assess the future input of cancer education.

There was discussion about a variety of schemes being used in Hungary for disseminating cancer information on a person-to-person and a data-to-person basis. The problems in information exchange which resulted from the application of these methods were highlighted; it was agreed that these were experienced by all countries. Reference was again made to the need for careful selection of research topics and for the widest possible dissemination of negative and positive data. The importance of data about ongoing projects was stressed. Mention was also made of the importance of adequate documentation and study of spontaneous remissions.

The major problems being studied in Czechoslovakia were similar to those elsewhere. A feature of the Czechoslovak cancer program is that it forms part of the international cancer program in the CMEA countries which is coordinated centrally in Moscow. This facility allows both unilateral and multilateral activities to take place on a coordinated basis.

There was particular interest in the suggestion by the Scientific Coordinating Departments of the Academy of Medical Sciences in Moscow that a systematized approach to research should be made on a problem-oriented basis rather than through the traditional disciplines since such a course took full account of the multidisciplinary nature of the problems in cancer research and brought together experts from widely differing fields to assist in their solution.

A paper of great interest was the paper on an information system for the selection of appropriate drugs.* Essentially

*See L.M. Zakharova and A.M. Petrovsky, in this volume.

the system is composed of a matrix whose sides include syndrones, drugs, and adverse reactions to drugs; the system operates in such a way that a drug can be chosen for a given patient without necessarily knowing the final diagnosis. This system has already been tested successfully in several clinics in Moscow.

Mention was made of the use of Cancer Intelligence Units attached to Cancer Registries as a mechanism for disseminating and coordinating cancer information. This has already been shown to work satisfactorily in Scotland; it relies on the voluntary collaboration of multidisciplinary groups of clinicians to use the data handling and statistical facilities of the Registry in pursuing cancer research in a variety of fields. It was suggested that the International Association of Cancer Registries might be used to promote this type of approach to information exchange at a local level.

Finally, attention focused on several methods and languages used in modeling cancer research systems and in applying these models to the study of cancer and health care systems. It was shown that models could indicate the direction of particular studies; mathematical descriptions of problems and algorithmic and modeling languages were of value, especially in evolving methods for organizing and coordinating existing biological investigations and in suggesting new methods for other investigations. The following recommendations were made:

- That systems analysis should be considered an essential component of the modern study of oncology if the multidisciplinary nature of the subject is to be fully exploited;

- That to achieve greater visibility for systems analysis in cancer research, a contribution on this subject should be made to the forthcoming International Cancer Congress in Buenos Aires;

- That consideration be given to holding more workshops for small groups of concerned individuals in order to discover a better system for effective collaboration between mathematics and medicine.

Concluding Address

A.S. Kiselev

First of all allow me to thank you for coming and to say that it gives me great satisfaction that you have responded to the request to meet here together. Thank you also for your interest in discussing questions with which the Biomedical Project is concerned, and for the feeling of fellowship which has been generated over this short period of time.

Of course the problems we have discussed over these last days are extremely complex. It is natural that there should still be more unanswered questions than answered ones. If everything could easily have been answered, then there would have been no point in our gathering here. It seems to me, however, that several very definitive statements have been formulated over these last four days, and with your permission I would like to give at this point a short resume.

To what should we devote our energies at IIASA? To the building of a new general macro-model of health care or to constructing partial models? It seems to me that in light of the discussions there is no difficulty in answering this question--in view of the highly specific nature of partial models. That is to say, IIASA cannot permit itself to build a hospital model or the model of some disease specifically for a particular country. IIASA can undertake only the broadest possible tasks--tasks of interest to all countries.

It is fortunate, indeed, that international health care has at its disposal the services of the World Health Organization. For a quarter of a century, WHO has been working on health care problems in various countries. IIASA cannot allow itself to duplicate the work of WHO or to compete in any way with WHO. Consequently IIASA should choose a task which will develop the ideas of WHO while taking into account the special nature of IIASA itself, with its emphasis on applied systems analysis.

From these two statements emerges a third--IIASA should concern itself with the macro-modeling of health care. In my opinion, IIASA possesses neither the strength nor the resources to fill such a macro-model with operational, specific data for any country. Instead, IIASA should occupy itself with developing a universal modeling methodology.

It is these three prerequisites, or, in the words of modeling specialists, constraints, which should determine the choice of themes for IIASA's Biomedical Project.

If we decide that IIASA should undertake the development of health care macro-modeling methodology, then we are faced with the problem that we have been discussing from the first to the last day of these discussions, i.e., is a universal health care macro-modeling methodology possible for countries with different socio-economic systems? If such a methodology is theoretically impossible, then we will have to bury the idea. If such a methodology is possible, then this topic should be developed. It gives me deep satisfaction that almost all the participants in this discussion have said "yes, such a methodology is possible".

Now let us examine what stage we have reached in the creation of a health care macro-model. There are four or five health care macro-models in the world, but not one of them has reached the stage where it might be recommended for other countries. This holds true for our model also, although it has been said about our model that it is the most ambitious, thorough-going and highly developed to date. I consider that, having regard to the amount of effort involved and the intellectual, financial and other resources required, the task of building a working health care macro-model is comparable only to the most ambitious programs, like the Apollo Project. We must therefore fully understand that we are just at the beginning of a long road.

From this follows the next statement. If we could unite our efforts in the field of macro-modeling methodology, then we might save years of labor, money and so forth. If we do not unite our efforts, then each country will spend significantly more to achieve the same results. As practical men, we should all appreciate we have a clear-cut common interest in the business of economizing.

Then there emerges the next problem. Granted we have reached agreement over these last few days on all the preceding statements, it is now time to proceed to a workable distribution of tasks: who should do what in the course of these activities. And in this regard I am pleased to say that during this conference, in spite of lack of time, we have succeeded in coming to an agreement with Mr. McDonald of the United Kingdom Department of Health and Social Security as to what place is to be occupied in our general scheme by those models being worked out by him and his associates. We have also succeeded in reaching an agreement with Dr. Miksl (CSSR) that he will undertake to develop a partial model--the relationship between a population's health and the degree of environmental pollution. I sincerely hope that I will have the opportunity to make similar agreements with all the remaining participants at our Conference. Unresolved problems still outnumber our achievements, but, thanks to our Conference, I am optimistic about the future of health care macro-modeling.

Finally, there is the problem which was touched upon today during discussions--the problem of money and resources to support work of the Biomedical Project. This, of course, is an essential requirement. But I think that this problem will, as we say in my country, be resolved "on the job", as work progresses.

And I thank you all again. We have received such a mass of useful information over these last few days that many weeks will be necessary to digest it all. I hope I will have the opportunity of being in touch with you many more times by correspondence.

Thank you very much.

Appendix 1

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Appendix 2

Agenda

Monday, 8 December, Moscow

Joint Session of the Two Conference Stages

10:00-13:00

Welcoming Address	N.N. Blokhin
Welcoming Address on Behalf of WHO	A.S. Pavlov
Welcoming Address	D.D. Venedictov
Welcoming Address on Behalf of IIASA	R.E. Levien
Systems Analysis and the Systems Approach in the Activities of WHO	G.J. Deboeck

14:00-19:00

The Elaboration of a Dynamic Model of Public Health	A.S. Kiselev
The Mathematical Basis of a Dynamic Model of Public Health	A.A. Klementiev
On the Experience in Public Health Management and on the Development for Different Branches (AMS) of Medical Care Services	S. Burenkov V. Golovteyev V.M. Timonin G.G. Sudarikov
Papers to be presented by scientists of the USA, the UK, the FRG, Japan, Austria, Czechoslovakia, and Bulgaria	

* * *

Tuesday, 9 December, Moscow

Sectional Meetings

10:00-13:00

First Section: Public Health Organizers

- On Possibilities and Approaches for the Creation of a Universal Model of Medical Care Services (MCS)
- The Linking of the MCS Model With a Social Model and Models of Various Associated Spheres (Economics, Population, etc.)
- On the Adequacy of the MCS Macro-Model Proposed for Discussion as Regards Different Public Health Systems
- Demands Made by the Public Health Officials on the Creation of the Model
- Demands on Models Being Developed at Different Levels (Separate Functions, Public Health Institutions, Districts, Country, and Region)
- On Defining Connections Between Macro- and Micro-Models and the Main Principles of Their Development
- Perspectives Regarding the Use and Further Development of MCS Macro-Models

Second Section: Methodologists, Mathematicians

- Formulation of the Main Problems Confronting Present Day National Public Health Services
- On Quantative Indicators of the Efficiency of a Medical Care Systems Measures for Treatment and Prophylaxis

- On Methods for Evaluating a Population's Morbidity, Latency and Use of This Index in Medical Care Planning

- Evaluation of the Effect of Environmental Pollution on Population Health

- On Quantative Characteristics of Other Social-Economic Subsystems as They Influence the Operation of Medical Care Services

- Which Algorithmic Language is the Most Convenient for the Synthesis of a Public Health Simulation Model

- How to Take into Account the Peculiarities of Socialist and Capitalist Systems in the Synthesis of a Public Health Simulation Model

14:00-17:00

(Continuation of Sectional Meetings)

Report to the Chairman of the Session

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Wednesday, 10 December, Moscow

10:00-13:00

Summary of Section Reports — A.S. Kiselev

- Discussion of the Report and on Possible Ways to Distribute Work on Dynamic Modeling Among Scientific Groups of Various Countries

14:00-Closing

Final Joint Session of the Two Conference Stages

- Closing Remarks — D.D. Venedictov, R.E. Levien, A.S. Pavlov, N.N. Blokhin

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Thursday, 11 December, Laxenburg

14:00-Closing

Advisory Committee Meeting

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Friday, 12 December, Laxenburg

9:00-12:00

Report on the Moscow Conference R.E. Levien